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Finite element stress analysis in mandibular molars with apical root resorption and crown destruction after root canal treatment using various materials

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Abstract

Aim: The objective of this study was to analyze the stress distribution of root canal treated teeth under occlusal forces and aid in the selection of appropriate materials for teeth with root tip resorption and crown destruction, using the finite element stress analysis method (FEM).

Methods: The study was conducted on two-rooted lower molar teeth, divided into five groups. The root length was 14 mm, the crown length was 7.5 mm, and the total length was 21.5 mm. It was assumed that the distal canals were resorbed by 4 mm. Group 1 consisted of untreated intact teeth. Group 2 involved filling the mesial canals with gutta-percha, filling the apical part of the distal canal with 4 mm Mineral Trioxide Aggregate (MTA), and fabricating the crown using glass fiber post and IPS e.max materials. Group 3 involved filling the mesial canals with gutta-percha, filling the apical part of the distal canal with 4 mm Biodentin, and manufacturing the crown using glass fiber post and IPS e.max materials. Group 4: The canals were filled with MTA, and an IPS e.max endocrown was used. Group 5: The canals were filled with Biodentin and an IPS e.max endocrown was used. The study examined the effect of a 100 Newton force applied in the occlusal direction on dental tissues using finite element stress analysis.

Results: The study found that the application of fiber posts resulted in less stress accumulation in tooth tissues compared to endocrown.

Conclusion: The use of Biodentin or MTA in endocrown teeth did not affect the stress in tooth tissues caused by applied force. In conclusion, while fiber posts increase durability by reducing stress in root-end resorbed teeth, the effect of Biodentin or MTA on stress resistance in dental tissues is limited.

Keywords: Apical resorption, Biodentine, endocrown, finite element analysis, glass fiber post, mineral trioxide aggregate

Introduction

Root canal treatment involves the removal of the diseased pulp, shaping and disinfection of the root canals, and filling of the canals up to the root apex. Teeth undergo biological and mechanical changes after root canal treatment (1). They become more susceptible to fractures, and the solutions used for disinfection during the procedure can reduce the tooth's resistance to fractures (1). Therefore, immediate restoration of the tooth is crucial after root canal treatment to preserve the remaining tooth structure (2).

Insufficient or weak restorations can pose a significant problem for the long-term retention of teeth that have undergone root canal treatment. Consequently, post-endodontic restorations play a vital role in the long-term success of these teeth. Due to the complex biomechanical nature of the oral cavity, in vitro studies are preferred over in vivo studies in biomechanical research. Accurate analysis and assessment of forces generated during chewing are essential (3). These analyses help distribute forces optimally within physiological limits and ensure proper restoration (4).

Factors influencing the success of endodontic treatments include irrigation regimens, canal shaping, filling techniques, filling materials, and restoration techniques. Understanding the stress and strain properties of the materials used in canal filling and crown restoration is crucial for the success of root canal treatment. Therefore, stress analysis studies are conducted to determine how materials withstand forces (5).

Various methods are employed for stress analysis, including: Finite Element Stress Analysis, Strain Gauge Analysis, Stress Analysis with Brittle Varnish Coating, Thermographic Force Analysis, Holographic Interferometry for Force Analysis. Radio Telemetry for Force Analysis, Photoelastic Stress Analysis (6-8). Detecting how tissues and organs respond to forces can be challenging and costly. Therefore, computer-assisted analysis and research are widely used in dentistry. In recent years, finite element stress analysis has become a common method for assessing the stress and strain that dental materials will experience under masticatory forces or trauma (9, 10).

In our study, we compare stress analyses using the FEM (Stress Evaluation by Strain Analysis) method in teeth treated with gutta-percha, MTA, and Biodentine following fiber post, endocrown, and crown restorations. We analyzed the stress distribution under occlusal forces in teeth with apical root resorption and extensive coronal destruction post-treatment using the FEM method. The findings of our study will contribute to clinicians' selection of the most appropriate materials for dental treatments. The data obtained will also serve as a foundation for future research, guiding researchers in this field.

The aim of this study was to examine the stress distribution under occlusal forces in teeth after endodontic treatment, aiding in the selection of the most suitable and stress-resistant material.

Materials and Methods

In this study, the arrangement of the three-dimensional mesh structure and its transformation into a mathematically appropriate solid mesh structure, the creation of three-dimensional finite element analysis models, and the finite element stress analysis process were carried out on HP workstations with INTEL Xeon E-2286 processors with a clock speed of 2.40 GHz and 64 GB of ECC memory.

The .stl model was generated from the tomography data using 3DSlicer software (free open-source software). Reverse engineering and three-dimensional CAD activities were performed using ALTAIR Evolve software, solid models were adapted to the analysis environment, and optimized meshing was performed using ALTAIR Hypermesh software; the Nastran-based implicit solver ALTAIR Optistruct (ALTAIR, Troy, MI, USA) was used to solve the finite element models.

Create tooth and bone models

To create the mandibular bone model and teeth used in the study, the tomography of the non-adult patient was taken. The tomography data was reconstructed with a slice thickness of 0.1 mm. The tomography data obtained as a result of the reconstruction were transferred to the 3DSlicer software in DICOM (.dcm) format. The CT data in DICOM format was segmented in the 3DSlicer software according to the appropriate Hounsfield values and converted into a three-dimensional model by segmentation. The model was exported in .stl format.
The three-dimensional model was transferred to ALTAIR Evolve software, where the appropriate mandibular cortical geometry was modeled. Trabecular bone was obtained by reference to the internal surface of the three-dimensional mandibular cortical bone.

In this study, an experiment was conducted using two-rooted mandibular molars. The length of the teeth was considered 21.5 mm. The root length was determined to be 14 mm, and the crown length was 7.5 mm. It was assumed that the distal canals of the teeth were resorbed by 4 mm. The cement layer was not modeled because the cement layer is very thin and its physical properties are similar to dentin (11).

The study consists of five different groups:

Group 1: Control Group - Untreated intact teeth (Fig. 1).

The enamel layer was obtained from the tooth model obtained from the tomography data. Dentin and periodontal ligament (PDL) were formed with respect to the inner surface of the enamel layer. Cementum was formed with reference to the inner surface of the PDL. The pulp was modeled in the area inside the dentin.

Group 2: Mesial canal gutta-percha + Distal canal apical MTA (4 mm) + Glass fiber post + Crown (IPS e.max) (Fig. 2).

The tooth obtained from the tomography data was modeled and appropriate crown, composite, posti and gutta-percha models were obtained. All prepared models were placed in the correct coordinates in 3D space in the ALTAIR Evolve software and the modeling process was completed.

Group 3: Mesial canals gutta-percha + Distal apical biodentine (4 mm) + Glass fiber post + Crown (IPS e.max) (Fig. 2).

Group 4: Canals filled with MTA + Endocrown (IPS e.max) (Figs. 3 and 4).

The tooth obtained from the tomography data was modeled and appropriate crown, MTA and Biodentin models were obtained. All prepared models were placed in the correct coordinates in 3D space in the ALTAIR Evolve software and the modeling process was completed.

Group 5: Canals filled with Biodentine + Endocrown (IPS e.max) (Figs. 3 and 4).

A single loading scenario was created for the three main models, with loading applied in the vertical direction. For models 2 and 3 and models 4 and 5, a total of 5 analyses were performed using two different material models (MTA and Biodentin). Loads of 100 N were applied to a hemisphere representing a 9.8 mm diameter food particle over the mandibular first molar. By using the food particle, the load definitions were distributed to the nodal points in the application regions, and stress singularity was avoided in the relevant regions.

The models were fixed at the nodes located in the mesial and distal regions of the cortical and trabecular bones by constraining all degrees of freedom to prevent movement in all three axes (Fig. 5).

Figure 1. Model 01 - Preparing Models of Enamel, Periodontal Ligament, Cement, Dentin, and Pulp

Figure 2. Model 02 and Model 03 - Modeling of Crown, Periodontal Ligament, Cementum, Composite, Dentin, Adhesive, Post, Gutta-Percha, MTA, and Biodentine

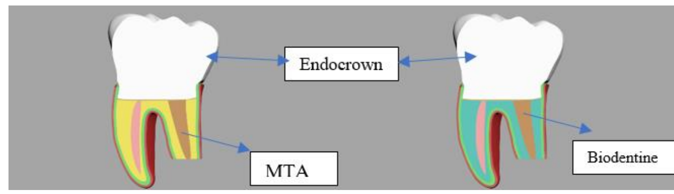

Figure 3. Model 04 and Model 05 - Modeling of Endodontic, Endocrown, Periodontal Ligament, Cementum, Resin Sealer, Gutta-Percha, MTA, and Biodentine

Information for the two different analysis models created is shared in Table 1.

Table 1. Total of nodes and elements

	Model - 1	Model - 2 &3	Model - 4 &5
Total # of Nodes	667249	633624	527294
Total # of Elements	2694129	2511689	2096684

Materials used in the study were assumed to be homogenous, and isotropic. The linear material properties of the materials with Young's modulus and Poisson's ratio were used in the analyses. The material properties of the analyzed model are defined numerically. Elastic properties of materials (Young's modulus (E) and Poisson's ratio (μ)) were determined from the literature and given in Table 2.

In order to analyze the mathematical models and obtain accurate results, it is necessary to define the surface relations between the parts of the model in the analysis program. For this purpose, a contact definition of the FREEZE type has been implemented in all areas where there is contact in all study models. This approach is based on the assumption that the parts move with full correlation during motion.

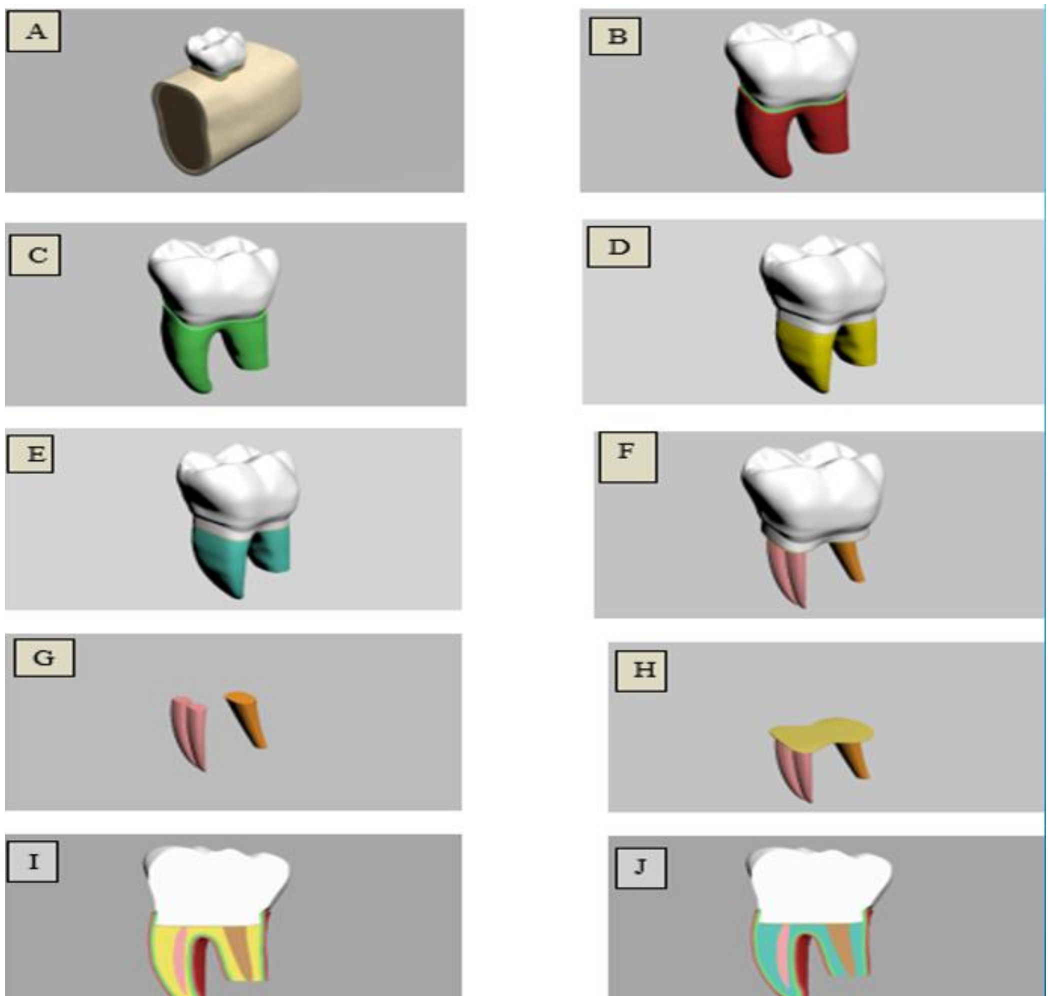

Figure 4. (A, B, C, D, E, F) Model 04 and 05; White color represents the endocrown, **(B)** Periodontal Ligament is shown in red color, **(E)** Cement is represented in green color, **(F, G, H, I, J)** Gutta Percha is in pink color, **(I)** MTA is in brown color and **(J)** Biodentine is also in brown color

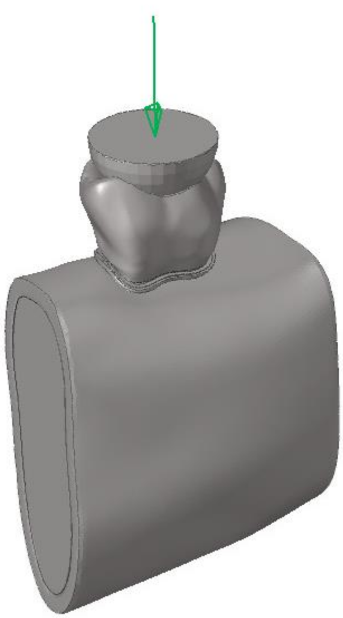

Figure 5. Chewing force scenario

Table 2. Mechanical properties of the materials used in the finite element model analysis.

Material	Elastic Modulus (GPa)	Poisson Ratio
Adhesive (12)	1	0.35
Composite (12)	18.6	0.26
Biodentine (13)	1.7	0.45
MTA (13)	1.13	0.4
Cortical bone (14, 15)	10.7	0.3
PDL (16)	0.0689	0.45
Fiber post (17)	40	0.26
Resin cement (*)	8.4	0.35
Dentine (12)	18.6	0.31
Gutta-percha (16)	0.00069	0.45
Enamel (18)	84.1	0.33
E-max veneer (19, 20)	65	0,24

* Obtained from manufacturer

Results

In this study, an analysis of stress on healthy teeth was conducted, examining the effects of five different treatment groups on the stress values in dental tissues. The results obtained for each group demonstrate how treatment options affect dental tissues in different ways.

In the control group (Group 1), the highest stress levels were detected, with the most intense concentration of stress observed in the enamel of the tooth. The stress was focused on the occlusal surface of the tooth. The regions where stress concentrated and the highest measured stress points were found to be in the same locations. The maximum principal stress was determined in the following order: enamel, cementum, cortical bone, and dentin. The von Mises stress was highest in the following dental tissues, respectively: enamel, cementum, cortical bone, dentin, pulp, and periodontal ligament. The sequence of the maximum principal stress was enamel > cortical bone > dentin > cementum. The dental tissue with the highest von Mises stress concentration was enamel > cementum > cortical bone > dentin > PDL > pulp (Table 3) (Fig. 6).

Table 3. All generated stress values

Group 1	Von Misses stress (MPa)	Maximum stress (MPa)
Enamel	18.441	5.244
Cement	12.998	2.423
Dentin	8.003	2.701
PDL	1.246	
Cortical bone	11.327	4.311
Pulp	0.00046	

In Group 2, fiber post, e.max crown, and MTA were used. In this group, the maximum principal stress values were, in order, dentin, composite, cortical bone, e.max crown, cementum, and MTA. The von Mises stress values were, in order, fiber post, e.max crown, cementum, dentin, cortical bone, composite, MTA, pulp, Mesio Buccal (MB) gutta-percha, and Mesio Lingual (ML) gutta-percha. According to these results, the maximum principal stress was highest in dentin, indicating that dentin is the tissue with the highest risk of fracture. Additionally, the region where stress concentrated was close to the cervical furcation area. The highest von Mises stress value was measured in the fiber post (63.433 MPa), indicating that stress concentrated in the fiber post, and the risk of fracture was in dentin. The sequence of maximum principal stress values from highest to lowest was: Fiber Post > Dentin > Composite > Cortical Bone > E.Max Crown > Cementum > MTA. The von Mises stress values in descending order were: Fiber Post > E.Max Crown > Cementum > Dentin > Cortical Bone > Composite > MTA > PDL > MB Gutta-percha > ML Gutta-Percha (Table 4) (Fig. 6).

Table 4. All generated stress values

Group 2	Von Mises stress (MPa)	Maximum Stress (MPa)
E-Max crown	27.219	3.063
Cement	27.731	2.828
Dentin	19.017	6.738
Fiber	63.433	7.992
Cortical bone	7.596	4.143
MTA	4.975	1.531
PDL	1.082	
ML - Gutta-percha	0.000207	
MB - Gutta-percha	0.000375	
Composite	7.153	5.392

In Group 3, fiber post, e.max crown, and Biodentine were used. In this group, the maximum principal stress values were, in order, dentin, composite, cortical bone, cementum, and Biodentine. The von Mises principal stress values were, in order, fiber post, e.max crown, cementum, dentin, cortical bone, composite, Biodentine, pulp, MB gutta-percha, and ML gutta-percha. According to these results, the maximum principal stress was highest in dentin, indicating that dentin is the tissue with the highest risk of fracture. Additionally, the region where stress concentrated was close to the cervical furcation area. The highest von Mises stress value was measured in the fiber post (57.875 MPa). The results were slightly lower than those of Group 1. The sequence of maximum principal stress values from highest to lowest was: Fiber Post > Dentin > Composite > Cortical Bone > E.Max Crown > Cementum > Biodentine. The von Mises stress values in descending order were Fiber Post > E.Max Crown > Cementum > Dentin > Cortical Bone > Composite > Biodentine > PDL > MB Gutta-Percha > ML Gutta-percha (Table 5) (Fig. 6).

Table 5. All generated stress values

Group 3	Von Mises stress (MPa)	Maximum stress (MPa)
E-Max crown	27.122	3.026
Cement	22.498	2.822
Dentin	17.007	5.555
Fiber	57.875	6.81
Cortical bone	7.573	4.137
Biodentin	5.391	1.773
PDL	1.079	
ML - Gutta-percha	0.000206	
MB - Gutta-percha	0.000374	
Composite	7.131	5.088

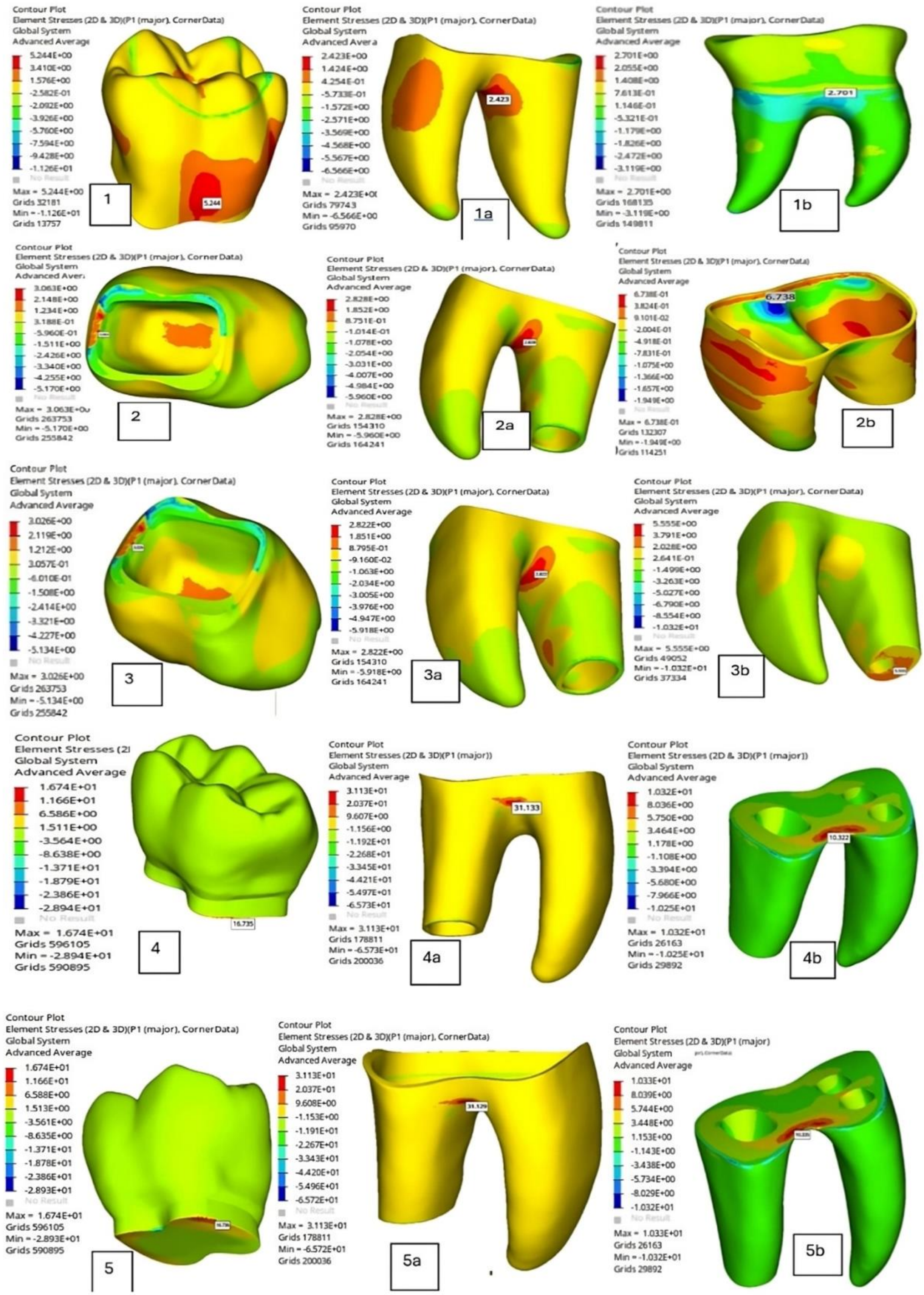

Figure 6. Red regions are the regions with the highest maximum principal stress. **(1)** First group enamel, **(2)** Second group crown, **(3)** Third group crown, (4) Fourth group endocrown, **(5)** Fifth group endocrown. **(1a)** First group cementum, **(2a)** Second group cementum, **(3a)** Third group cementum, **(4a)** Fourth group cementum, **(5a)** Fifth group cementum. **(1b)** First group dentin, **(2b)** second group dentin, **(3b)** Third group dentin, **(4b)** Fourth group dentin, **(5b)** Fifth group dentin.

In Group 4, MTA and endocrown were used. In this group, the maximum principal stress values were, in order, cementum, endocrown, dentin, cortical bone, distal root MTA, ML root MTA, and MB root MTA. The von Mises principal stress values were, in order, endocrown, cementum, dentin, cortical bone, distal root MTA, ML root MTA, MB root MTA, and periodontal ligament. According to these results, the maximum principal stress was highest in the cementum tissue, indicating that cementum is the tissue with the highest risk of fracture. The stress also concentrated most in areas near the cervical furcation. The second-highest stress was observed in the areas of endocrown contacting the cervical furcation. The highest von Mises principal stress value was measured in endocrown. These results indicate that stress concentrated in endocrown and that the stress in endocrown was in areas close to the furcation. The measured stress values were higher than those of Groups 1, 2, and 3. The sequence of maximum principal stress values from highest to lowest was: Cementum > Endocrown > Dentin > Cortical Bone > Distal root MTA > ML root MTA > MB root MTA. The von Mises stress values in descending order were: Endocrown > Cementum > Dentin > Cortical Bone > Distal root MTA > ML root MTA > MB root MTA > PDL (Table 6) (Fig. 6).

Table 6. All generated stress

Group 4	Von Mises stress (MPa)	Maximum stress (MPa)
ML rot - MTA	2.147	2.210
Distal root - MTA	2.960	2.774
MB root MTA	1.564	1.502
Dentin	34.059	10.322
PDL	1.030	
Cement	50.102	31.133
Cortical bone	7.614	4.219
Endocrown	79.593	16.735

In Group 5, Biodentine and endocrown were used. In this group, the maximum principal stress values were; in order, cementum, endocrown, dentin, cortical bone, distal root Biodentine, ML root Biodentine, and MB root Biodentine. The von Mises principal stress values were; in order, endocrown, cementum, dentin, cortical bone, distal root Biodentine, ML root Biodentine, MB root Biodentine, and periodontal ligament. The stress values obtained were almost the same as those in Group 4. The maximum principal stress value was measured in the cementum tissue, indicating that cementum is the tissue with the highest risk of fracture. The stress also concentrated most in areas near the cervical furcation. According to the results, the sequence of maximum principal stress values from highest to lowest was: Cementum > Endocrown > Dentin > Cortical Bone > Distal root Biodentine > ML root Biodentine > MB root Biodentine. The von Mises stress values in descending order were: Endocrown > Cementum > Dentin > Cortical Bone > Distal root Biodentine > ML root Biodentine > MB root Biodentine > PDL (Table 6) (Fig. 6).

Table 7. All generated stress values

Group 5	Von Mises stress (MPa)	Maximum stress (MPa)
ML root - Biodentin	1.481	1.401
Distal root - Biodentin	2.263	2.347
MB root - Biodentin	1.234	1.183
Dentin	34.047	10.335
PDL	1.029	
Cement	50.097	31.129
Cortical bone	7.610	4.216
Endocrown	79.578	16.736

When groups interact among themselves, the von Mises stress value has been observed to be most concentrated in the 4th and 5th groups, where e.max is located in the endocrown. The second-highest value was found in the 2nd and 3rd groups, specifically in the fiber posts, with values closely comparable. The stress concentration in the cementum tissue is highest in the 4th and 5th groups, i.e., in the groups where endocrown is applied. In dentin, the highest values are also found in the 4th and 5th groups. Stress concentration occurring in periodontal tissue and cortical bone shows closely similar values across all groups. Accumulated stress values in MTA and Biodentine were found to be high in the 2nd and 3rd groups (Fig. 7).

When comparing the maximum principal stress values within groups, the highest stress in cementum and dentin was observed in the 4th and 5th groups. When comparing the accumulated stress values in e.max, the highest stress was again measured in the 4th and 5th groups. The stress in the fiber post was found to be close in the 2nd and 3rd groups. The stress accumulated in Biodentine and MTA was higher in the 4th and 5th groups. The stress in cortical bone was found to be similar across all tissues (Figs. 6 and 8).

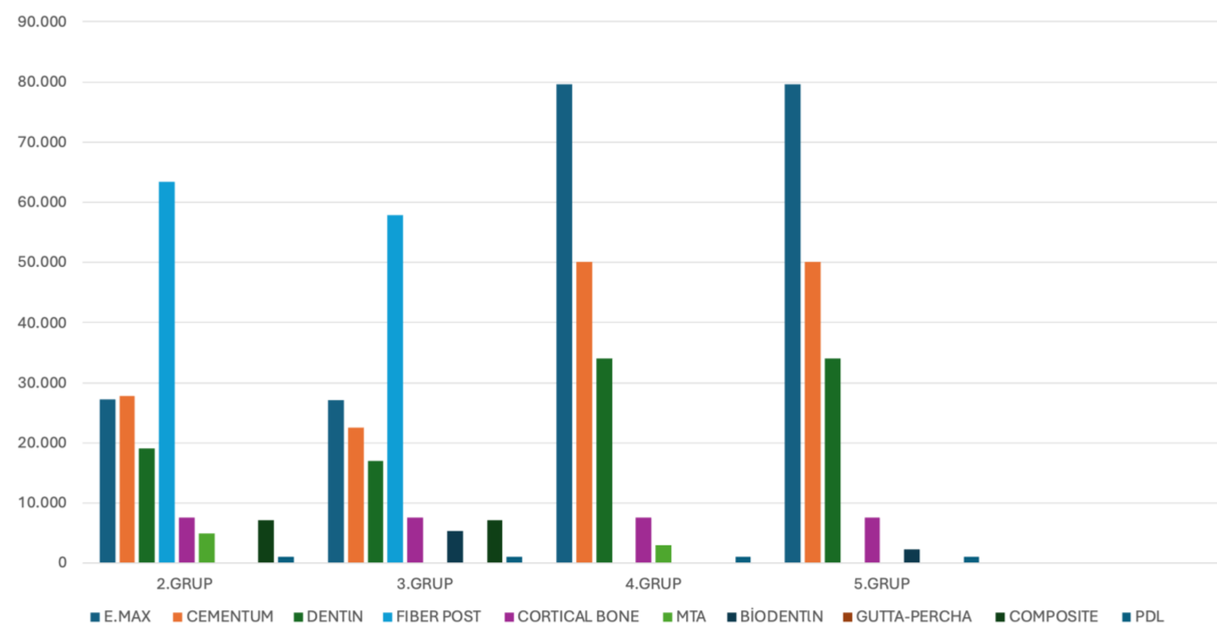

Figure 7. The von Mises stress analysis

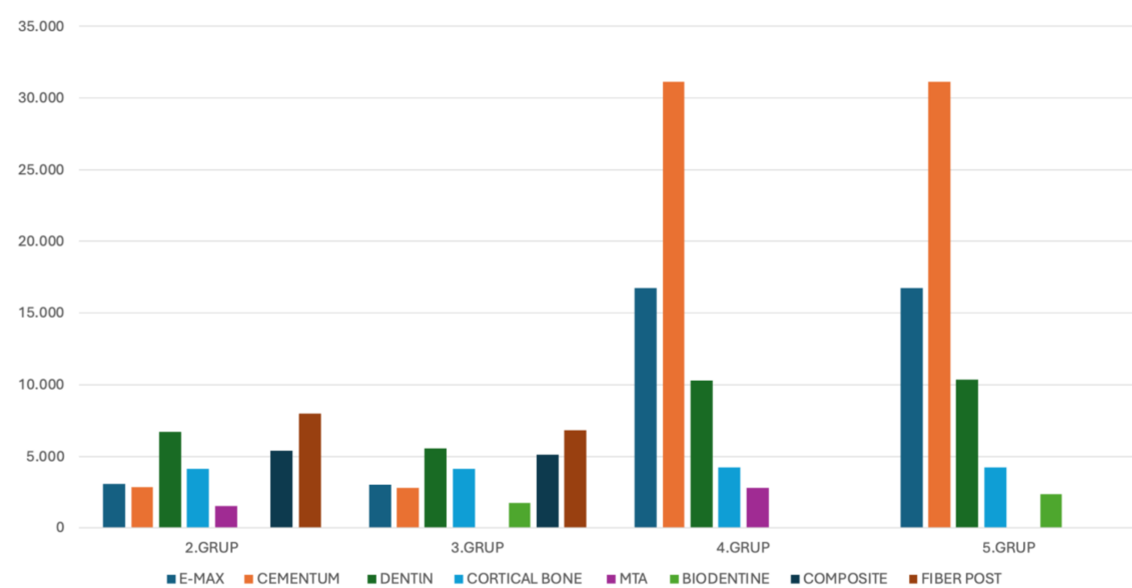

Figure 8. Maximum principal stress values

Discussion

Teeth undergo biological and mechanical changes after endodontic treatment (1). The increased susceptibility of root canal-treated teeth to fractures is due to tissue loss within the tooth. As the cavity depth and dimensions increase, the flexibility of the tooth reaches its maximum (21).

Additionally, solutions used during root canal treatment can increase the risk of tooth fracture. Therefore, it is essential to restore the tooth immediately after completing endodontic treatment. Weak or incomplete restorations can reduce the long-term success of root canal-treated teeth. Hence, post-endodontic restorations performed after endodontic treatment are crucial for the long-term success of root canal-treated teeth. Following the loss of tooth vitality due to endodontic treatment, the moisture content of the tooth changes slightly. Moisture loss leads to changes in dentin fluid but does not result in changes in organic and inorganic components of dentin fluid (22). These changes result in slight alterations in the tooth's elastic modulus and proportional limit values (21). However, changes in compression and tensile forces are not observed with the alteration in fluid content. Fundamental changes in tooth biomechanics occur due to hard tissue losses such as caries, fractures, or canal preparation. The loss of hard tissue following a conservative access cavity preparation only affects tooth strength by 5%. However, the subsequent canal preparation leads to a decrease in fracture resistance (23).

Mechanoreceptors in the periodontal ligament and sensory receptors in the muscles perceive the magnitude and direction of forces applied to the teeth. Nerves in the pulp also play a role in touch and pressure perception in the apical region (24).

With root canal treatment, the pulp tissue is removed, causing the loss of the sensory feedback mechanism. In this case, the tooth's protective function during chewing decreases, leaving it vulnerable to external factors (24). Root resorption in teeth can occur due to various factors, including orthodontic treatment, trauma, periapical or periodontal inflammation, tumors, cysts, occlusal trauma, impacted teeth, and tooth replantation (25).

Inflammatory root resorption associated with apical periodontitis occurs due to the periradicular inflammatory response to bacteria and bacterial products present in apical or lateral canals. When apical dentin is exposed, inflammation becomes continuous as dentin tubules contact inflamed periradicular tissues, leading to dentin-cement resorption. If left untreated, this process can result in extensive damage to the root. Since inflammatory root resorption is often related to bacterial infection in the root canal system, the application of antimicrobial treatments yields ideal treatment outcomes (26). Depending on the type of resorption, when a connection or perforation occurs between the periodontal tissues and the pulp chamber, canal obturation should be performed with a biocompatible material. For this purpose, MTA is preferred because it supports hard tissue formation and provides a biocompatible seal. It can be used effectively in apexification therapy and the treatment of teeth with open apex resorption (27). The use of MTA offers significant advantages, such as reducing the risk of cervical root fracture and preserving dentin's mechanical properties (28). In recent years, materials composed of calcium silicate, such as Biodentine, have become popular alternatives to MTA. Biodentine can be used in endodontic repairs and pulp capping, possessing bioactive properties for dentin replacement and similar mechanical characteristics to dentin. In cases of teeth with apical resorption and extensive coronal damage, the use of Biodentine instead of MTA has been introduced to ensure apical sealing (29). However, there is insufficient stress analysis in the literature regarding the use of Biodentine and MTA with gutta-percha. Furthermore, three-dimensional stress distribution analysis after canal treatment or only after apical sealing using Biodentine or MTA in mandibular molars with apical resorption and glass fiber post-core and endocrown restorations is lacking in the literature.

Despite numerous studies on restoration options, the restoration of non-vital teeth and potential complications after treatment remain a complex and contentious issue. Finite element stress analysis is a commonly used method in dental research, especially for analyzing materials with complex geometries, such as dental materials. Analyzing such materials can be challenging, but finite element analysis is an effective method to overcome these challenges. This analysis method allows for the evaluation of dental materials' performance, particularly when dealing with complex geometries (6, 7, 9).

In dental studies, three common methods are typically used for finite element stress analysis. These methods include maximum stress analysis, von Mises stress analysis, and minimum stress analysis. Each method offers different approaches and helps assess material characteristics from different angles. Minimum stress analysis focuses on the lowest stress values within the material. It can be used to identify weak areas or regions with low stress, which is particularly important for situations like stress fragility or stress fatigue (16). The von Mises stress analysis, on the other hand, assesses the equivalent stress condition within the material. It considers all stress components and evaluates their combined effects. The von Mises stress is widely used as a measure to determine material plastic deformation tendencies and assess material strength. When examining the literature, it is observed that most finite element studies focus on either von Mises or stress-type stress values (30). Maximum stress analysis examines the formation of the highest stress values when the material reaches its strength limits. This method is used to identify points where high stress concentrations can occur. It is essential for identifying areas where material damage or fracture is more likely to happen (31).

In a study by Bozkus and colleagues (31), consistent results were obtained using FEM and in vivo methods on cadavers, confirming the reliability of FEM. Inan et al. (32) compared FEM and photoelastic methods for evaluating stress in the supporting bone around implants and found that both methods provide stress distribution information, but FEM provides more detailed and comprehensive results. Mousa et al. (33) analyzed obturator biomechanical stresses using FEM and concluded that FEM can be reliably used to analyze stress distribution in various defect types, prosthesis rehabilitations, and supporting structures. Based on these studies, stress analysis using FEM was conducted in our research. The results were obtained without the need for statistical analysis because they were based on mathematical calculations with no variance. In our study, both tooth tissues and restorative materials were evaluated separately for force results applied. When examining stress distribution, it was observed that von Mises principal stress and minimum principal stress had similar distributions, but in some groups, maximum principal stress differed. These results indicate that the areas at risk of fracture differ from von Mises and compression areas. Maximum principal stress evaluations are crucial for identifying areas at risk of fracture. In previous studies, forces were usually applied from a single point. However, in this study, a force was applied from the entire occlusal surface, simulating a more realistic scenario with a 9.8 mm-diameter hemisphere to mimic a food particle (34).

Intraoral forces can vary depending on factors such as the number of teeth, occlusal type, and occlusal habits. Normal intraoral forces have been reported to range from 10 to 431 N (35). In this study, a 100 N occlusal force was used, which is consistent with loading similar to other studies (34). In our study, the adhesive thickness was determined to be 10 µm. Since this interface was minimal, adhesive interfaces were considered part of the tooth tissues in our study. Although similar studies exist in the literature, the limitation of our study is that interface stress values were not determined (35). This study focused on modeling the first mandibular molar teeth with a high risk of fracture. Fractures in the first molars often result in significant tissue loss and account for approximately 50% of all fractures. With advancements in adhesive dentistry, the importance and indications for the use of post-core structures have been debated (36). Structural improvements in materials and their resulting mechanical properties have provided the option to restore teeth with adhesive technology without the need for post-core restorations. However, it is recommended that the height of the retention area should be 5 mm for premolar and molar teeth. Especially in cases where significant damage occurs to the enamel-cement composition and only 1-2 mm of healthy tissue remains, interventions based on root support may be required (37).

Nevertheless, endocrown restorations are contraindicated when the pulp chamber depth is less than 3 mm, and the cervical margin width is less than 2 mm. Endocrown restorations are single-piece restorations applied to teeth with deep pulp chambers and cavity margins. A study on fracture resistance found no significant difference between Biodentine and MTA materials. Similarly, in healthy teeth, there was no significant difference in fracture resistance between Biodentine and gutta-percha (38). Our study also yielded similar results consistent with these studies. Biodentine and MTA yield different results in studies on root fracture resistance. A study found no significant difference between these materials (39). In contrast, another study demonstrated that Biodentine was more resistant than MTA (40). In another study, there was no significant difference in fracture resistance when comparing Biodentine with gutta-percha (41).

Zhabuawala et al. (42) found that Biodentine was a weak material, particularly in immature teeth, and did not provide sufficient reinforcement. Our study found no significant difference between Biodentine and MTA. In conclusion, the application of a fiber post reduces stress accumulation in tooth tissues and can enhance tooth resistance. However, other applications have limited or negligible effects on stress. These findings underscore the importance of selecting the right material and method in dental applications. Additionally, our study found that Biodentine or MTA used in the canal did not alter the stress resulting from applied forces. Dejak and Mlotkowski's (30) study demonstrated that in FEM studies, the stress in dentin was higher in restorations using fiber posts compared to those using endocrowns.

In an in vitro study conducted by Biacchi and Basting (4), the fracture resistance of glass fiber post-reinforced traditional crowns and endocrowns was examined. This study showed that the endocrown restoration reinforced with a glass fiber post had higher fracture resistance compared to the traditional crown restoration.

Our study results revealed that the maximum principal stress values in dentin were highest in the 4th and 5th groups. When comparing the stress values in E-max, the highest stress was measured again in the 4th and 5th groups. The stress in the fiber posts was found to be close in the 2nd and 3rd groups.

Our study found that the stress in dentin in restorations made with fiber posts was lower. We believe that this may be due to the support resistance provided by the fiber post to the root after resorption, and the different ceramic crown material and post material used in other studies, meaning that the elastic modulus value entered into the system is different. Additionally, in these studies, the authors reported that the ferrule effect in the models made the fiber posts resistant to stress. The stress generated in cortical bone was found to be close in all tissues.

The results of our study should be supported by laboratory studies and long-term in vivo research.

Conclusion

In teeth with shortened root length due to resorption, it has been observed that the application of fiber posts reduces stress accumulation in dental tissues and may enhance the resilience of teeth. On the other hand, endocrowns has been observed to increase stress accumulation in resorbed roots.

It has been noted that the elastic moduli of materials used in restoration can directly impact tooth resistance. These findings underscore the importance of proper material and method selection in dental applications.

Furthermore, it has been determined that the use of Biodentine or MTA in the canal during endocrown procedures on teeth does not alter the stress generated as a result of applied forces.

Disclosures

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