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RESEARCH ARTICLE

COMPARATIVE EVALUATION OF FRACTURE RESISTANCE OF ENDOCROWNS FABRICATED USING DIFFERENT MACHINABLE CERAMICS

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Abstract

Introduction: The purpose of this in-vitro study was to evaluate the fracture resistance and failure modes of three types of CAD/CAM fabricated endocrowns.

Methodology: Thirty extracted permanent maxillary first molars were selected based on inclusion and exclusion criteria. Endodontic treatment was done in all the teeth following the standardized preparation with 2-mm intracoronal extension of endocrown into the pulp chamber. Teeth were divided into three groups (n=10); Group A: feldspathic porcelain blocks (FP), Group B: lithium-disilicate blocks (LD), Group C: resin nanoceramic blocks (RN). Each group was restored with standardized CAD/CAM fabricated endocrowns using one of the three tested materials. After cementation with resin cement, specimens were stored in distilled water at 37°C for one week. A compressive load was applied at 35º to the long axis of the teeth using a universal testing machine until failure. Failure load was recorded, and specimens were examined for modes of failure.

Results: Group C (RN) exhibited highest fracture resistance followed by Group B (LD) and Group A (FP). However, no statistically significant difference was found between Group B and C. ($p>0.05$) Highest prevalence of catastrophic fracture (Type IV) was demonstrated by Group B (60%) followed by Group A (40%), while Group C exhibited a higher occurrence of favourable failure modes (30% type I and 50% type II).

Conclusion: Resin nanoceramic and lithium disilicate blocks exhibited higher fracture resistance than feldspathic porcelain. However, a more favourable mode of failure was shown by resin nanoceramic block, which may favour its use for restoration of endodontically treated teeth.

Introduction:-

Restoration of endodontically treated teeth (ETT) continues to be a challenge in reconstructive dentistry. The most frequent causes for diminution in fracture resistance of ETT are the wastage of tooth tissue accompanied with trauma, decay, existing restoration, and wide cavity preparation.(1) In addition, the desiccation and biomechanical changes in the dental tissues result in restraining the sensory feedback during peak loads.(2)

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The major changes seen in an endodontically treated teeth are: 1. Loss of tooth structure, 2. Altered physical properties, 3. Altered aesthetic characteristics of residual tooth. Helfer et al (1972) had stated that pulpless teeth have 9% less moisture than vital teeth.(3) Rivera et al (1988) stated that the degree of work required to fracture dentin may be less in endodontically treated teeth because the collagen intermolecular cross-links may be weaker.(4) Gutmann JL(1992) concluded that endodontically treated teeth exhibit changes in collagen crosslinking and dehydration of the dentin that result in a 14% reduction in strength, toughness and structural integrity.(5)Thus, selection of restoration designs and materials for ETT should be capable to substitute the loss of tooth structure to ensure aesthetics, marginal seal, mechanical, and functional characteristics.(6,7)

A common protocol of restoring ETT has been to build up the tooth with a post and core, either by direct or indirect approach, followed by an overlying crown. However, many clinical and laboratory studies have notified that placing a post will contribute to the retention of the core portion of the restoration but may have a weakening effect on the root with increased risk for accidental root fracture.(8,9)

With advances in adhesive systems, dental materials, and computer-aided design/computer-aided manufacturing (CAD/CAM) technologies,(10,11) there had been a shift in treatment decisions towards a more conservative modality. Ceramic inlays, onlays, and endocrowns have been introduced as alternative restorations for endodontically treated molars, depending on the availability of remaining tooth structure.

Initially proposed by Pissis in 1995, as the “monoblock porcelain technique”.(12) The nomenclature endocrown was described by Bindl and Mormann in 1999.(13) Endocrowns are a type of restoration consisting of the entire core and crown as a single unit (i.e., monoblock). It uses the available surface of the pulp chamber axial walls as macro-retentive resources and adhesive resin cement as a means of micromechanical retention. Additionally, this type of restoration is made available through CAD/CAM technology, which provides the possibility for chair-side design and fabrication.

Endocrowns are especially indicated in cases of inadequate clinical crown length, limited interocclusal space, and extensive loss of dental tissues that do not allow the use of an adequate ferrule. They are also an alternative in cases of root complexes like calcification or curved canals.(14,15)

A wide range of ceramic materials has been available for CAD/CAM technology, ranging from feldspathic ceramic and leucite glass ceramic to high-strength lithium disilicate glass ceramic and zirconia blocks. Most recently, a resin nanoceramic has been introduced for CAD/CAM fabricated restorations. Ultrastructure, physical, and mechanical properties of available CAD/CAM materials vary widely, and, accordingly, their mechanical behaviour in the tooth restoration complex is expected to vary as well.

Thus, the purpose of this study was to evaluate the fracture resistance, and failure modes of three types of CAD/CAM fabricated endocrowns when they were subjected to oblique compressive force.

Materials & Methods:-

30 extracted permanent maxillary first molars were selected based on the inclusion criteria of no developmental anomalies and fully formed apices and exclusion criteria of cracked tooth or fractured tooth. Age, sex, race of the patients and reason for their extraction were unknown. After extraction, the teeth were placed in 3% sodium hypochlorite, debrided of periodontal tissue, rinsed under running tap water and stored in physiologic saline until the beginning of the experiment. The crown of each tooth was sectioned at 2-mm above cemento-enamel junction, using diamond disc under water coolant, to remove the occlusal tooth surface and to deroof the pulp chamber.

Endodontic procedures:

The canals were located using a DG-16 endodontic explorer. The patency and working length of each canal were determined bypassing the size-10 K-file to the anatomic foramen. This length was recorded, and the final working length was established 0.5 mm short. After confirming apical patency, shaping procedures was performed with an engine-driven rotary NiTi system up to size F1in MB and DB canals and size F2 in palatal canals (ProTaper Gold, Dentsply Maillefer) using crown down technique. Irrigation was performed with 3% sodium hypochlorite solution using 30G side-vented irrigation needle. The same procedure was repeated until the file reached the working length (WL). After completion of the procedure, final irrigation was done with 2ml distilled water. Root canals were dried with F1 and F2 paper points (ProTaper Gold paper points, Dentsply Maillefer) and obturated with gutta perchapoints of size F1 in MB and DB canals, size F2 in palatal canals and root canal sealer (AH Plus, Dentsply Maillefer).

The coronal aspect of the gutta-percha material was removed using a small carbide bur (SF-31, Dia-burs, Mani) to 1 mm below the orifice of each canal, then flowable resin composite (Te-Econom Flow, Ivoclar Vivadent) was used to fill the canals up to the level of the pulp chamber.

Endocrown preparation:
The teeth were individually fixed in fast-cure acrylic resin using aluminium rectangular molds. Intracoronal height of the prepared walls was reduced to 2.0 mm (WR-13, Dia-burs, Mani), measured from the internal cavity margin to the floor of the pulp chamber, using a periodontal probe. Internal taper of 8-10 degrees was made using a tapered diamond coated stainless-steel bur with rounded end (TF-12, Dia-burs, Mani). The axial walls were prepared from the pulpal side to provide for a standardized cavity wall thickness of 2.0 ± 0.2 mm. All endocrowns were designed to have similar occlusal anatomy as having the same occlusogingival height.

Teeth were randomly distributed into three equal groups (n=10) according to the block material:
1. Group A: feldspathic porcelain blocks (FP)
2. Group B: lithium-disilicate blocks (LD)
3. Group C: resin nanoceramic blocks (RN)

Before cementation, the intaglio surfaces of each endocrown were treated according to the manufacturer's instructions. Etching with 5% hydrofluoric acid gel was done for 60 seconds for FP and LD blocks, then rinsed for 60 seconds with running water and dried for 30 seconds with oil and moisture-free air. Intaglio surfaces of RN block were sandblasted with ≤25-μm aluminium oxide particles, then sand was removed with alcohol and dried with oil and moisture-free air. A ceramic primer containing silane coupling agent was applied to the intaglio surfaces of all endocrowns and allowed to dry for 60 seconds.

Prepared tooth surfaces were etched with 37% phosphoric acid gel (D-tech etchant etching gel) for 15 seconds, rinsed for 20 seconds, and dried with oil-free air for 5 seconds. The bonding agent (Te-Econom Bond, Ivoclar Vivadent) was applied, left for 20 seconds and light-cured for 10 seconds. The restorations were cemented with self-cure adhesive resin cement (RelyxU200). Excess material was removed with the help of an explorer. The resin cement was light activated at each surface for 20 seconds using a light-emitting diode curing unit (Bluephase N, Ivoclar vivadent). Margins of the restorations were finished with sandpaper polishing discs (Sof-Lex, 3M ESPE). Specimens were stored in distilled water at 37ºC for one week to allow for bonded interface maturation.

Fracture resistance testing:
Each mounted tooth was placed in a universal testing machine (Instron, Mahatma Gandhi University, Kottayam) positioned at an angle of 35° between the long axis of the tooth and the loading jig. (Figure 1) Force was applied through a stainless-steel ball (5 mm in diameter) representing the antagonist tooth. Load was applied to the incline of the palatal cusp at a crosshead speed of 0.5mm/min. The fracture load needed to cause failure of the specimen, which was signalled as a peak in the load-displacement tracing, was recorded in newtons (N).

Mode of fracture was examined for each specimen and categorized according to El-Damanhoury et al, 2015 (16)
1. Type I: Complete or partial debonding of the endocrown without fracture (favourable failure)
2. Type II: Fracture of the endocrown without fracture of the tooth (favourable failure)
3. Type III: Fracture of the endocrown/tooth complex above the height of bone level simulation (acceptable failure)
4. Type IV: Fracture of the endocrown/tooth complex below the height of bone level stimulation (catastrophic failure)

Figure 1:- Mounted tooth placed in universal testing machine with stainless steel ball attached.

Statistical analysis was done using One-way ANOVA test. P value of < 0.05 was considered as statistically significant.

Results:-

The means, standard deviation for fracture resistance of three investigated CAD/CAM blocks are given in Table 1, illustrated in Graph 1 and failure mode of each blocks in Table 2.

Table 1:- Mean, Standard deviation for fracture resistance of different CAD/CAM blocks.

Groups	No.	Mean (N)	SD	Maximum	Minimum
A	10	1159	152.09	1346	948
B	10	1498.60	189.54	1733	1156
C	10	1571.20	200.80	1852	1293

Graph 1:- Mean fracture resistance of different CAD/CAM blocks.

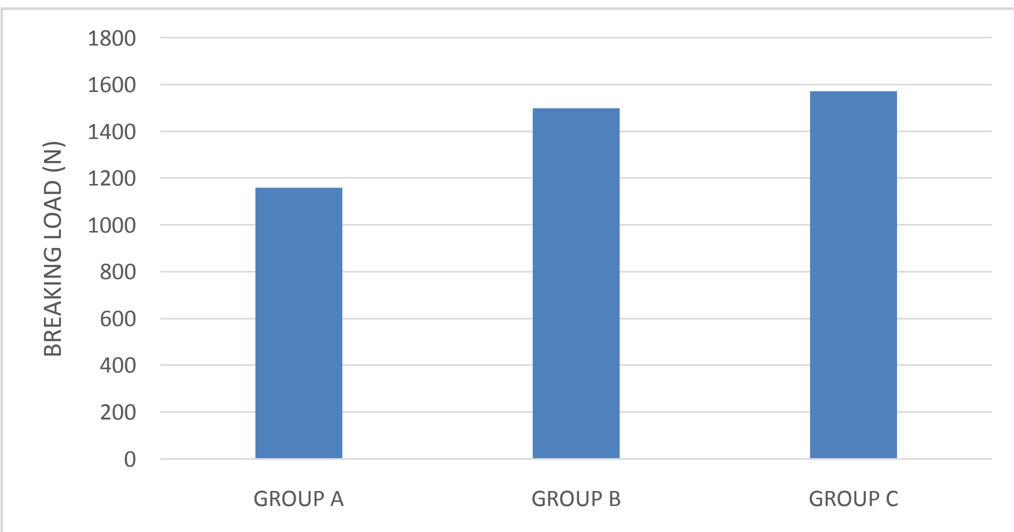

Table 2:- Mode of failure of three tested CAD-CAM blocks.

MATERIAL	MOODE OF FAILURE %			
	TYPE 1	TYPE II	TYPE III	TYPE IV
GROUP A	10%	20%	30%	40%
GROUP B	10%	10%	20%	60%

GROUP C	30%	50%	20%	0

From the results, it can be inferred that Group C (RN) exhibited highest fracture resistance followed by Group B (LD) and Group A (FP). However, no statistically significant difference was found between Group B and C. ($p>0.05$)

Highest prevalence of catastrophic fracture (Type IV) was demonstrated by Group B (60%) followed by Group A (40%), while Group C exhibited a higher occurrence of favourable fracture modes (30% type I and 50% type II).


A


B

Figure 2:- A- Complete debonding of the endocrown without fracture of the tooth (favourable failure), B- Fracture of the endocrown/tooth complex (catastrophic failure)

Discussion:-

The need for proper restoration of endodontically treated teeth is well known. Tang et al (2010) reported that failure to provide permanent restorations after endodontic treatment resulted in greater than 65% tooth loss during a mean follow-up time of three years.(17) They emphasized the need for expedient sealing of all endodontic access cavities followed by cuspal coverage restorations to alleviate bacterial recontamination of obturated root canals, which has been reported to occur as quickly as 25 to 30 days after re-exposure.(18)

Endocrowns take advantage of recent developments in adhesives, ceramics, and CAD/CAM technologies. Its minimally invasive preparation preserves maximum amount of tooth surface for bonding and where extensive macro retention designs are no longer a prerequisite. The utilization of the available space inside the pulp chamber adds to the stability and retention of the restoration and reduces the operational errors possible during post-space preparation.(12,13)

To exclude the effect of variances in the intracoronal extensions of the endocrowns, a standardized cavity design following guidelines by Pissis was used.(12) The preparations were done to allow for an intracoronal extension of 2mm. This was in accordance with study by Hayes et al (2017) who evaluated the effect of endocrown pulp chamber extension depth on molar fracture resistance and concluded that 2 -mm pulp chamber extension displayed greater tooth fracture resistance.(19)

The results of this study showed that Group C (resin nano ceramic) exhibited higher fracture resistance followed by Group B (lithium disilicate) and Group A (feldspathic porcelain). However, no significant difference was found between Group B and C. ($p>0.05$)

The unique composition of resin nanoceramic allows the material to have a modulus of elasticity (12.8 GPa) similar to that of dentin (5.5-19.3 GPa).(20) The modulus of elasticity influences the susceptibility to fracture of a cemented ceramic restoration since materials with more compatible elastic moduli tend to bend under load and distribute stresses more evenly, while rigid materials with different elastic moduli, produce stress concentrations at critical areas that might cause catastrophic failures. In addition, unlike other ceramics, resin nanoceramics contains 80% nanoceramic particles embedded in a highly cured resin matrix (20%), the presence of this resin matrix facilitates bonding to resin composite luting materials, resulting in more uniform stress distribution when compared to feldspathic and reinforced ceramics and therefore better fracture resistance.(16,21)

Lithium disilicate ceramic exhibit good adhesive properties and high resistance to displacement because it is acid-etched; providing micromechanical interlocking with the resin cement, as well as adhesion between dental tissue and resin cement. Moreover, the presence of crystalline particles increases the fracture strength against loading.(22,23)

Highest prevalence of catastrophic fracture (Type IV) was demonstrated by Group B (60%) followed by Group A (40%), while Group C exhibited a higher occurrence of favourable fracture modes (30% type I and 50% type II). This could be explained by the differences in the elastic modulus of the material, lithium disilicate and feldspathic porcelain is more rigid and has a high modulus of elasticity (81 GPa and 45GPa respectively), which concentrates strain in weak area and resulted in more irreparable fractures.(16,24)

One limitation of this study was other factors that influence the fracture strength and failure modes of endocrowns such as tooth preparation, restoration shape, loading technique, method of fabrication, and luting method, were not evaluated. Additionally, size of the groups was limited by 10 samples and three types of CAD/CAM materials were only tested. Therefore, further studies with more types of CAD/CAM materials are suggested to investigate the effect on the mechanical behaviour and success of endocrown restorations, in clinical situations.

Conclusion:-

Within the limits of the study, it can be concluded that resin nanoceramic and lithium disilicate blocks exhibited higher fracture resistance than feldspathic porcelain. However, a more favourable mode of failure was shown by resin nanoceramic block, which may favour its use for restoration of endodontically treated teeth.

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