



Evaluation of Strain on Mandibular Molars Restored with Peek Endocrown -Experimental Study

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KEYWORDS

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ABSTRACT:

Context :Endocrowns are increasingly used as a restorative option for endodontically treated teeth, offering a conservative and esthetic alternative to traditional crowns. Polyetheretherketone (PEEK) has emerged as a promising biomaterial due to its favorable mechanical properties and biocompatibility. Understanding stress distribution is crucial for the longevity of such restorations. The aim of this study was to assess the stress distribution in mandibular molars restored with polyetheretherketone (PEEK) endocrowns.

Materials and Methods:

A total of 10 patients were selected for the study, which was conducted in the Department of Prosthodontics, Thai Moogambikai Dental College and Hospital, Chennai. Strain was measured using a strainmeter on the day of insertion, at one week, one month, six months, and one year.

Results:

The mean strain distribution was found to be highest one week after insertion (245.4 ± 5.68), followed by the day of insertion (236.70 ± 4.94). A gradual decrease in strain was observed over time, with values recorded at one month (190.0 ± 5.81), six months (134.80 ± 9.35), and one year (108.10 ± 5.08). Statistically significant differences were observed between several time intervals: one year and the day of insertion ($p = 0.000^*$), six months and the day of insertion ($p = 0.005^*$), one month and one week ($p = 0.005^*$), six months and one week ($p = 0.000^*$), one year and one week ($p = 0.000^*$), and one year and one month ($p = 0.005^*$).

Conclusion:

The study concluded that mandibular molars restored with PEEK endocrowns exhibited a reduction in strain over time.

1.Introduction

Endodontically treated mandibular molars often suffer from significant structural loss, making them prone to fractures and biomechanical failure. Traditional restorative options, such as post-and-core crowns, may lead to stress concentration and weaken the remaining tooth structure. Endocrowns have gained attention as a conservative alternative, preserving more tooth structure while ensuring adequate retention and stability. These monoblock coronal restorations are held by the pulp chamber and adhere to the remaining tooth structure.^[1] These restorations are recommended for endodontically treated posterior teeth with significant crown loss, weakened axial walls, restricted interocclusal space, and/or short clinical crowns.^[2] Recently, endocrown has gained popularity as a conservative alternative. Endocrowns are conservative coronal restorations used

to repair endodontically treated teeth with considerable loss of coronal structure.

Endocrowns are a stress-free procedure with short clinical time, low cost, simple application, and aesthetic features. Endocrowns offer the advantage of removing less sound tissue than other techniques and effectively disperse masticatory stresses at the tooth/restoration interface, resulting in a more stable tooth structure. Endocrown-restored molar teeth may endure physiological chewing forces without fracture or debonding. Fracture strength and adhesive characteristics are critical for the lifespan of any endocrown, marginal, or internal adaption.^[3] In simulated masticatory function, endocrowns have lower dentin stress concentration than standard post and core. Endocrowns exhibit higher fracture resistance values than traditional crowns. This restorative approach is suitable for endodontically treated molars with impaired



tooth integrity, ensuring proper function and appearance.^[4]

Several materials, such as lithium disilicate glass-ceramic, zirconia-reinforced lithium silicate glass-ceramic, zirconia, and resin composites, have been used to fabricate endocrowns.^[5-7] The choice of material can impact the mechanical properties and the performance of the endocrown.

Polyetheretherketone (PEEK), a high-performance polymer, has emerged as a favourite restorative material among researchers over the last decade^[7]. Several modifications of PEEK have been proposed to achieve desirable characteristics for restorative applications. The primary advantage of modified PEEK material (20% ceramic fillers) is its 3.6-4 GPa modulus of elasticity, which makes it as elastic as bone and allows it to operate as a stress breaker, reducing the pressures imparted to the restoration and tooth root.^[8] Furthermore, surface changes to this material can result in good adherence to tooth structures when luted with resin cement. It has been utilised to make implant fixtures, fixed and removable dental prosthesis frameworks, and could be a viable alternative to endocrown material.

Given that PEEK possesses a modulus of elasticity comparable to dentin, it is hypothesized that PEEK endocrowns could effectively distribute occlusal forces, thereby minimizing the risk of fractures and improving the longevity of restorations. However, empirical evidence specifically assessing stress distribution in PEEK endocrowns is limited, necessitating further research to validate these assumptions and inform clinical decision-making.

Finite Element Analysis (FEA) serves as an effective tool to assess stress concentration, allowing for a detailed understanding of load distribution within the restored tooth structure. Finite Element Analysis (FEA) studies have demonstrated that restorative materials with elastic moduli similar to dentin can enhance stress distribution and reduce stress concentrations in tooth structures.^[9]

The biomechanical behavior of PEEK endocrowns needs to be thoroughly evaluated to determine their clinical feasibility and long-term success. Stress distribution analysis can provide insights into the material's ability to withstand masticatory forces and its potential advantages over traditional restorative materials^[10]. By investigating the stress distribution in mandibular molars restored with PEEK endocrowns, this study will contribute valuable data to restorative dentistry, aiding clinicians in selecting appropriate materials and improving treatment outcomes for endodontically treated teeth.

2.Objectives

1. To measure the strain values in mandibular molars restored with PEEK endocrowns at different

follow-up intervals (day of insertion, 1 week, 1 month, 6 months, and 1 year).

2. To analyze the pattern of strain reduction over time and assess the functional adaptation of PEEK endocrowns under masticatory forces.

3. To evaluate the ability of PEEK, with its modulus of elasticity comparable to dentin, to effectively distribute occlusal stresses and minimize fracture risk.

4. To assess the clinical feasibility and durability of PEEK endocrowns as a conservative restorative option for endodontically treated mandibular molars.

3.Methods

Material & Methods:

This in vivo experimental study was conducted in the Department of Prosthodontics at Thai Moogambikai Dental College and Hospital, Chennai, following approval from the Institutional Review Board and the Institutional Ethical Committee (Reg. No: EC/NEW/INST/2022/2753). A total of 10 patients were selected using a convenience sampling method, and the required sample size was calculated using G*Power software version 3.0. The study included endodontically treated mandibular molars with sufficient coronal remnants, adequate root length with closed apex, no periapical pathology, and enough occlusal space to accommodate a single-unit restoration. Teeth with severely compromised structure, root fractures, active periodontal disease, severe periapical pathology, insufficient crown height for bonding, or cases with parafunctional habits such as bruxism or clenching were excluded from the study.

Tooth preparation began with a uniform occlusal reduction of 2–3 mm to create a flat surface parallel to the occlusal plane, ensuring sufficient space for the PEEK endocrown while preserving sound tooth structure. The reduction was extended to the cavity margins to create a smooth transition between the prepared and unprepared tooth surfaces. A supragingival butt-joint margin of 1.0–1.2 mm was prepared. A central retentive cavity was then created within the pulp chamber, shaped cylindrically-conically, with a minimum depth of 3 mm and an occlusal divergence angle of 8°–10°(Figure 1). The armamentarium used included diamond burs for occlusal and axial reduction, specifically the 856 bur for pulpal floor preparation and the ISO 801-012 bur for rounding internal line angles. Gingival retraction cords were used to facilitate impression procedures, and light-body silicone was used for both impressions and adaptation checks. A one-step impression technique was employed using putty and light-body polyvinyl siloxane (PVS). The light-body



material was injected onto the prepared surface using an automix syringe, and the putty was loaded into a tray and placed over the preparation with firm pressure (Figure 2).

The endocrowns were fabricated using CAD/CAM technology. A digital impression of the cast was obtained using a scanner, and the restoration was designed using CAD software. The PEEK block was then milled using a CAM unit to produce the final restoration. A silicone replica technique was employed to assess the internal fit and marginal adaptation, where light-body silicone was applied to the internal surface of the crown and seated on the prepared tooth. Once set, the material was examined for voids or high spots (Figure 3). After verification, the final restoration was cemented using resin-modified glass ionomer cement (RMGIC). The internal surface of the crown was coated with mixed cement, and the prepared tooth was isolated using a rubber dam. The crown was seated with finger pressure, and excess cement was gently removed before complete setting to ensure proper marginal sealing (Figure 4).

For the evaluation of strain, the buccal surface of the PEEK endocrown was cleaned and prepared. A thin layer of cyanoacrylate adhesive was applied to the strain gauge and the tooth surface, and the gauge was carefully positioned mesiodistally at the center of the buccal surface to accurately record tensile and compressive strain. The gauge was connected to a digital strain indicator system for real-time monitoring. Strain measurements were taken under functional movements such as simulated mastication and lateral excursions (Figure 5). Data were recorded in microstrain ($\mu\epsilon$) units on the day of crown insertion, and at follow-up intervals of one week, one month, six months, and one year to evaluate changes in stress distribution over time.

Statistical analysis

Statistical analysis of the data was done using IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp. Descriptive statistics including mean and standard deviation, were calculated for strain at various time intervals. Normality of the data assessed using Shapiro-Wilk test revealed that the data significantly deviate from normal distribution. Therefore, further analysis was done using non-parametric test. The mean rank differences of strain at different time periods were compared using Related-Samples Friedman's Two-Way Analysis of Variance by Ranks along with pairwise comparison adjusted by Bonferroni correction. The level of significance in the present study was kept at $p < 0.05$.

4. Results:

The present study evaluated the stress distribution in mandibular molars restored with PEEK endocrowns by measuring strain at various time intervals. The mean strain was highest at one week post-insertion (245.40 ± 5.68), followed by the day of insertion (236.70 ± 4.94). A progressive decline was observed over time, with strain reducing to 190.00 ± 5.81 at one month, 134.80 ± 9.35 at six months, and 108.10 ± 5.08 at one year. The differences between time intervals were statistically significant ($p = 0.000$), indicating a gradual reduction in stress and effective functional adaptation of PEEK endocrowns over time (Table 1, Figure 6).

The pairwise comparisons revealed significant reductions in strain between several time intervals. A statistically significant difference was observed between one year and the day of insertion (adjusted $p = 0.000$), as well as between six months and the day of insertion (adjusted $p = 0.047$), indicating a meaningful reduction in stress over time. Similarly, significant differences were noted between one month and one week (adjusted $p = 0.047$), six months and one week (adjusted $p = 0.000$), one year and one week (adjusted $p = 0.000$), and one year and one month (adjusted $p = 0.047$). However, comparisons between adjacent intervals such as the day of insertion and one week, or one year and six months, did not show statistically significant differences. These results suggest that the most notable reduction in strain occurred between early and late time points, reflecting the gradual and effective stress adaptation of PEEK endocrowns over time (Table 2).

5. Discussion:

Endocrowns are monolithic restorations that utilize the pulp chamber and remaining coronal tooth structure for retention. They offer several advantages over traditional crowns, including reduced preparation time and preservation of tooth structure. The choice of restorative material significantly impacts the biomechanical behavior of these restorations. PEEK is known for its excellent mechanical properties, including high tensile strength and elasticity, making it an attractive option for dental applications.^[11] Endocrown restorations, particularly those made from Polyetheretherketone (PEEK), represent a conservative and durable solution for restoring endodontically treated mandibular molars. The current study focuses on the stress distribution of PEEK endocrowns on the day of insertion, at 1 week, 1 month, 6 months, and 1 year using a strainmeter.

PEEK is a high-performance polymer known for its favorable mechanical properties, including low modulus of elasticity, excellent biocompatibility, and resistance to



fatigue. These characteristics allow PEEK endocrowns to distribute stresses more evenly across enamel and dentin compared to brittle materials like lithium disilicate. Studies have demonstrated that PEEK endocrowns exhibit higher post-fatigue resistance (PFR) under cyclic loading conditions, making them suitable for long-term use in molars subjected to significant masticatory forces.^[12,13] In the current study, the stress distribution was high on the day of insertion, with a significant reduction in stress observed over time. On the day of insertion, stress distribution is primarily influenced by occlusal forces and the bonding process. Zeng B et al. (2024) stated that PEEK endocrowns generate lower von Mises stresses compared to other restorative materials like LS2 and zirconia. The stress is concentrated at the cemento-enamel junction and the chamber wall of dentin under vertical loading conditions.^[14,15] Proper occlusal adjustment at this stage is critical to prevent localized stress points that could lead to microfractures.

In the current study, the strain distribution was high on the day of insertion (236.70 ± 4.94). After one week, due to the hardening of the cement, the strain increased slightly (245.40 ± 5.68) compared to the day of insertion. As the restoration begins to adapt to functional loads, PEEK's flexibility allows it to absorb tensile stresses effectively while minimizing damage to enamel and dentin. Stress concentrations remain stable at the external edge of enamel and the chamber wall of dentin under normal occlusal forces. However, oblique or uneven loading can increase stress levels in enamel, particularly near the margins. Regular follow-up appointments are recommended at this stage to ensure proper occlusion and marginal integrity.

By one month, cyclic loading from daily mastication leads to slight changes in stress distribution. Supporting this, the current study found that the strain at one month was lower (190.00 ± 5.81) compared to the day of insertion and one week. Abduljabar AH et al. (2024) stated that thermocycling studies simulating oral conditions revealed that PEEK endocrowns maintain their structural integrity under repeated thermal and mechanical stresses. Stress concentrations remain balanced between enamel and dentin, with enamel supporting tensile stresses and dentin undertaking compressive stresses.^[16] This period marks the stabilization phase for the restoration as it adapts to normal functional loads.

In the current study, the strain continued to decrease at six months (134.80 ± 9.35), supporting findings by Amjadi et al. (2024), who demonstrated that PEEK endocrowns exhibit superior fatigue resistance compared to LS2 restorations. This is attributed to PEEK's low

modulus of elasticity, which allows it to distribute masticatory forces evenly across tooth structures while minimizing irreparable fractures.^[12] Stress analysis shows that enamel supports tensile stresses while dentin undertakes compressive stresses, ensuring balanced load distribution even under oblique forces.^[16]

After one year, the strain recorded in the current study was significantly lower (108.10 ± 5.08) than at earlier time points. Thermocycling studies equating this period with 10,000 cycles reveal excellent durability of PEEK endocrowns under normal masticatory forces. Stress concentrations remained within physiological limits even under lateral or oblique loading conditions. However, enamel may experience increased tensile stress near the cemento-enamel junction due to prolonged use.^[17] Regular follow-up appointments are essential at this stage to monitor marginal wear or early signs of failure. Amjadi M et al. (2024) stated that PEEK endocrowns outperform traditional materials like LS2 in terms of post-fatigue resistance and stress distribution. While LS2 restorations exhibit higher fracture rates under cyclic loading conditions, PEEK's elasticity minimizes catastrophic failures and maintains structural integrity over time.^[12] Additionally, FEA studies indicate that PEEK frameworks generate higher compressive stresses on abutments compared to cobalt-chromium frameworks but remain within safe limits.^[16]

PEEK endocrowns demonstrate superior biomechanical performance over time due to their ability to distribute stresses evenly across tooth structures. Their resilience against cyclic loading and thermocycling makes them an ideal choice for restoring mandibular molars subjected to high masticatory forces. From insertion through one year of clinical service, they maintain structural integrity while minimizing failure risks compared to brittle alternatives like LS2 or zirconia. PEEK's ability to mimic dentin's mechanical properties makes it ideal for preserving tooth structure while reducing catastrophic failures. Its radiolucency aids in diagnosing secondary caries, while its wear resistance ensures long-term performance.^[3,18] Emam M et al. (2023) also evaluated the stress distribution and fracture resistance of green reprocessed PEEK in comparison to un-reprocessed PEEK and zirconia single implant crown restorations. The study concluded that reprocessed PEEK implant restorations transmit similar stresses to the dental implant and surrounding bone as non-reprocessed PEEK and zirconia restorations.^[19]

Due to its high elasticity, PEEK could reduce stresses and distal torque on the abutment teeth during function. In agreement with this, a three-dimensional finite element analysis by Chen et al. (2019) found that PEEK



frameworks caused lower stress values on the periodontal ligament than cobalt-chromium and Ti-6Al-4V alloy. Thus, PEEK RPDs could be recommended for patients with poor periodontal conditions.^[20] However, in the same study, it was found that PEEK caused the highest stresses on the mucosa and the greatest displacement on the free-end, which could lead to pain, advanced bone resorption, denture base failure, and compromised chewing efficiency. The authors concluded that PEEK should be used with caution in distal extension RPDs. Moreover, compared to metal frameworks, PEEK showed significantly lower internal stresses.

Compared to zirconia, lithium disilicate, and high-content gold alloy, PEEK presented a higher value for the modulus of resilience than lithium disilicate and comparable to that of gold alloy, indicating a high capability to elastically absorb destructive fracture energy.^[21] Dal Piva AMO et al. (2018) stated that based on the stress-strain curves observed, PEEK also has a high capacity to dissipate energy plastically. Furthermore, PEEK has a low modulus of elasticity (4 GPa) compared to chrome-cobalt alloys (220 GPa), gold alloys (91 GPa), zirconia (220 GPa), alumina (314 GPa), lithium disilicate (95 GPa), zirconia-reinforced lithium silicate (70 GPa), and feldspathic porcelain (48.7 GPa) [37]. A 3D finite element analysis of monolithic full posterior crowns revealed that materials with higher elastic modulus present higher tensile stress concentration on the crown intaglio surface and higher shear stress on the cement layer, which could facilitate crown debonding in oral conditions.^[22] Due to its low modulus of elasticity, PEEK allows absorption of functional stresses by deformation and acts as a stress breaker, reducing forces transferred to the abutment teeth. For this reason, two clinical reports suggested the use of pressed PEEK-based frameworks veneered with light-polymerized composite resin for the fabrication of single crowns or endocrowns in cases of weakened or severely damaged abutment teeth, metal allergies, or parafunctional habits.^[21,22]

Additional advantages of PEEK include its radiolucency, which may facilitate cement removal and screw loosening diagnosis, and its low specific weight, permitting the construction of lighter prostheses. The white color of PEEK frameworks eliminates the grayish appearance of metal frameworks and, when combined with composite veneering materials, achieves a high esthetic outcome. Furthermore, PEEK exhibits good biocompatibility, low water solubility, and high chemical and thermal stability.^[17]

This was a longitudinal *in vivo* study with periodic follow-ups up to one year, offering clinically relevant insights into the performance of PEEK endocrowns under natural masticatory forces. The use of a strainmeter allowed for objective evaluation of stress distribution over time.

The small sample size limits the generalizability of the results. Patient-related variables such as parafunctional habits, dietary factors, and occlusal patterns could not be fully controlled, introducing variability in stress measurements. Also, long-term outcomes beyond one year were not assessed.

Future studies should incorporate larger sample sizes with randomized controlled designs to minimize variability. Comparative clinical trials evaluating PEEK against other restorative materials such as zirconia and lithium disilicate are needed. Long-term evaluations exceeding one year would provide deeper insights into the durability and performance of PEEK endocrowns in varied clinical scenarios.

Conclusion:

The present study demonstrated that PEEK endocrowns effectively reduce strain over time, indicating excellent stress distribution and biomechanical compatibility with natural tooth structures. From the day of insertion through one year of clinical service, the restorations maintained structural integrity and adapted well to functional loads. These findings support the use of PEEK as a conservative, durable, and reliable material for restoring endodontically treated mandibular molars, offering an ideal balance of strength, flexibility, and long-term performance.

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