Delta University Scientific Journal
Journal home page: https://dusj.journals.ekb.eg

Fracture resistance of endodontically treated teeth restored with post-core system and endocrown

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ABSTRACT

Mechanical testing of teeth received root canal treatment and final filling with different restorations is one of the most accepted methods to evaluate the strengthening effect. The aim of the present study was to investigate the resistance to fracture maxillary premolars received root canal treatment and final restoration with either posts-core or endocrown and detect the type of tooth fracture. Forty human bifurcated maxillary premolars were selected for testing after receiving root canal treatment (n=10). The teeth received either composite filling, or post and core or endocrown. Ten intact teeth were tested as a control group. The endocrwon as a coronal restoration. All samples were examined with the universal testing machine at a speed of 0.5 mm/minute and maximum load at fracture time was measured by Newton (N). The collected data was analyzed by one-way ANOVA and independent sample t-test. The significance was considered at 0.05.

Endocrwon samples significantly exhibited the highest value of load and longest time to fracture ($p<0.5$) followed by post -core and composite exhibited the lowest value. Most of failure mode of all groups were unfavorable 75.5% of samples. The unfavorable fracture represented 100% of samples in the endocrown group. The fracture in post group was 50%% unfavorable and the fracture in composite group was 60%.

In conclusion, Endocrwon as a coronal restoration of endodontically treated maxillary premolar increase the fracture resistance more than post-core or composite.

1. Introduction

Teeth may be subjected to hard structure loss due to caries or trauma. Loss of tooth structure may lead to pulp involvement that indicate root canal treatment. Root canal treatment of badly broken teeth results in more loss of hard tooth structure during access preparation and cleaning and shaping (Daniel et al. 2024). Loss of tooth structure of endodontically treated premolars adversely affect its fracture resistance (Bassir et al. 2013). Subsequently, need to be restored with coronal restoration that act as strengthening factor and prevent early tooth loss and extend its survival (Lynch Burke et al. 2004). Different variety of coronal restorations were utilized including direct composite, post and core build up, endocrown or even complete crown.

Different composite restorations were utilized after root canal treatment. Recent generations of composite as nanohybrid composite increased the resistance to fracture of teeth received root canal treatment (Mohamed Sameer et al. 2020; Nezir & Ozcan 2024). Short fiber-reinforced composite is resisting fracture with great efficiency when tested under occlusal force (Eapen et al. 2017).

The original concept of using posts and core in endodontically treated teeth was generated to enhance retention of coronal restoration if there is insufficient remaining tooth structure (Yoshino et al. 2015). Many post designs with different materials were used with different mechanical properties. The main weakening point s of fiber posts is their ability to be removed easily from the root in cases of endodontic retreatment or post failure.

D.T. LIGHT-POST Illusion (Bisco Inc, Schaumburg, IL) is one of newly introduced colored posts which constructed from unidirectional, quartz fibers with two tapers that represent the root canal geometry providing more intimate adaptation to the canal wall than other available fiber posts. This post is highly radiopaque so it gives better visualization on radiographs and it has similar modulus of elasticity to dentins that benefits in distribution of stress. The unique feature of this post is its ability to color modification when temperature is changed and this feature called “Patented color-on-command technology”. In other words, when the post is exposed to the oral cavity its color converts to white for esthetic purpose. However, it returns back to its original color and this property helps to easily distinguished as a different color from dentin which simplify the removal of the post when root canal retreatment is ever required (Hampe et al. 2017).

Endocrown is used for cuspal coverage of endodontically treated posterior because they give benefits of similar anatomy as natural teeth. Endocrowns are strengthen teeth received root canal. The endocrown is needed for teeth that lost its structure, with small occlusal hight available, or in case of short crown. It is processed by either heat pressing or computer-aided design/computer-aided processing from different material blocks (CAD/CAM) (AboElhassan et al. 2024). When we compare teeth received root canal treatment and fiber-reinforced composite. Inlay, onlay, and endocrowns, the endocrown showed maximum fracture resistance among them (Huda et al. 2021).

However, no previous study was conducted in the current literature to investigate the fracture resistance of maxillary premolar had root canal treatment and final restoration restoration by hybrid nanocomposite, D.T. LIGHT-POST Illusion and endocrown. So, the aim of the current study was to evaluate the fracture resistance of endodontically treated maxillary premolars restored with either posts-core or endocrown and detect the type of tooth fracture after exposure to stress either it is favorable or non-favorable.

The null hypothesis was that all coronal restorations will increase the fracture resistance of maxillary premolar which had root canal treatment.

2. Material and methods

2.1. Sample selection and preparation:

The Local Research Ethics Committee instructions were followed after ethical approval no: DU:0240521013.

A total of forty human bifurcated maxillary premolars that extracted for periodontal or orthodontic reasons were chosen. They were cleaned off plaque, calculus and periodontal tissues. Each tooth was examined using the microscope (ZEISS OPMI pico, Carl Zeiss Meditec AG, Germany) with 1.6x magnification to ensure the absence of carious lesions, cracks, fractures and previous restorations. All selected samples had fully developed apices, moderately curved roots (between 10-25). Canal curvature was calculated according to Pruett direction (Pruett et al. 1997). The selected teeth were free of previous endodontic treatments, posts, or crowns. All teeth were immersed in Chloramine T for 24 hours at 4 C° for sterilization.

Standard periapical radiographs in mesio-distal and bucco-lingual directions were applied to identify canal morphology and included samples had two roots. Then after, samples were kept in saline at 37 C° until use.

2.2. Root canal preparation:

An endodontic access cavity was performed using high-speed hand-piece with a round diamond bur size 021 (Dentsplay Sirona, USA).

Working length determination was calculated by using a size #10 K-file (DENTSPLY Maillefer, USA) to reach the apex then subtract 1 mm of the length. Instrumentation was performed for all root canals using the selected NiTi rotary instruments using X smart Plus Endo motor (DENTSPLY, Sirona, USA): One Curve 25/. 06 (Micro-Mega, Besancon, France) at 300 rpm and torque 2.5N.cm for both canals. Irrigation for all root canals was done among canal shaping with 3ml 5.25% sodium hypochlorite (Prime Dental products, Mumbai, India) then 1 ml of 17% Ethylene diamine tetra acetic acid (RC help, Prime Dental PVT LTD, India) and irrigation with10 ml of 0.9% saline. The root canals were dried using absorbent paper points (DENTSPLY Maillefer, Ballaigues, Switzerland). Master cone was fitted then warm vertical condensation technique was performed for obturation by using of suitable gutta-percha points (DENTSPLY, Petropolis, RJ, Brazil) with AH26 sealer (DENTSPLY, DeTrey, Konstanz, Germany) using System B unit and Obtura II (Morita Corporation, Tokyo, Japan).

2.3. Teeth grouping:

Random distribution of specimens in four groups depending on the coronal restoration (n=10) as follow:

Group 1: teeth did not receive neither root canal treatment or coronal restoration and kept intact to be considered as a control group

Group 2: teeth received coronal access restoration with composite after root canal treatment.

*Groups 3***:** teeth restored with D.T. Light-Post Illusion (Bisco Inc, Schaumburg, IL) in palatal canal after removal of gutta-percha and leaving only 5 mm from apical part.

The space of post was prepared in this group following manufacturer instructions.

Group 4: teeth received E-Max endocrown using CAD/CAM system for fabrication

2.4. Composite restoration (Group2):

The coronal access cavity was filled with Tetric N-Ceram Bulk Fill (Ivoclar Vivadent products, Schaan, Liechtenstein). The access cavities were etched with acid etch of the same company followed by bonding with N-Bond (Ivoclar Vivadent, Schaan, Liechtenstein) following the manufacturer's instructions. Teeth were filled with Bulk-fill composite. To maximize marginal adaptation, suitable ultrasonic tip and ultrasonic handpiece

(Woodpecker, Guilin, China), were applied to the composite for 1 min with medium energy. Modification of the ultrasonic tip to be round at the tip. Followed by contouring of the material by a selected plastic instrument and finally the light-emitting diode (Woodpecker, Guilin, China) was used for curing with intensity (1000 mW/cm2) for 40 s. As a last step, composite finishing and polishing with fine-grit diamond points (Mani Inc., Japan) (Sajjan Dutta et al. 2022).

2.5. Sample Preparation for D.T. Light-Post Illusion group (Group3):

The chosen post was the red one size 1 post (diameter at tip 0.9 mm, double taper: and coronal 1.5 mm). The canal space was prepared and enlarged using its corresponding drill from the D.T. Light-Post Kit (#2, diameter of 1.0 mm in) (BISCO Dental Products, Schaumburg, IL, USA) following the manufacturer's instructions with only 5 mm of gutta-percha at the apical part. The post length and adaptation was confirmed by a radiograph

The gutta-percha was removed with a #1 or #2 Peeso Reamer. For canal shaping followed by black Drill. For canal lubrication sodium hypochlorite was used. The final preparation with the subsequent drills was utilized to finish canal preparation. For length determination, an endodontic rubber stopper on the shaft of the drill was utilized and verified by a radiographic. Finally, water spray was used to remove the debris from canal with a water spray, followed by paper points.

2.6. Post Cementation:

All prepared canals were rinsed to remove any visible debris. Next, each canal space was etched by using 37% phosphoric acid (3M Scotchbond Acid Etch; 3M ESPE, St Paul, Minn) up to 15 s. then flushed with distilled water and dried out by paper point (Dentsply Maillefer, Ballaigues, Switzerland). The fifth-generation bonding agent dual cure (SEALBOND ULTIMA, RTD, ST Egreve, France) was applied to the post and also to the canal followed by light air pressure. resin cement Luxa Core Z (DMG, America LLC, USA). Filling of the canal space with light cured resin cement Luxa Core Z (DMG, America LLC, USA). The post was covered with the cement then inserted into canal with gentle pressure to allow removing of extra material. The extra material was cleaned then the canal was light cured up to 40 seconds.

2.7. Teeth build up

The exposed part of the post and tooth surface was etched for 15seconds and bond was applied to both. Then, air-drying followed by light cure for 10 seconds. The LuxaCore material was added around the post and continued until filling the whole access cavity to the occlusal level. The specimens were kept in 100% humidity for 7 days.

2.8. Endocrown (Group 4):

The same operator performed all the steps. Specimens decapitation from the occlusal surface at a level 2 mm occlusal highest point of the proximal cemento-enamel junction (CEJ) using a diamond saw blade mounted in a water-cooled, low-speed sectioning machine (IsoMet 4000) (Dartora de Conto Ferreira et al. 2018). Then after specimens were sealed with an epoxy resin-based sealer.

A layer of flowable composite resin material (Tetric N Flow, (Ivoclar Vivadent, Schaan, Liechtenstein) was applied and light-cured for 10-15 seconds (El-Damanhoury et al. 2015) followed by air-thinning for 10 seconds and light-cured for 10 seconds using a LED light-curing unit (Woodpecker, Guilin, China) according to the manufacturer's instructions.

Using a dental CAD software (Dental DB 2.2 Valletta), the design for endocrown preparation for each scanned tooth was made. It included firstly smoothening and finishing of a circumferential butt margin and then maintaining a central cavity with a depth of 4 mm axial wall internal taper of 6° and a circular axial wall thickness of 2 ± 0.2 mm. Internal cavity preparation was limited to remove only undercut areas while maintenaning the original anatomy of the pulp chamber to be smooth with rounded internal line angles. Construction of the endocrown by wet-milling of 10 IPS e.max CAD blocks. Then crystallization and glazing processes were performed using a compatible ceramic furnace (Programat P500).

2.9. Cementation of endocrowns

All endocrowns were cleaned well using steam and dried with oil-free air for 20 seconds. the fitting surfaces were treated with 9.5% hydrofluoric acid etching gel (Porcelain Etchant) for 90 seconds, rinsed off properly for 90 seconds and then thoroughly air-dried for 20. After that, 2 thin coats of a silane coupling agent (Porcelain Primer) were applied for 30 seconds and then carefully air-blown for 5 seconds. After surface treatment completed, a dual-cured, adhesive composite resin luting cement (Breeze, Pentron Clinical, CA, USA) was used (Shams Sakrana et al. 2022).

2.10. Preparation of molds to simulate PDL:

Teeth were covered with a thin layer of 0.2mmthickness polyvinyl siloxane impression material 2 mm below the cemento-enamel junction (ESPE, 3M, USA). Then, vertical embedding of the specimens along their long axes within in self-cured squared acrylic resin blocks of 2x2cm volume and 15 mm depth (Carla Zoheib Germain Sfeir et al. 2018) (GC America Company; USA) *(Figure 1)* (Sirimai Riis et al. 1999) (Alghamdi et al. 2020).

2.11. Fracture Resistance:

The acrylic blocks with embedded samples were placed in the universal testing machine (LR 300K; Lloyd Instruments Ltd., Bognor Regis, UK) and a vertical compressive load was performed at a speed of 0.5 mm/minute with the spherical tips at the center of the occlusal surface until fracture. The computer linked to the machine that recorded the maximum applied force at fracture in Newton and time needed to fracture each specimen (Belli et al. 2004; Alghamdi et al. 2020) *(Figure2).*

2.12. Fracture mode

After fracture, the specimens were inspected visually by examining them under the stereomicroscope (MEIJI, EMZ-13TRD, MEIJI Techno, Japan) with 10x magnification to define the failure mode. The categories of failure were divided into two types as follow:

Type I: Favorable fracture: above the CEJ

Type II Unfavorable fracture: below the CEJ (Bitter H et al. 2010; Rodrigues MP et al. 2010).

2.13. Statistical Analysis:

The software "Statistical Product and Service Solutions" Version 20.0 (SPSS Inc., Chicago, IL, USA) was used for data statistical analysis. Kolmogrov-smirnov test was done to evaluate the normal distribution of the collected data. The difference in fracture resistance between all groups was investigated by one-way ANOVA while comparison between the two groups was done by independent sample t-test. The level of significance was set at 0.05.

3.**Results**

The data for all groups were normally distributed (KST; $p>0.05$) regarding the data of fracture resistance test.

Fracture resistance test

A statistically significant difference was found among all groups ($p<0.05$). The means of fracture resistance of the four groups are presented in (Table 1). The endocrown group have the highest mean of fracture resistance value (1216.21N) followed by post group with load of (1183.31N), while the control group exhibited the lowest fracture resistance value (683.66N) after composite group (802.51N) and the difference between them was significantly different from control group ($p<0.05$). *(Figure3) (Table 1)*

Time to fracture

There was a statistically significant difference among groups ($p<0.05$) (Table 2). The endocrown group consumed the most extended time to fracture among the groups (233.60 sec.) followed by composite group with (186.20sec.). The post group fracture time recorded (152.50 sec.), while the control group fracture was the significantly the fastest to fracture at (149.30sec) ($p<0.05$). *(Table 2)*

Mode of failure

Unfavorable fracture was the most observed in all groups representing 75.5%, while the favorable fracture represented 24.5% of samples. The unfavorable fracture represented 100% of samples in the endocrown group. The fracture in post group was 50%% unfavorable and the fracture in composite group was 60% while control group exhibited the highest percentage of unfavorable fracture 90% and without significant difference when comparing groups ($p>0.05$). (Figure 4)

Analysis of fracture behaviour

In the endocrown the fracture occurred perpendicular to the loading axis at the central fossa leading to unfavourable fracture or completely badly broken samples with brittle fracture curve.

The fracture in the post group occurred at one cusp separated and the remaining cusp was attached and supported by the post. The fracture curve represented resilient fracture

For the composite group, the fracture curve represents brittle fracture. It was observed that at the time of fracture when there is multiple fracture line it is accompanied with favourable fracture but in case of one fracture line there was an unfavourable fracture.

In the control group always brittle fracture curve with one oblique fracture line to the cusp.

4.**Discussion**

Testing the fracture resistance of teeth received root canal treatment in vitro to determine the capability of coronal restoration materials and design to evaluate their strengthening effect is an accepted method to assess their functionality against masticatory forces after treatment.

The fracture resistance of premolars decreased after access cavity preparation and endodontic treatment because of loss of teeth structure even they were restored with composite filling, using fiber posts or even endocrown (Bassir A et al. 2013). Maxillary premolars exhibit a lower resistance to masticatory forces and their anatomical configuration is the main cause for high susceptibility to fracture; especially when there is loss of tooth structure. Therefore, material used and technique should be considered to improve fracture resistance (Bassir et al. 2013) used lower premolars. Other studies used anterior teeth (Menezes et al. 2008; Mosharraf & Ranjbarian 2013), premolars and molars (Belli et al. 2005) and reported different values. The direction of force also influences on the value of the maximum load during testing. Some studies used vertical force application (Belli et al. 2004) and others used oblique force (Revathi et al. 2019).

In the current study, there was a significant difference between the tested groups. So, the null hypothesis was rejected.

The force of mastication is about 70 to 150 newtons when eating regular food, The maximum masticatory force in adults could be up to 500 to 700 newtons (CS Oxford 2003). The maximum bite force in males is greater than that in females (Nickolay A 2014). The values of masticatory force in the molar is 3 times greater than those in the anterior region (Nickolay 2014). These values decrease with age (Poli M et al. 2021). According to the results of the current study all groups fractured at or above the maximum load of the masticatory force.

The intact teeth fractured at the same level of the maximum load reported by previous studies (CS Oxford 2003). In the meantime, their values were lower than treated group which could be the external and internal shape including cuspal anatomy, cuspal height, sizes of labio-lingual and mesio-distal cervix, location of pulp chamber and root size and tooth age (Nazari B et al. 2009). Other influencing factors include: type of saliva and oral environment, storage time, race, age, gender, arch position, and abrasion. All of these factors have an impact on teeth fracture resistance (Burke 1992; Chang-yong et al. 2019).

For root canal treated teeth, it is well documented that the restorative technique influences teeth biomechanical behavior. According to the results of the current study, restoring endo-treated maxillary premolar with endocrown improved the fracture resistance which came in agreement with many previous studies who found endocrown system enhance the biomechanical properties of the tooth/restoration complex in severely-destructed maxillary first premolar teethwho received root canal treatment (Hassouneh et al. 2020; Shams et al. 2022; Abbas et al. 2024).

On contrary, Guo et al in 2016 found that mandibular premolar restored with endocrown exhibited no improvement in fracture resistance when compared with the composite method. They concluded that, both of the two methods cannot rehabilitate endodontically treated teeth with the same fracture resistances that intact mandibular premolars have (Guo et al. 2016). This could be referred to the difference in fracture resistance of lower and maxillary premolars and the difference in the material for endocrown construction.

Lin et al in 2020 Found that, the endocrowns minimize concentration of stress for the root canal internal wall when compared to the teeth restored with post-core crown. As a conclusion, molars received endocrowns are less susceptible to root fracture than teeth received posts (Lin et al. 2020). This came in agreement with the current results where teeth restored with endocrown. They referred this to the increased stress at the inner wall of the root canal in teeth restored with post and core.

The use of fiber post and composite restoration has been studied with aim of increasing the resistance to fracture of endodontically treated teeth in many studies (Soares et al. 2008; Göktürk et al. 2018; Selvaraj a et al. 2023). The glass fiber post completely bond to composite core and improve the teeth strength. The core composite material should have an excellent adaptation and bonding strength with tooth structure to create monoblock and reinforce the intra radicular tooth structure. The post material and core material should have approximate modulus of elasticity close to dentin to equally distribute stresses. For post with low modulus of resilience is exposed to permanent deformation under compressive stresses and acts as a foreign structure in the core material and weaken it (Makade et al. 2011; Öztürk et al. 2019).

According to Boksman et al who were discussing the efficacy of the new generation of adhesive and if they are always better regarding their bonding strength and durability. They concluded that using the fifth-generation of adhesives not associated with bond strengthening in all clinical conditions. (Leendert et al. 2012; Song et al. 2015). This can explain the results in the current study, the group restored with composite without post insertion reported lower fracture resistance compared to teeth restored with DT post and composite. The present results came in concurent with Göktürk et al study, where premolars with composite filling combined with fiber post exhibited more resistance to fracture than others restored with composite filling only when compared with intact teeth (Göktürk et al. 2018).

In contrary, Cobankara et al and Gokturk et al did not find a difference in the resistance to fracture between premolars received final filling with composite and others restored with composite and fiber post. They considered that incremental technique of composite decreased the cuspal deflection and polymerization shrinkage. They referred this to presence of glass fiber in the composite filling that alters its elastic modulus and modify the stress distribution and transmitting to the cavity walls (Scotti et al. 2016).

In the current study, all groups had a high prevalence of unfavorable fracture. The same observation was reported by Gokturk et al study. They reported more unfavorable fracture with teeth either restored with composite or with fiber post and composite (Göktürk et al. 2018). However, studies by Reeh *et al* failed to find statistically significant differences between teeth with MOD cavity and sound teeth (Reeh et al. 1989).

Restoration of teeth with more rigid material produce a high incidence of un-restorable fracture compared to intact teeth (Oliveira et al. 1987; Mohammadi et al. 2009; Göktürk et al. 2018). Also, more unfavorable fracture was reported with tapered post design due to unequal distribution of force and stress concentration at the coronal shoulder and wedging effect and stress concentration of the tapered design (Fernandes & Dessai 2001; Madfa et al. 2014; Revathi et al. 2019). This could explain the high prevalence of unfavorable fracture in the group of DT post. On the other hand, these results came in contrary with Makade et al finding who reported no root fracture for fiber post restored maxillary incisors teeth when restored with fiber post and tested for fracture resistance (Chetana et al. 2011). This could be related to different teeth selected for their study and oblique force application.

In this study the teeth received with endocrown reported the highest rate of unfavorable fracture among groups which could be related to the highest value of force and the longer time taken by samples to fracture. This came in agreement with other studies who reported higher incidence of unfavorable fracture under higher load than the values reported for normal masticatory forces (Ghoul et al. 2020)

5.Conclusion

We can conclude that, restoration of root canal treated maxillary premolar with endocrown displayed the highest value of resistance to fracture, followed by group restored post-core. The group restored with composite filling exhibited the lowest value of fracture resistance among restored teeth.

All tested group reported unfavorable fracture where the endocrown group had the highest incidence followed by post and core and composite. The DT group exhibited the highest percentage of favorable fracture among groups

Figure 1: The mounted teeth in the acrylic resin mould

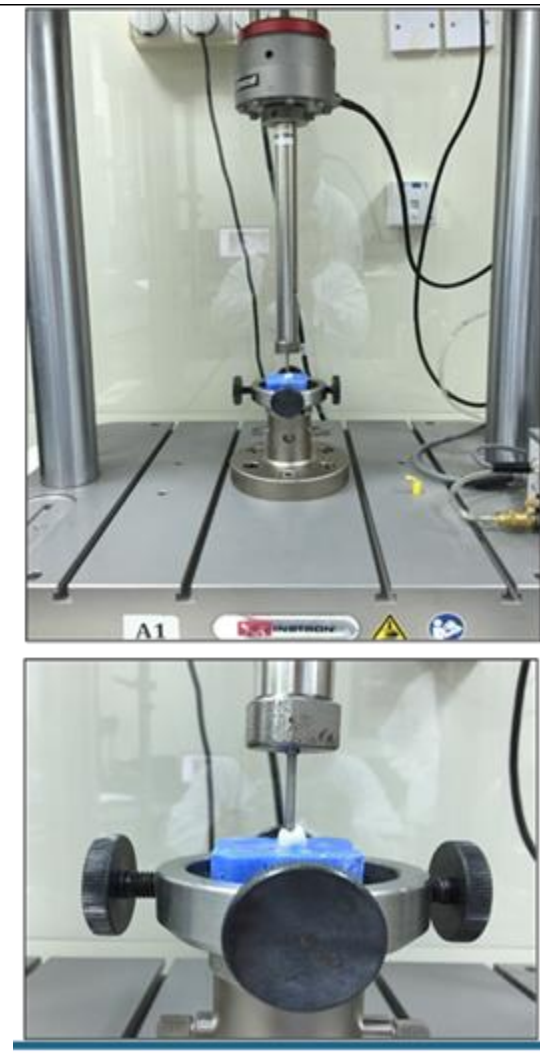

Figure 2:Rge Universal Testing Machine used for the fracture Testing of Mounted Teeth

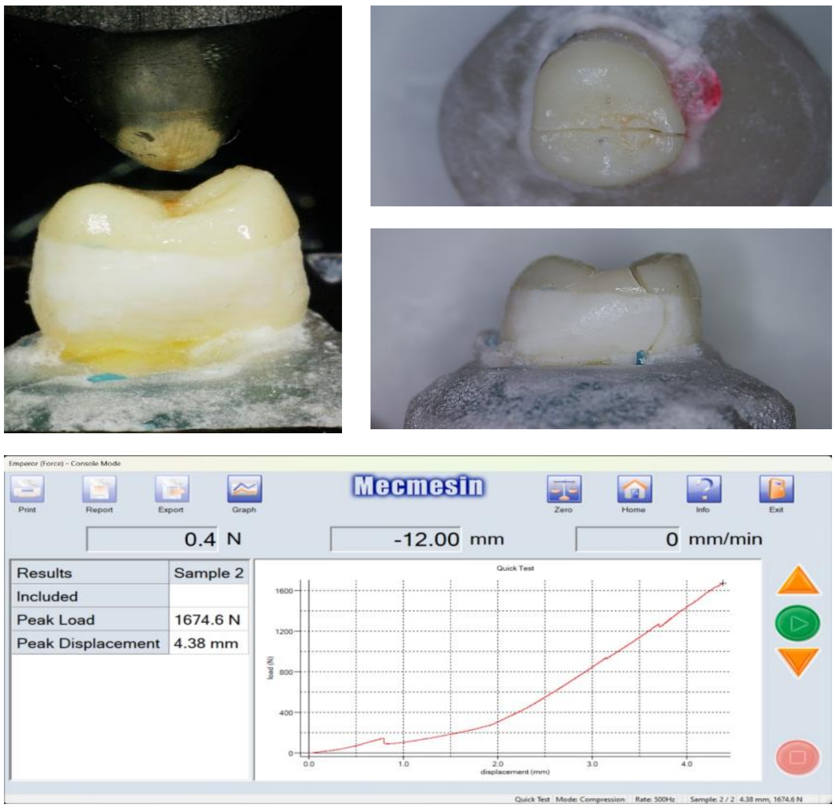

Figure3: Testin of endocrown samples and fracture mode

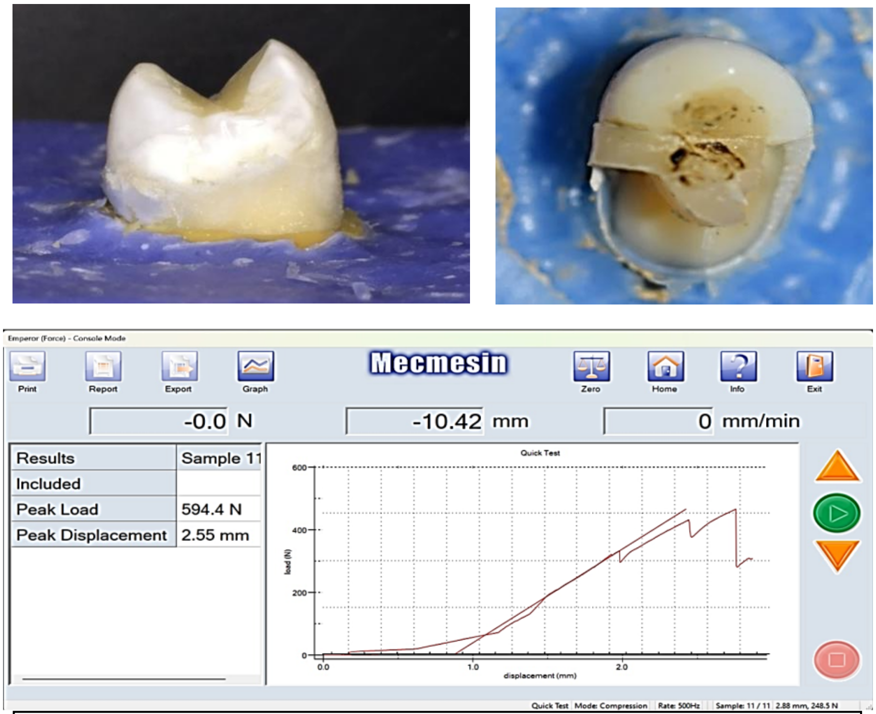

Figure 4: Post and core samples with unfavorable fracture

Table 1: Max and minimum load to fracture in all tested groups

Tested group		N	Mean	SD	95% CI Mean Lower	95% CI Mean Upper	Min	Max	F	P-value
max load in Newton	Composite	10	802.51	158.84	688.9	916.1	594.4	1006.0	8.047	<0.001
	Control group	10	683.66	63.02	638.6	728.7	560.5	790.2		
	Endocrwon	10	1216.21	374.69	948.2	1484.3	821.7	1831.1		
	Post group	10	1183.31	434.22	872.7	1493.9	783.1	2090.7		
	Total	40	971.42	371.58	852.6	1090.3	560.5	2090.7		

Table2: The total time taken by samples to fracture in each group

Tested groups		N	Mean	SD	Std. Error	95% CI Mean Lower	95% CI Mean Upper	Min	Max	F	P-value
time in seconds	Composite	10	186.20	19.25	6.09	172.4	200.0	167.0	230.0	34.454	<0.001
	Control group	10	149.30	9.26	2.93	142.7	155.9	131.0	160.0		
	Endocrwon	10	233.60	33.14	10.48	209.9	257.3	190.0	294.0		
	Post group	10	152.50	15.13	4.78	141.7	163.3	121.0	173.0		
	Total	40	180.40	39.92	6.31	167.6	193.2	121.0	294.0		

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