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MECHANICAL BEHAVIOR OF DIFFERENT TREATMENT PLANES FOR RESTORING ENDODONTICALLY TREATED PREMOLARS WITH MODIFIED GLASS CERAMIC

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ABSTRACT

Objectives: The purpose of this research is to investigate the impact that the restoration design (either "3-mm deep endocrown," "5-mm deep endocrown," or "5-mm deep post&crown") & the kind of CAD/CAM material (Zirconia reinforced lithium silicate glass ceramic) have on load-to-failure of endodontically managed premolars when there is no ferrule present.

Methods: The crowns of forty-five premolars with a single root have been removed, and endodontic treatment was performed on the roots. Teeth have been randomly separated into three groups, each consisting of fifteen. Teeth in each group were repaired with either traditional crowns (five millimeters deep post-crown) or standardized CAD/CAM-fabricated endocrowns (three millimeters or five millimeters deep intra-radicular extension). Following the application of luting resin cement for the procedure of cementation, the specimens have been immersed in distilled water and then exposed to 25000 cycles of thermocycling. Once that has been done, a universal testing apparatus has been utilized to apply a compressive load on the tooth at an angle of ninety degrees to its long axis until the tooth breaks. Following the recording of the load-to-failure (N) value, the samples have been studied using a stereomicroscope with a magnification of 3.5x to ascertain the manner of failure.

Results: All of the specimens were able to endure the aging process that was brought about by the 25000 cycles of thermos cycling without suffering any obvious harm. Utilizing One-way ANOVA. A non-significantly greater load-to-failure has been observed for the '3-millimeters deep endocrown ' than other groups (5-millimeters deep endocrown & 5-millimeters deep post & core).

KEYWORDS: CAD/CAM, Compressive load, Cyclic aging, Endocrown, Lithium silicate, Post and core, Zirconia reinforced.

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INTRODUCTION

Endodontic therapy is utilized regularly in modern dentistry; nevertheless, when the root canal has been managed, a restorative remedy that is satisfactory is required. There are many types of methods and materials suggested for restoring pulpless teeth. (1)

When a tooth needs endodontic therapy, it is typically a tooth that has lost a significant volume of tissue of tooth & has been severely restored. Typically, these teeth are more susceptible to breaking than others. (2)

Recently, there have been changes in the restoration of teeth that have been endodontically managed. Increasing the availability of adhesive methods has raised the range of options available to clinicians when it comes to the restoration of teeth. (3).

The application of intra-root canal posts and cores is typically recommended as a means of providing macro-retention for conventional crowns. This is done to keep the crowns in place. Fiber posts, in contrast to metal posts, which have the potential to damage the root, have an elastic modulus that is more comparable to that of dentin. It is believed that this property significantly reduces the likelihood of catastrophic root fractures occurring if the tooth is overloaded. (4)

The only cause for the premolars to fail was a loss of adhesion, which suggests that the surface area that was accessible to adhesive bonding might not have been sufficiently great. In addition, the unfavorable ratio among the crown base and the height may result in a moment of force, which is the requirement that cavities have a depth of five millimeters. (5)

When it comes to the biomechanical behavior of restored endodontically treated premolars, there is a lack of information about the significance of the endo-crown design. Furthermore, there has been very few research that has studied the influence of the duration of the intra-radicular extension up until this point.

In the course of root canal treatment, the medications and irrigants that are utilized have the potential to alter the physical characteristics of dentine. Furthermore, the continuous application of calcium hydroxide causes dentine to be more fragile & susceptible to fracture. Furthermore, non-vital teeth have a loss of proprioception and perform less well when it comes to feeling increasing load. (6)

It is desirable to preserve the coronal tooth tissue without compromising the endodontic access needed for the procedure. The dentist is able to increase the amount of existing residual tissue of tooth through the application of adhesive procedures. These methods do not need the production of macromechanical tension, which enables the retention of hard tooth structure instead of its removal. Because the remaining tooth gives the solid platform that is necessary for restoration of tooth and since it determines the structural strength of the repaired tooth, it is essential that the integrity and quality of the tooth that is still present be preserved with restored caution. (7)

If there are enough surfaces of tooth for bonding, adhesive restorations have the benefit of not requiring a macro-retentive design. This is made possible by the progress of adhesive methods and ceramic materials, which have made it possible for adhesive restorations to be used. A circular shoulder margin with a width of one millimeter & a central retention cavity that is the same size as the pulp chamber are the components that make up the endocrown preparation. This preparation enables the core and crown to be constructed as a single unit. In addition, the realities of chair-side design & automated manufacture of these single-unit ceramic restorations were made possible by dental computer-aided design & computer-aided manufacturing (CAD/CAM) systems. Bonded endocrowns have

been shown to have fracture load values that are similar to those of traditional crowns, according to in vitro investigations. [8]

Consequently, the goal of this in vitro investigation was to assess the influence of design of restoration (which may be "3-millimeters deep endocrown," "5-millimeters deep endocrown," or "5-millimeters deep post & crown") on the load-to-failure of the endodontically treated premolars that had been repaired.

The null hypotheses that have been evaluated were that the restoration design & the computer-aided design & computer-aided manufacturing material type don't have an effect on load-to-failure of restored teeth.

MATERIALS AND METHODS

Power analysis for sample size determination

To have sufficient power to conduct a statistical test, a power analysis has been designed to have appropriate power.

Through the utilization of a significance level of ninety-five percent, an alpha level of 0.05, & a beta level of 0.2 were adopted. In other words, the power was assessed to be eighty percent according to the findings of the prior research (9), and the size of the sample that was projected to be used was a total of forty-five samples. Through the utilization of G-power 3.1.9.4 (Heinrich-Heire, Dusseldorf, Germany), the computation of the sample size has been carried out. ANOVA F test has been utilized: fixed effect, one-way, and omnibus.

Forty-five extracted human maxillary first premolars were gathered and shown in Figure 1. Teeth were extracted for orthodontic or periodontal reasons. Teeth have been cleaned from soft tissue attachments using an ultrasonic scaler, and they have been stored in distilled water until complete gathering of teeth. Careful examination with 2.5X magnifying loupes to ensure they were free from any caries, defects & cracks was carried out. The anatomical crown length and mesiodistal diameter were measured utilizing a digital caliper. The difference in dimensions of Teeth were not more than ±5%. Each patient completed an informed consent form allowing the use of his or her teeth in the study. Teeth were given to the university hospital's incinerator after the research was over.

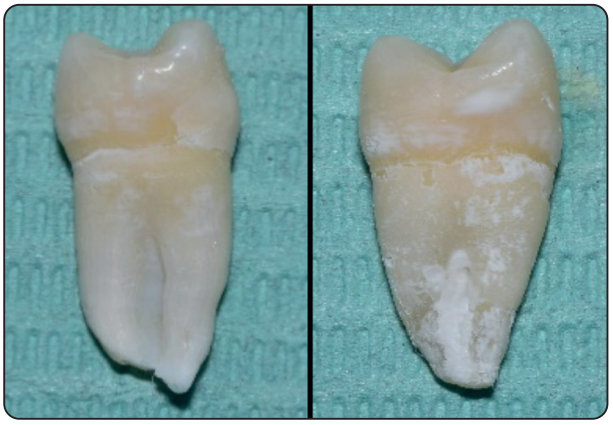

Fig. (1) Extracted teeth specimens.

TABLE (1) Contains information on the manufacturers, brands, compositions, kinds, and batch numbers of the materials that were utilized.

	Brand Name	Material's Description	Manufacturer	Lot Number
1	Vita suprinity	Zirconia reinforced lithium silicate glass ceramic	Vita Zahnfabrik Germany	#65701
2	Aluminum Oxide powder	Sandblasting powder	Shera Werkstoff-Tech, Germany	#667
3	TheraCem	Dual-cure Self-Adhesive Resin Cement	Bisco, U.S.A	#2100006297
4	PORCELAIN PRIMER	Pre-Hydrolyzed Silane Primer	Bisco, U.S.A	#2100008551
5	Phosphoric acid Etchant	37% phosphoric acid gel	META BIOMED CO. LTD. Korea	#MET2207111

All of the roots have been coated on the outside with a coating of latex solution (Erkoskin, Erkodent, Pfalzgrafenweiler, Germany) that had been air-thinned and had a thickness of approximately 0.3 millimeters. This was done to simulate periodontal ligament (Fig. 1). To simulate an appropriate biological breadth among the alveolar bone and the preparation finish lines, samples were first positioned in a cylindrical plastic mold that was twenty millimeters high and ten and a half millimeters in diameter. The specimens were subsequently placed in methylmethacrylate resin (ClaroCit, Struers, Ballerup, Denmark) at a distance of three millimeters from the CEJ. A random distribution of Teeth was carried out in accordance with the three distinct designs of preparation.

Crowns of teeth have been removed through cutting at the level of the CEJ with a water-cooled, low-speed diamond saw (Isomet 1000, Buehler, Lake Bluff, IL, United States of America (Fig. 1). This was done to remove the crowns completely. On the roots that were still there, there was no enamel left. They have been managed endodontically utilizing a rotary file system (Pro-Taper, Dentsply-Maillefer, Konstanz, Germany; X-Smart-Endo-motor, Dentsply-Maillefer). The treatment has been carried out in accordance with a standardized crown-down procedure. Following the completion of each instrument alteration, the apical foramen has been prepared to a size of thirty, and the root canal has been irrigated with a solution of 2.5 percent Sodium Hypochlorite. Utilizing a hot constant-wave condensation method (System-B Heat Source, Sybron Endo, Amersfoort, The Netherlands), root canals have been dried utilizing paper points & subsequently sealed with an epoxy resin-based root-canal sealer (Top Seal, Dentsply-Maillefer) & tapered gutta-percha points. This process was also performed. In addition to keeping all of Teeth in distilled water at a temperature of thirty-seven degrees Celsius for twenty-four hours, the root access has been temporarily filled with composite material (Clearfil AP-X, Kuraray Noritake, Tokyo, Japan).

Teeth were classified into three groups:

Group I:

A standardized three-millimeter deep central inlay-type cavity has been prepared utilizing a diamond bur with a 5° tapered and eighty micrometer grit (SBR5 Smooth Cut, GC). This bur has been mounted in a high-speed air turbine (650, KaVo, Biberach, Germany), and it has been guided by a plexiglass matrix that was made-to-order by MicroSpecimen Former, University of Iowa, Iowa City, Iowa, United States of America. The cavities were oval, with a width of two millimeters from the mesial to the distal, 4.5 millimeters from the

Fig. (2): Extracted teeth mounted in acrylic resin.

buccal to the palatal region at the top, and dentin edges that were at least one millimeter broad (Fig. 1). For the purpose of polishing the finish lines, the internal cavo-surface line angle was rounded, & a twenty-five-micrometers grit diamond bur (SBR5f Smooth Cut, GC) & abrasive discs (Sof-Lex 2382C & 2382F, 3 M ESPE) have been utilized.

Group II:

5-millimeter deep endocrown, each root has been prepared & completed in a similar standardized way as the group that came before it; nevertheless, the depth of center inlay-type cavity was five millimeters in depth.

Group III:

5-mm deep post & crown. Utilizing a low-speed tungsten bur (Drill Refill, GC, Tokyo, Japan), post spaces have been prepared at a depth of five millimeters into root canal. The diameter of the post spaces was 1.6 millimeters. With the application of paper tips, each root canal that had been constructed was washed with distilled water and then dried. Translucent glass-fiber posts with a 4° taper and a color code of blue have been used for the GC Fiber Post. These posts had a coronal diameter of 1.6 millimeters and an apical diameter of 0.7 millimeters. They were cut at a length of ten millimeters from the most apical section, cleaned utilizing alcohol, & salinized for sixty seconds using porcelain primer from Bisco. An application of dual-curing self-adhesive luting cement (Theracem, Bisco) was used to cement the posts, and the cement was allowed to cure for fifteen seconds beginning at the top of the posts. The identical dual-curing composite material has been used to construct standardized cores, and it has been dispensed into a transparent silicon matrix that was produced to order (mesio-distal dimensions of 2.4 millimeters, bucco-lingual dimensions of 4.4 millimeters, and height of 5 millimeters; Memosil 2, Heraeus Kulzer, Hanau, Germany). Dentin margins of at least one millimeter in width have been ensured, and each post has been completely covered by matrix, which has been situated in the middle by the same operator. Once the matrix had been removed, the core preparation has been completed by utilizing a 5° tapered & twenty-five micrometers grit diamond bur (SBR5f Smooth Cut, GC) & abrasive discs (Sof-Lex 2382C & 2382F, 3 M ESPE, Seefeld, Germany). This was done following light-curing for ten seconds. From each surface, including lingual, buccal, occlusal, distal, & mesial.

At the locations where teeth had been fixed in the past, a dental typodont that was made to order made it possible to position the methylmethacrylate cylinders in a standardised manner. The upper 2nd premolar site has been given a niche that had dimensions that were comparable to those of the cylinders. The niche was twenty millimeters in height and ten and a half millimeters in width. The cervical region served as the stop. In order to guarantee that the preparation margins of total samples were at the same level, it was necessary to verify that each sample was positioned precisely and that it was a tight fit within the typodont. Digital optical impressions have been obtained with a powder-free chairside intraoral scanner (Cerec Omnicam, Sirona, Bensheim, Germany). From occlusal aspect to lingual & buccal sides, the camera has been turned at an angle to long axis of tooth. During the process of capturing images of internal surfaces of the preparations, a wave movement of the camera has been utilized in both the bucco-lingual and mesio-distal directions. This was done in order to ensure that the '5-millimeter deep endocrown' specimens were appropriately acquired. In addition, a typodont preserved in the lower jaw has been scanned and utilized as an antagonist for the purpose of occlusal bite registration. Utilizing the Biogeneric Variation of 0.20, the Cerec AC CAD/CAM program (SW 4.3, Sirona) was utilized in order to conduct the process of automatically designing restorations.

The restoration design parameters included a spacer with a diameter of 50 micrometers, an occlusal milling offset of 0 micrometers, proximal contact strength of 25 micrometers, occlusal contacts strength of 25 micrometers, dynamic contacts strength of 25 micrometers, minimal radial thickness of 1000 micrometers, minimal occlusal thickness of 1000 micrometers, and margin thickness of 500 micrometers.

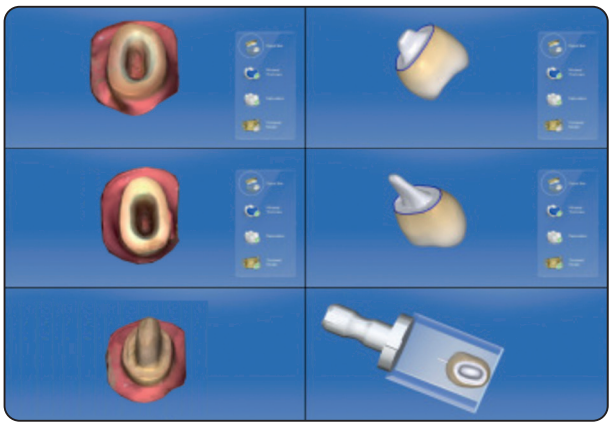

Fig. (3) Digital optical impressions and designs

Digital optical impressions have been obtained by using a powder-free chairside intraoral scanner (Cerec Omnicam, Sirona, Bensheim, Germany). The camera has been rotated from the occlusal aspect to lingual & buccal sides with an angle to long axis of tooth. In addition, images of internal surfaces of preparations have been correctly collected for the specimens that were described as having a "5-millimeter deep endocrown." This was accomplished by employing a wave movement of camera in bucco-lingual & mesio-distal directions. Utilizing the Biogeneric Variation of 0.20, Cerec AC CAD/CAM program (SW 4.3, Sirona) was utilized in order to conduct the process of automatically designing restorations. A spacer of 50 micrometers, an occlusal milling offset of 0 micrometers, proximal contact strength of 25 micrometers, occlusal contacts strength of 25 micrometers, dynamic contacts strength of 25 micrometers, minimal radial thickness of 1000 micrometers, minimal occlusal thickness of 1000 micrometers, and margin thickness of 500 micrometers were the parameters that have been used in the restoration design. Zirconia reinforced lithium silicate glass-ceramic (Vita Suprinity) has been used as the material for the restorations, which were constructed using a 14-size CAD/CAM block. Using the 'normal' milling mode, all of the restorations were milled at the same computer-aided manufacturing equipment (Cerec MC XL, Sirona). ZLS was crystallized in a ceramic furnace for twenty-five minutes at a temperature ranging from 840 to 850 degrees Celsius. It was necessary to put ceramic restorations consistently on the silicon nitride firing tray to facilitate the process of reassembly to the prepared tooth that matched them. To completely crystallize the crowns, the tray was positioned in the middle of a ceramic furnace's firing chamber. It is possible to do restorations without the application of provisional restorations. This led to three experimental groups (number = 15) with regard to the preparation design.

After specimen restorations have been inspected for errors and evaluated for fit. Regarding the manufacturer's instructions, fitting surfaces of all samples have been treated (air-abraded) with fifty µm aluminum oxide particles at 1.8 bar of pressure. Dried with pressurized oil-free air after being washed with alcohol. All restorations' internal surfaces were then salinized for 60 seconds with a silane coupling agent (porcelain primer, Bisco), followed by five seconds of air drying.

With care to avoid over-drying, the prepared teeth have been rinsed with water and dried with air. Using 37.5% phosphoric acid, enamel and dentine of occlusal surfaces were etched for fifteen seconds for enamel surface and five seconds for dentin surface. And then they were rinsed and blot dried without dehydrating the dentin. Then, using self-adhesive, dual-cure resin cement (TheraCem), the restorations

were cemented. Each occlusal veneer was placed on its matching tooth and stabilized for setting while a sitting pressure of a static load of 50 N was provided for 10 minutes to simulate finger pressure.[10] (Fig. 21) The luting agent has been exposed to light in five different directions. A thin layer of anti-oxygen seal has been placed to the restoration margin. Before testing, all samples have been kept in distilled water at room temperature for a week.

All the specimens have been subjected to thermo cycling (SD Mechatronic Thermo cycler, Westerham, Germany) for 25000 cycles, 5-55 ± 2 ^{0}C with a one-minute dwell time for each temperature and a 10-second interval time at ambient air between baths.

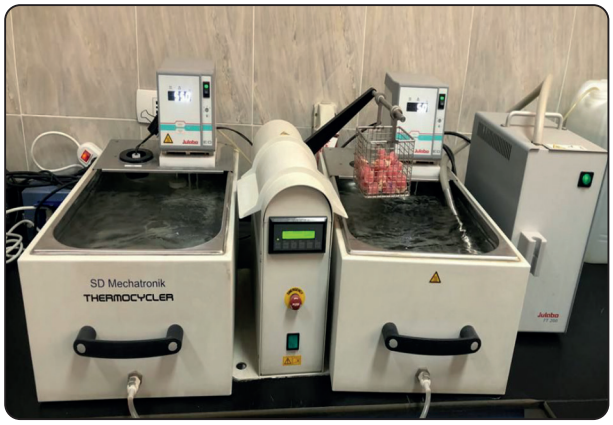

Fig. (4) Thermo cycling machine

Each sample has been placed separately on a computer-controlled materials testing device (INSTRON-CAT.NO:2710-115.USA) (fig 5). By tightening screws, samples were fixed to the testing machine's lower fixed compartment. Utilizing a steel rod with a round tip (6 mm diameter) and a crosshead speed of 1mm/minute, a fracture test has been carried out applying an oblique mode of stress delivered occlusally with 45 degrees of long axis of tooth. An audible fracture and a rapid drop in the deflection of loading curve were considered the maximum load at failure and were measured using computer software in Newton.

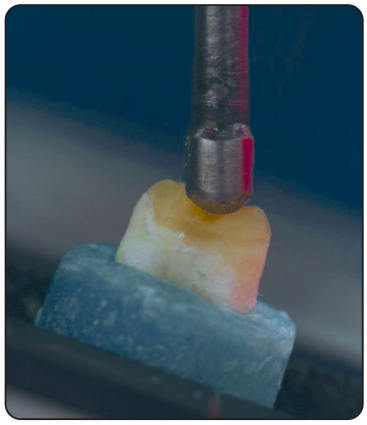

Fig. (5) Steel rod with a round tip used in fracture test

RESULTS

To determine whether or not the information is normally distributed, the Shapiro-Wilk test has been utilized. Comparisons across groups were made utilizing one-way analysis of variance (ANOVA) since load-to-failure information (N) has a normal distribution (p-value above 0.05). Additionally, post-hoc Tukey multiple comparisons were performed with a significance level of p.

All examples survived the aging caused by 25,000 rounds of thermal cycling without observable damage. The load-to-failure outcomes for three experimental groups are illustrated in the picture. No significant variances have been seen when the means have been aggregated for restoration design (p-value equal 0.485).

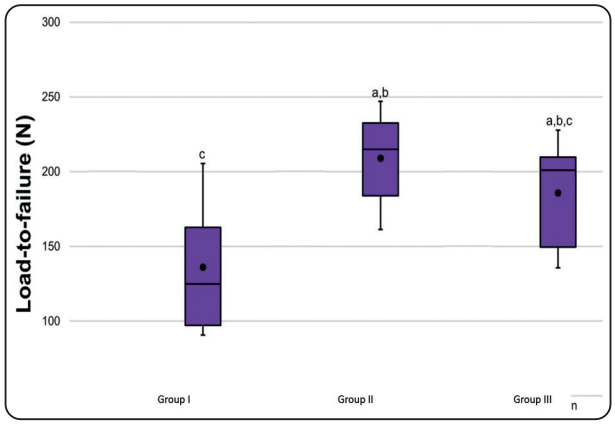

Fig. (6) Load-to-failure (N) A non-significantly greater load-to-failure has been documented for group II (the 5-millimeter deep endocrown) than for other groups.

DISCUSSION

The research aimed to examine biomechanical performance of endodontically treated premolars repaired using various restoration designs & computer-aided design and computer-aided manufacturing materials through assessing load-to-failure & failure mode under oblique compressive load following fatigue aging. Natural premolars of a comparable dimensions have been chosen to minimize confusing variations. The tooth dimensions had no impact on load-to-failure values obtained (r2 = 0.0089; p-value equal 0.2798). Each specimen has been placed in an identical custom-made typodont model with adjacent teeth, utilizing occlusal bite reference from the antagonist model. Consequently, the computer-aided design & computer-aided manufacturing system successfully produced Specimens that were approximately uniform in coronal volume (distance among proximal contact regions: 6.8 millimeters; distance among lingual and buccal faces: 8.9 millimeters; height from margin to top of buccal cusp: 7.5 millimeters; height from the margin to the top of lingual cusp: 6.8 millimeters) & occlusal anatomy, ensuring adjustment of load application point throughout testing.

Insignificant distinction has been seen among the evaluated restoration strategies; hence, the null hypothesis remains rejected. Upon evaluating just the restoration design element, no proof has been discovered indicating that a deeper retention of five millimeters might enhance 45° load-to-failure of restored premolars. A shallow preparation may be advantageous as it mitigates the possibility of accidental perforation of root & prevents unnecessary removal of healthy dental tissue that might compromise tooth-root complex. Nonetheless, even with the '3-millimeters deep endocrown' preparation design, fractures of root has been detected in over fifty percent of the specimens, corroborating the findings of Forberger et al. [11].

The retention after the '3-millimeters deep endocrown' design depended primarily on pure adhesion. In this case, the entire interface is positioned in proximity to the rotational center of the moment of force produced via the oblique load, given that the three-millimeter extension is situated above simulated bone level indicated via embedding resin. Increased restorations displacements owing to de-bonding at luting interface have been seen with lithium disilicate glass-ceramic (7 out of 10) at lower oblique loads (136.1 ± 47.4 N). Over fifty percent of '3-millimeters deep endocrown' specimens composed of lithium disilicate glass-ceramic exhibited no root fractures, which may be advantageous since de-bonded restorations may be re-luted following surface conditioning. [12]

A current in vitro & finite element analysis investigation examined mechanical properties of a five-millimeter deep cavity preparation [13]. It has been asserted that endodontically treated premolars repaired with a post and crown or a five-millimeter deep endocrown may have a comparable failure possibility under typical occlusion, hence supporting the conclusions of this investigation. Earlier research indicated that posts with an elastic modulus comparable to that of dentin led to a reduced incidence of root fractures compared to posts with a greater elastic modulus. [14]

The maximum load-to-failure observed in our investigation is less to that often reported in the literature [11] [15], attributable to (1) the severe aging regimen in the thermos cycler, (2) the forty-five-degree oblique load that generated a significant moment of force on premolar, & (3) the lack of a ferrule. All specimens endured the 25,000 fatigue cycles, indicating that restorations may endure the frequent occlusal loads typically experienced by teeth throughout oral function.

Despite this, it is possible that the tooth-restoration complex was subjected to stress as a result of this aging approach, which ultimately led to a decreased load-to-failure ratio seen during the compressive test. Due to the fact that the tension wasn't equally distributed along the tooth's long

axis, but rather localized in the cervical area [16], the 45-degree load that was applied made the situation more dangerous. The repetition of this oblique orientation results in a significantly higher single load-to-failure ratio, which in turn raises the probability of [17]. Due to the fact that, in contrast to other research [18], no ferrule has been found in any of the groups, the worst-case scenario has been simulated. This is because it is known that the absence of a ferrule tends to significantly reduce fracture resistance, which in turn makes the impact of the restoration design potentially more important. [19] Furthermore, in the absence of a ferrule, it is expected that the post & core materials, as well as the length of the post, will have a greater impact on the stress distribution within the restored tooth. [20]

CONCLUSION

Due to the fact that the conditions have been standardized, the following conclusions may be derived regarding the restoration of endodontically treated premolars: In the absence of any ferrule, the 3 designs of restoration group I, group II and group III (referred to as "3-mm deep endocrown," "5-millimeters deep endocrown," & "5-millimeters deep post&crown") offered sufficient resistance to endure the effects of thermal aging. It has been found that greater load-to-failure values are related to a significantly elevate number of root fractures.

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