ORIGINAL RESEARCH

Resistance against Fracture in Teeth Managed by Root Canal Treatment on Restoring with Onlays, Inlays, and Endocrowns: A Comparative Analysis

Irfanul Huda[1], Anuradha Pandey[2], Naveen Kumar[3], Sachin Sinha[4], Kumari Kavita[5], Rachna Raj[6]

Abstract

Aim and objective: To compare the fracture resistance in teeth managed by root canal treatment after restoring with different types of onlays, inlays, and endocrowns prepared with hybrid ceramics and pulp chambers restored with fiber-reinforced composite and resin composite that were radiopaque, light-cured, and flowable.

Materials and methods: The present study was carried out on 252 extracted mandibular molars. All the specimens were divided into six groups randomly. Each group consisted of 42 specimens. Group 1 consisted of intact teeth without any access cavity. It was the control group. Group 2 consisted of teeth with endocrown and empty pulp chamber. Group 3 consisted of teeth with mesio-occlusal-distal (MOD) onlay prepared with hybrid ceramics and pulp chamber filled with flowable, light-cured, radiopaque resin composite. Group 4 consisted of teeth with MOD onlay and pulp chamber filled with fiber-reinforced composite. Group 5 consisted of teeth with MOD inlay and pulp chamber filled with flowable, light-cured, radiopaque resin composite. Group 6 consisted of teeth with MOD inlay and pulp chamber filled with fiber-reinforced composite. Inlay, onlay, and endocrowns were prepared with computer-aided design (CAD) and computer-aided machine (CAM) using hybrid ceramics. Universal testing machine was used for the measurement of the fracture resistance of each specimen. Inferential statistics were performed by applying Fisher's exact test and chi-square test.

Results: Fracture strength was found to be maximum in the intact teeth group followed by the endocrown. The fracture strength was minimum in the inlay group. The fracture strength was intermediate in the onlay groups.

Conclusion: Endocrown showed maximum fracture resistance as compared to the inlay and onlay restorations.

Clinical significance: Proper management of root canal-treated teeth is one of the greatest challenges for endodontists. It has been observed that tooth preparation design and the material used for the restoration of root canal-treated teeth play a vital role in the resistance against fracture in the teeth.

Keywords: Cerasmart, Endocrown, Inlay, Onlay, Root canal treatment.

The Journal of Contemporary Dental Practice (2021): 10.5005/jp-journals-10024-3123

Introduction

The most common negative outcome of root canal-treated teeth is the highest possibility of getting fractured, as compared to vital teeth. This is due to the loss of significant tooth structure and other changes in the structure of the endodontically treated teeth.[1,2] One of the important steps after endodontic therapy is to restore the resistance of teeth against fracture, which gets affected adversely as a result of loss of tooth structure during cavity preparation during root canal treatment.[3,4] It should be taken care of during the restoration of root canal-treated teeth that biomechanical properties of the treated teeth should be similar to that of a tooth when intact. The resistance against fracture is achieved through adequate retention and maintaining the integrity of adhesiveness between dentin of the root, reconstruction of core, and the final restoration that should form a complex, which should be integrated and unique.[5,6]

The restoration of the tooth after root canal treatment involves the direct restoration as well as indirect posterior restoration of teeth. Various types of indirect posterior restorations after root canal treatment are classified on the basis of the amount of the coverage of the cusp.[7,8] The most common indirect restorations are onlays, inlays, overlays, and endocrowns. In inlays, there is no coverage of cusp, whereas in onlays, there is at least coverage of one cusp, and in overlays, all the cusps are covered.[9,10] Coverage of cusps leads to an increase in the durability of the indirectly applied posterior restorations. Another such type of indirect posterior restorations is endocrowns that consist of the core, inter-radicular post, and

[1]Department of Prosthodontics, Crown, Bridge and Implantology, Patna Dental College and Hospital, Patna, Bihar, India

[2]Department of Orthodontics and Dentofacial Orthopaedics, Buddha Institute of Dental Sciences and Hospital, Patna, Bihar, India

[3,6]Department of Community Dentistry, Patna Dental College and Hospital, Patna, Bihar, India

[4]Primary Health Centre, Khusrupur, Patna, Bihar, India

[5]Department of Dentistry, Nalanda Medical College and Hospital, Patna, Bihar, India

Corresponding Author: Anuradha Pandey, Department of Orthodontics and Dentofacial Orthopaedics, Buddha Institute of Dental Sciences and Hospital, Patna, Bihar, India, Mobile: +91 8298919420, e-mail: aradha334@gmail.com

How to cite this article: Huda I, Pandey A, Kumar N, *et al.* Resistance against Fracture in Teeth Managed by Root Canal Treatment on Restoring with Onlays, Inlays, and Endocrowns: A Comparative Analysis. J Contemp Dent Pract 2021;22(7):799–804.

Source of support: Nil

Conflict of interest: None

© Jaypee Brothers Medical Publishers. 2021 Open Access This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by-nc/4.0/), which permits unrestricted use, distribution, and non-commercial reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The Creative Commons Public Domain Dedication waiver (http://creativecommons.org/publicdomain/zero/1.0/) applies to the data made available in this article, unless otherwise stated.

the crown in one assembly causing the formation of a monoblock restoration.[11,12] It is taken care that preparation of cavity for posterior restoration should be the least invasive, which has the advantage of tooth structure conservation as well as proper distribution of stress.[13]

It has been reported in the literature that indirect posterior restorations have better resistance to fracture in comparison to the direct restorative techniques. The selection of the restorative material for endodontically treated teeth should be in such a manner that it must maintain a balance between two components; first is for improved strength of the restoration, and the second is for the preservation of the tooth structure.[14,15] For the components mentioned here, three designs of tooth preparation were selected, namely inlay, onlay, and endocrowns. Newly introduced computer-aided design and computer-aided machine (CAD/CAM)-based hybrid nanoceramics, namely Cerasmart, were selected for this study, because it has been found that Cerasmart has a higher fracture resistance load when compared with other contemporary materials.[16,17] In recent times, several new varieties of composites have been introduced with the purpose to simulate dentin in order to absorb maximum stress for reducing the occurrence of fracture.

Composite reinstated with fibers (EverX posterior) and composite that are flowable, radiopaque, and light-cured (G-aenial Universal Flo) are few of these composites.[18] These materials are observed to have a low modulus of elasticity, so they are able to absorb stress in such a way that it gets concentrated inside of the restoration without transferring it to the tooth structure.[19] As per the best of our knowledge, no such research has been conducted to compare the impact of different patterns of indirect posterior restorations like inlays, onlays, and endocrowns made up of CAD or CAM hybrid ceramics and different new composites (EverX posterior and G-aenial Universal Flo) used for the restoration of pulp chamber in teeth that underwent root canal treatment.

Therefore, for carrying out such analysis, five different techniques were compared, which were endocrowns prepared from Cerasmart, inlay made up of Cerasmart with fiber-reinforced composite occupying pulp chamber, inlay made up of Cerasmart with light-cured flowable composite occupying pulp chamber, onlay made up of Cerasmart with fiber-reinforced composite occupying pulp chamber, and onlay made up of Cerasmart with light-cured flowable composite occupying pulp chamber.

Materials and Methods

It was an *in vitro* study conducted in the Patna Dental College and Hospital. This research was approved by the ethical committee of the institution. The study was conducted on 252 specimens. The calculation of the sample size was carried out in accordance with the findings of Kadam and Bhalerao.[20]

The inclusion criteria for specimens in the study were extracted mandibular molars with similar dimensions for all the teeth. The exclusion criteria were the presence of caries and cracks in the teeth, abnormal tooth anatomy, and fractured tooth. Mandibular molars were selected for the study because they are the most common teeth that undergo root canal treatment.

Cleaning and Storage of Study Specimens

All the extracted teeth were cleaned and stored in thymol solution. The concentration of the thymol solution was 0.2%. Then, all the extracted molars were rooted in a self-polymerizing resin 2 mm below the cementoenamel junction. The molars were placed perpendicular to the self-polymerizing resin.

Root Canal Treatment of Study Specimens

Root canal treatment was carried out in the same manner in all extracted teeth by the same operator. After completion of root canal treatment in all teeth, ethylene alcohol was used for cleaning the access cavity of every tooth to eliminate the debris and residual sealer from the walls of the access cavity. It was taken care that the size of the access cavity in each tooth was almost the same.

Division of All Specimens in Six Groups

All the teeth were divided randomly into six groups (groups 1–6). Each group consisted of 42 specimens. Group 1 consisted of intact teeth without any access cavity. It was the control group. Group 2 consisted of teeth with endocrown and an empty pulp chamber. Group 3 consisted of teeth with mesio-occlusal-distal (MOD) onlay prepared with Cerasmart and pulp chamber filled with G-aenial Universal Flo. Group 4 consisted of teeth with MOD onlay prepared with Cerasmart and pulp chamber filled with EverX posterior. Group 5 consisted of teeth with MOD inlay prepared with Cerasmart and pulp chamber filled with G-aenial Universal Flo. Group 6 consisted of teeth with MOD inlay prepared with Cerasmart and pulp chamber filled with EverX posterior (Table 1).

Filling of the Pulp Chamber with Fiber-reinforced Composite and Flowable Composite

Access cavities were prepared in teeth of groups 3, 4, 5, and 6 and were etched with 37% phosphoric acid (AM dental etching gel). After that, the bonding agent (Ivoclar bonding agent) was applied followed by light curing for the duration of 20 seconds (Waldent Smart). Then, there was a filling of access cavities present in the teeth included in groups 3 and 5 with light-cured and flowable composite resin, while access cavities of the teeth included in groups 4 and 6 were filled with EverX posterior, and they were cured for 40 seconds. The restoration of composite resin material was shaped flat at the roof of the pulp chamber.

Preparation of the Cavity Design for Indirect Posterior Restorations

Then, standard MOD was prepared on all teeth with the help of high-speed tapered diamond bur (6° taper) by the same operator along with copious irrigation. The cavity was prepared in such a manner that the minimum thickness of the remaining buccal and lingual walls was compulsorily made up of 2 mm. The depth of the horizontal pulp wall was 3 mm. There was the preparation of proximal boxes such that there was the preparation of isthmus of 2 mm depth. The lingual and buccal axial walls were made divergent. The gingival margin was prepared such that it was placed 1 mm above the cementoenamel junction. During the onlay preparation, there was a reduction in nonfunctional and

Table 1: Groups and type of restoration

Groups	*Types of restoration*
Group 1	Intact teeth
Group 2	Endocrown prepared from Cerasmart
Group 3	Onlay prepared with Cerasmart with flowable, radiopaque, and light-cured composite
Group 4	Onlay prepared from Cerasmart with EverX
Group 5	Inlay prepared with Cerasmart with flowable, radiopaque, and light-cured composite
Group 6	Inlay prepared with Cerasmart with EverX

functional cusps by 2 mm, and also a 90° butt-joint margin can be created (Fig. 1).

Preparation of Indirect Posterior Restorations with Cerasmart

The indirect restorations like inlay, onlay, and endocrowns were prepared with resin nanoceramic CAD or CAM Cerasmart blocks utilizing the CAD or CAM machine. Designing of the restorations was carried out with the help of Exocad software so that the anatomy and contour of all the restorations were similar. The milling of the Cerasmart blocks was carried out with the help of a milling machine according to the instructions prescribed by the manufacturer. After the formation of all the restorations, 9% hydrofluoric acid was used for treating the surfaces of the teeth followed by rinsing with water. Then, the restorations were air-dried and coated with a silane agent according to recommendations by the manufacturer.

Cementation of the Posterior Indirect Restorations like Inlay, Onlay, and Endocrowns

Now 37% phosphoric acid was used for etching of all teeth surfaces for 15 seconds, and then water was used for rinsing. Then, they were air-dried for the duration of 10 seconds. Then, there was the placement of a bonding agent that was polymerized for the duration of 20 seconds. After that, cementation of all restorations was done. There was the use of dual-cure composite resin cement that was dual-cured (Prevest Fusion). Finally, a universal testing machine was used for the measurement of the fracture resistance of all teeth.

Statistical Analysis

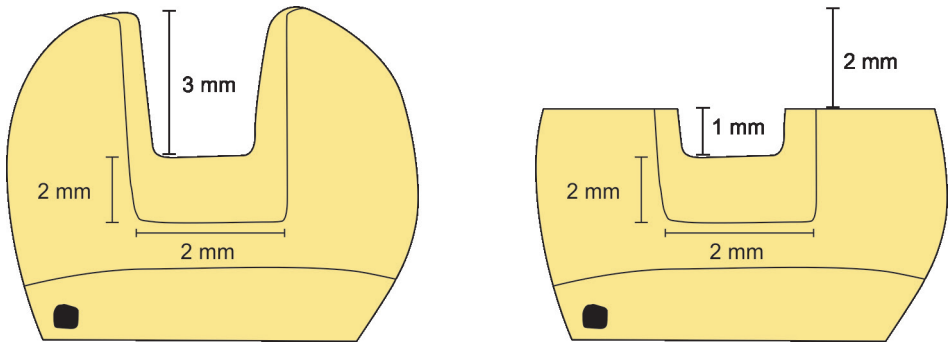
After that, the fracture pattern in all teeth was evaluated on the basis of classification for the type of fracture and pattern of fracture (Table 2). Statistical analysis was carried out and Kolmogorov-Smirnov test was utilized for the evaluation of the distribution of continuous variables. On the contrary, analysis of variance was used for comparison of the fracture strength among groups. Chi-square tests and Fisher's exact tests were used to evaluate the pattern of fracture. $p \leq 0.05$ was considered statistically significant. The calculation of the sample size was carried out in accordance with the findings of Kadam and Bhalerao.[20]

Results

There was a statistically significant difference in the resistance against fracture among the groups with p-value ≤ 0.05. Fracture strength was found to be maximum in the intact teeth group. It was followed by the endocrown group in terms of fracture resistance. The fracture strength was minimum in the inlay groups (groups 5 and 6). The fracture strength was intermediate in the onlay groups (groups 3 and 4). However, the difference was not statistically significant between the specimens of groups 5 and 6. It showed that the fracture strength was not statistically different in the specimens consisting of inlay prepared with Cerasmart along with pulp chamber filled with flowable, radiopaque, and light-cured composite and the specimens consisting of inlay prepared with Cerasmart along with pulp chamber filled with EverX posterior. However, the resistance against fracture was slightly more in the specimens consisting of inlay prepared with Cerasmart having flowable, radiopaque, and light-cured composite occupying the pulp chamber.

The difference in fracture resistance was not statistically significant between the specimens of groups 3 and 4. It showed that the fracture strength was not statistically different in the specimens consisting of onlay prepared with Cerasmart having flowable, radiopaque, and light-cured composite occupying the pulp chamber and specimens consisting onlay prepared using Cerasmart having pulp chamber filled with EverX posterior. However, the resistance against fracture was slightly more in the specimens consisting of onlay prepared with Cerasmart and flowable, radiopaque, and light-cured composite occupying the pulp chamber (Table 3).

When the pattern of fracture was analyzed, then it was found that type 2 fracture was most common in the group 1 specimen.



Figs 1A and B: (A) Teeth preparation required for placement of inlay restoration; (B) Teeth preparation required for placement of inlay restoration was reduced by 2 mm from the occlusal surface for placement of onlay restoration and endocrown restoration

Table 2: Types of fracture and fracture patterns

Fracture type	*Patterns of fracture*
Type 1 fracture	There is no sign of visible fracture
Type 2 fracture	Fracture is limited to the tooth
Type 3 fracture	Fracture is limited to the restoration
Type 4 fracture	Fracture found in both the tooth and restoration located above the cementoenamel junction
Type 5 fracture	Fracture found in both the tooth and restoration located below the cementoenamel junction

Table 3: Data showing values of resistance against fracture in different study groups

	Number of specimens (n)	*Mean values (N)*	*Std deviation values (N)*	*Minimum value (N)*	*Maximum value (N)*	*p value*
Group 1	42	2498.90	458.390	930	3,200	
Group 2	42	2300.53	398.167	975	3,047	
Group 3	42	2065.03	333.119	863	2,566	
Group 4	42	1030.70	288.207	807	2,400	
Group 5	42	872.10	232.388	630	2,040	0.04*
Group 6	42	866.90	255.806	616	2,187	

*Statistically significant

Type 5 was most common in group 2, while type 3 and type 5 were most common in group 3; type 3 was most common in groups 4, 5, and 6. It can be observed that the type 3 pattern of fracture was most common in the inlays made of Cerasmart (Table 4).

Table 4: Data showing type of fracture in different groups

Groups	*Pattern of fracture*			
	2	*3*	*4*	*5*
Group 1	42 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Group 2	4 (10.0%)	10 (23.80%)	8 (19.04%)	20 (47.61%)
Group 3	5 (10.0%)	17 (40.47%)	3 (7.16%)	17 (40.47%)
Group 4	0 (0.0%)	28 (66.66%)	09 (21.42%)	5 (11.9%)
Group 5	0 (0.0%)	29 (69.04%)	11 (26.19%)	2 (4.77%)
Group 6	0 (0.0%)	30 (71.42%)	10 (23.80%)	2 (4.78%)

Discussion

In the current study, it was found that maximum fracture resistance was found in the intact teeth. Several studies in the past have concluded that fracture resistance was low in root canal-treated teeth.[21,22] It was found in our study that the fracture resistance was maximum in the endocrowns as compared with inlays and onlays. The fracture resistance was lowest in the inlays. These results were similar to several studies conducted in the past in which it was found that fracture resistance was maximum in endocrowns.[23,24] However, Gré et al. conducted a study and found that fracture resistance was similar in endocrowns as compared to other conventional crowns.[25]

It was also found in the present study that fracture resistance was greater in onlays as compared with inlays. Concordant results were shown by Yoon et al.; they conducted a study and concluded that protection provided by the onlay restoration was greater as compared with the inlays in the endodontically treated teeth.[26] In our study, it was observed that fracture resistance was greater in specimens with flowable, radiopaque, and light-cured composite occupying the pulp chamber as compared to the EverX posterior occupying the pulp chamber with onlays as indirect posterior restorations. These results are similar to the results obtained in a study conducted by Atalay et al. in which it was found flowable composite showed high fracture resistance.[27]

Özkır conducted a study to compare the effect of cavity design on the resistance against fracture in root canal-treated teeth and observed that composite reinforced with fibers showed better resistance against fracture.[28] Goracci et al. also conducted a similar study and found that the resistance against fracture was maximum when composite with reinforced fibers was used as compared with other conventional composite resin materials. But in the present study, the resistance against fracture was not affected due to reinforcement of composite with fibers.[29]

Rocca et al. conducted a similar study to evaluate the resistance against fracture in root canal-treated teeth in which fiber-reinforced composite was placed in the pulp chamber and the overlying indirect posterior restorations were prepared with hybrid ceramics. It was found that reinforcement of composite with fibers did not improve the resistance against fracture.[30] In the present study also, similar results were obtained because the resistance against fracture was lesser in composite reinforced with fibers as compared to the flowable, radiopaque, and light-cured composite.

The management of teeth that have undergone root canal treatment is one of the greatest challenges for endodontists. There are several etiological factors for the fracture of tooth, which have undergone root canal treatment and most of them are not under the direct control of the clinician.[31] Proper tooth preparation and proper material used for the restoration of the teeth managed by root canal treatment are one of the important factors affecting the fracture resistance. Hence, continuous efforts are being made regarding the search for the ideal preparation of the tooth and adequate restorative material for the root canal-treated teeth to decrease their negative effect on the resistance against fracture.[32] This study was conducted in this direction to find ideal cavity design and restorative material for teeth that underwent root canal treatment.

There are several recent materials that can be used for the restoration of lost tooth structure. During recent times, hybrid ceramics have been introduced, which are based on CAD and CAM. These hybrid ceramics have characteristics of both polymer and ceramic. They are formed as a result of the infiltration of ceramic materials in the polymer matrix.[33] One such materials is Cerasmart (GC India Dental).[34] They are blocks of nanoceramic composite resin that is formed when the matrix of polymer gets reinforced with nanohybrid fillers of ceramic. Another recent material for the posterior restoration of root canal-treated teeth is EverX posterior (GC India Dental). It is a glass and polyethylene fibers reinstated composite.[35] Some of the important properties of this material are its contribution to increasing the strength of the tooth and ability to absorb stress like dentin. Therefore, it is advised to use in the form of a bulk base in those areas where high stress is present.

Another recent restorative material that can be used in root canal-treated teeth is G-aenial Universal Flo (GC India Dental). It is a radiopaque composite that is light-cured and flowable.[35] Both G-aenial Universal Flo and EverX posterior are used for restoring the pulp chamber of the root canal-treated tooth, while Cerasmart (hybrid ceramics) is used for preparing indirect posterior restorations (inlay, onlay, and endocrown) in root canal-treated teeth. No study has been conducted to compare the effect of these indirect posterior restorations and other restorative materials in the pulp chamber on resistance against fracture in root canal-treated teeth. It was found that endocrown prepared with Cerasmart is the

better restoration in terms of fracture resistance for the teeth that underwent root canal treatment. It may be due to the fact that there is the utilization of the space of pulp chamber in endocrowns that helped in increasing the stability of restoration.

The clinical implication drawn from this study was that endocrown prepared with Cerasmart can be a better option as indirect posterior restoration in root canal-treated teeth to avoid fracture.

The limitations of this study were that it was an *in vitro* study due to which clinical conditions were not simulated. Another limitation was the high expenses during the study due to which the size of the sample was limited. Another limitation was that in this study, self-cured adhesive cement was used instead of light-cured adhesive resin cement, which is used normally for Cerasmart because this Cerasmart is a variant of hybrid ceramics. This can reduce the integrity of the tooth restoration complex.

In order to achieve adequate integrity, there was pretreatment of enamel before carrying out luting. This helped in increasing the strength of bonding of self-cured adhesive resin cement with enamel.[36]

Conclusion

It can be concluded from this study that endocrown showed maximum resistance against fracture in teeth that underwent root canal treatment in comparison to other types of restorations and flowable, radiopaque, and light-cured composite used for restoring the pulp chamber presented more resistance against fracture in teeth that underwent root canal treatment. More studies should be carried out simulating the clinical conditions.

References

1. Basaran ET, Gokce Y. Evaluation of the influence of various restoration techniques on fracture resistance of endodontically treated teeth with different cavity wall thicknesses. Niger J Clin Pract 2019;22(3):328–334. DOI: 10.4103/njcp.njcp_346_18.
2. Harsha MS, Praffulla M, Babu MR, et al. The effect of cavity design on fracture resistance and failure pattern in monolithic zirconia partial coverage restorations – an in vitro study. J Clin Diagn Res 2017;11(5):ZC45–ZC48. DOI: 10.7860/JCDR/2017/25305.9856.
3. Soares CJ, Rodrigues MP, Faria-E-Silva AL, et al. How biomechanics can affect the endodontic treated teeth and their restorative procedures? Braz Oral Res 2018;32(Suppl. 1):e76. DOI: 10.1590/1807-3107bor-2018.vol32.0076.
4. Plotino G, Grande NM, Isufi A, et al. Fracture strength of endodontically treated teeth with different access cavity designs. J Endod 2017;43(6):995–1000. DOI: 10.1016/j.joen.2017.01.022.
5. Salamoni Sinhori B, Vieira LCC, Baratieri LN. Influence of preparation reconstruction on the compressive strength of cad/cam ceramic inlays. Int J Biomater 2019;2019:7307649. DOI: 10.1155/2019/7307649.
6. Abou-Elnaga MY, Alkhawas MAM, Kim HC, et al. Effect of truss access and artificial truss restoration on the fracture resistance of endodontically treated mandibular first molars. J Endod 2019;45(6):813–817. DOI: 10.1016/j.joen.2019.02.007.
7. Dartora G, Rocha Pereira GK, Varella de Carvalho R, et al. Comparison of endocrowns made of lithium disilicate glass-ceramic or polymer-infiltrated ceramic networks and direct composite resin restorations: fatigue performance and stress distribution. J Mech Behav Biomed Mater 2019;100:103401. DOI: 10.1016/j.jmbbm.2019.103401.
8. Alshiddi IF, Aljinbaz A. Fracture resistance of endodontically treated teeth restored with indirect composite inlay and onlay restorations–an in vitro study. Saudi Dent J 2016;28(1):49–55. DOI: 10.1016/j.sdentj.2015.09.001. PMID: 26792970; PMCID: PMC4688433.
9. Oyar P, Durkan R. Effect of cavity design on the fracture resistance of zirconia onlay ceramics. Niger J Clin Pract 2018;21(6):687–689. DOI: 10.4103/njcp.njcp_424_17.
10. Sedrez-Porto JA, Rosa WL, da Silva AF, et al. Endocrown restorations: a systematic review and meta-analysis. J Dent 2016;52:8–14. DOI: 10.1016/j.jdent.2016.07.005. PMID: 27421989.
11. Altier M, Erol F, Yildirim G, et al. Fracture resistance and failure modes of lithium disilicate or composite endocrowns. Niger J Clin Pract 2018;21(7):821–826. DOI: 10.4103/njcp.njcp_175_17. PMID: 29984710.
12. Vianna ALSV, Prado CJD, Bicalho AA, et al. Effect of cavity preparation design and ceramic type on the stress distribution, strain and fracture resistance of CAD/CAM onlays in molars. J Appl Oral Sci 2018;26:e20180004. DOI: 10.1590/1678-7757-2018-0004. PMID: 30133672; PMCID: PMC6110459.
13. Doshi P, Kanaparthy A, Kanaparthy R, et al. A comparative analysis of fracture resistance and mode of failure of endodontically treated teeth restored using different fiber posts: an *in vitro* study. J Contemp Dent Pract 2019;20(10):1195–1199. DOI:10.5005/jp-journals-10024-2668. PMID: 31883256.
14. Mainjot AK, Dupont NM, Oudkerk JC, et al. From artisanal to CAD-CAM blocks: state of the art of indirect composites. J Dent Res 2016;95(5):487–495. DOI: 10.1177/0022034516634286. PMID: 26933136.
15. Taha D, Spintzyk S, Sabet A, et al. Assessment of marginal adaptation and fracture resistance of endocrown restorations utilizing different machinable blocks subjected to thermomechanical aging. J Esthet Restor Dent 2018;30(4):319–328. DOI: 10.1111/jerd.12396. PMID: 30113129.
16. Goujat A, Abouelleil H, Colon P, et al. Mechanical properties and internal fit of 4 CAD-CAM block materials. J Prosthet Dent 2018;119(3):384–389. DOI: 10.1016/j.prosdent.2017.03.001. PMID: 28552287.
17. Garoushi S, Gargoum A, Vallittu PK, et al. Short fiber-reinforced composite restorations: a review of the current literature. J Investig Clin Dent 2018;9(3):e12330. DOI: 10.1111/jicd.12330.
18. Sabeti M, Kazem M, Dianat O, et al. Impact of access cavity design and root canal taper on fracture resistance of endodontically treated teeth: an ex vivo investigation. J Endod 2018;44(9):1402–1406. DOI: 10.1016/j.joen.2018.05.006. PMID: 30049471.
19. Tang W, Wu Y, Smales RJ. Identifying and reducing risks for potential fractures in endodontically treated teeth. J Endod 2010;36(4):609–617. DOI: 10.1016/j.joen.2009.12.002.
20. Kadam P, Bhalerao S. Sample size calculation. Int J Ayurveda Res 2010;1(1):55–57. DOI: 10.4103/0974-7788.59946.
21. Panitiwat P, Salimee P. Effect of different composite core materials on fracture resistance of endodontically treated teeth restored with FRC posts. J Appl Oral Sci 2017;25(2):203–210. DOI: 10.1590/1678-77572016-0306.
22. Scotti N, Coero Borga FA, Alovisi M, et al. Is fracture resistance of endodontically treated mandibular molars restored with indirect onlay composite restorations influenced by fibre post insertion? J Dent 2012;40(10):814–820. DOI: 10.1016/j.jdent.2012.06.005. PMID: 22743344.
23. Keçeci AD, Heidemann D, Kurnaz S. Fracture resistance and failure mode of endodontically treated teeth restored using ceramic onlays with or without fiber posts-an ex vivo study. Dent Traumatol 2016;32(4):328–335. DOI: 10.1111/edt.12252.
24. Clausson C, Schroeder CC, Goloni PV, et al. Fracture resistance of CAD/CAM lithium disilicate of endodontically treated mandibular damaged molars based on different preparation designs. Int J Biomater 2019:2475297. DOI: 10.1155/2019/2475297.
25. Gré CP, de Ré Silveira RC, Shibata S, et al. Effect of silanization on microtensile bond strength of different resin cements to a lithium disilicate glass ceramic. J Contemp Dent Pract 2016;17(2):149–153. DOI: 10.5005/jp-journals-10024-1818. PMID: 27207004.
26. Yoon HI, Sohn PJ, Jin S, et al. Fracture resistance of CAD/CAM-fabricated lithium disilicate MOD inlays and onlays with various

cavity preparation designs. J Prosthodont 2019;28(2):e524–e529. DOI: 10.1111/jopr.12787. PMID: 29533499.
27. Atalay C, Yazici AR, Horuztepe A, et al. Fracture resistance of endodontically treated teeth restored with bulk fill, bulk fill flowable, fiber-reinforced, and conventional resin composite. Oper Dent 2016;41(5):E131–E140. DOI: 10.2341/15-320-L. PMID: 27352045.
28. Özkır S. Effect of restoration material on stress distribution on partial crowns: a 3D finite element analysis. J Dent Sci 2018;13:311-317. DOI: 10.1016/j.jds.2017.03.010.
29. Goracci C, Cadenaro M, Fontanive L, et al. Polymerization efficiency and flexural strength of low-stress restorative composites. Dent Mater 2014;30(6):688–694. DOI: 10.1016/j.dental.2014.03.006. PMID: 24703547.
30. Ilgenstein I, Zitzmann NU, Bühler J, et al. Influence of proximal box elevation on the marginal quality and fracture behavior of root-filled molars restored with CAD/CAM ceramic or composite onlays. Clin Oral Investig. 2015 Jun;19(5):1021-8. doi: 10.1007/s00784-014-1325-z. Epub 2014 Sep 25. PMID: 25248949.
31. Forster A, Braunitzer G, Tóth M, et al. In vitro fracture resistance of adhesively restored molar teeth with different MOD cavity dimensions. J Prosthodont 2019;28(1):e325–e331. DOI: 10.1111/jopr.12777. PMID: 29508474.
32. Yang H, Park C, Shin JH, et al. Stress distribution in premolars restored with inlays or onlays: 3D finite element analysis. J Adv Prosthodont 2018;10(3):184–190. DOI: 10.4047/jap.2018.10.3.184. PMID: 29930787; PMCID: PMC6004358.
33. Ereifej NS, Oweis YG, Altarawneh SK. Fracture of fiber-reinforced composites analysed via acoustic emission. Dent Mater J 2015;34(4):417–424. DOI: 10.4012/dmj.2014-325.
34. Yasa B, Arslan H, Yasa E, et al. Effect of novel restorative materials and retention slots on fracture resistance of endodontically-treated teeth. Acta Odontol Scand 2016;74(2):96–102. DOI: 10.3109/00016357.2015.1046914. PMID: 25982519.
35. Morimoto S, Rebello de Sampaio FB, Braga MM, et al. Survival rate of resin and ceramic inlays, onlays, and overlays: a systematic review and meta-analysis. J Dent Res 2016;95(9):985–994. DOI: 10.1177/0022034516652848. PMID: 27287305.
36. Sekhri S, Mittal S, Garg S. Tensile bond strength of self-adhesive resin cement after various surface treatment of enamel. J Clin Diagn Res 2016;10(1):ZC01–ZC04. DOI: 10.7860/JCDR/2016/13409.7026.