Original Article

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Dentistry Section

A 3D Finite Element Analysis on Stress Distribution of Two Ceramic Materials Used for Fabrication of Laminate Veneers using Two Preparation Designs: An In-vitro Study

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ABSTRACT

Introduction: Veneers have been successfully used in cases of aesthetic and cosmetic dentistry. As the thickness of veneers needs to be 0.5 mm to enable bonding to enamel, the preparation of teeth is crucial to ensure longevity. There are numerous incisal preparation designs for veneers, but there is no uniform opinion among various investigators regarding the preferred design parameters. Knowledge of the intensity and distribution of stresses may aid in predicting the failure patterns of veneers with different types of preparations.

Aim: To evaluate the maximum principal stresses generated on the model of a maxillary central incisor tooth designed to be restored with veneers made from two different materials: Lithium disilicate and Zirconia, and prepared according to two distinct incisal designs: with "incisal butt-joint" and with "incisal palatal mini-chamfer".

Materials and Methods: This was an in-vitro study conducted at Guru Nanak Institute of Dental Science and Research, Kolkata, India between March 2018 and June 2019. A three-dimensional (3D) Finite Element Analysis (FEA) was employed to evaluate the maximum principal stresses. A virtual 3D model of an extracted maxillary central incisor tooth was obtained using Digital Imaging and Communications in Medicine (DICOM) images from a micro Computer Tomography (CT) scan and assembled using Materialise Interactive Medical Image Control System (MIMICS) software. One model was created for each of the four variable designs and materials. The 3D objects corresponding to the "veneer," "underlying cement layer," and "remaining tooth structure" were meshed in the Materialise 3-matic (3-MATIC) software. A single static load consistent with incisal bite force in natural dentition was applied to the tooth in the incisal third on the palatal surface at a 135° angle. The pattern of stresses in the model was calculated in numerical values and depicted in colour coding. The maximum principal stress values were calculated separately for the "veneers," "underlying cement layer," and "remaining tooth structure," and were tabulated. The mean and p-values were calculated.

Results: The butt-joint preparation showed less maximum stress on the "veneers" {p-value 0.51 (F1) and 0.01 (F2)}, "cement layer" {p-value 0.0007 (F1) and 0.0004 (F2)}, and "remaining tooth structure" {p-value 0.40 (F1) and 0.47 (F2)} compared to the palatal chamfer preparation. The zirconia-restored veneers with butt-joint preparation {p-value 0.12 (F1) and 0.05 (F2)} and palatal mini-chamfer preparation {p-value 0.05 (F1) and 0.80 (F2)} imparted less stress than the lithium disilicate restored veneers.

Conclusion: Butt-joint preparation of the veneers proved to be better than the palatal chamfer, and zirconia proved to be a better restorative material than lithium disilicate for veneers.

Keywords: Dental laminate, Lithium disilicate, Three dimensional analysis, Zirconia

INTRODUCTION

A surge of interest in possessing an aesthetically pleasing smile has been observed globally among patients seeking dental treatment. Furthermore, with a decline in the prevalence of dental caries and increased dental awareness among individuals, aesthetic dental consultations are currently on the rise [1]. The dental components that play the most crucial role in the creation of an attractive smile include the size, shape, colour, alignment, and crown angulation of the teeth, as well as the midline and arch symmetry [2]. Among the various treatment options available to achieve aesthetic results, veneers can serve as an elegant solution to certain aesthetic problems while being conservative at the same time. A veneer is defined as: "1) A thin sheet of material usually used as a finish; 2) A protective or ornamental facing; 3) A superficial or attractive display in multiple layers, frequently termed a laminate veneer" (GPT-9) [3].

Since their introduction by CL Pincus in 1928 [4], veneers have been successfully used to treat intrinsic staining of teeth, teeth with enamel hypoplasia, minor malformations, spacing, and minor malpositioning of teeth [5]. As the thickness of veneers needs to be 0.5 mm to enable bonding to enamel [6], the preparation of the teeth is very important to ensure longevity. The incisal preparation of a veneer can vary: window preparation, feather-edge preparation, bevel or butt-joint preparation, and incisal bevel preparation [7]. The incisal overlap preparation has been given preference by various authors (Weinberg, 1989 [8]; Nixon, 1990 [6]) as this type of preparation allows the technician to have more control over the aesthetic characterisation of the incisal portion of the tooth. This preparation is also more effective in achieving a wide distribution of occlusal forces and, hence, prevents fractures of veneers [9]. However, in-vitro studies by Hui et al., [10] presented results that were contrary to the findings of the previous authors [6,8,9]. They found that the incisal overlap design transmitted maximum stresses to the veneer and resulted in a higher incidence of cohesive fractures than the more conservative window technique [6].

All these studies have failed to reach a uniform conclusion due to the variety of testing parameters and methods employed [6-9]. They did not analyse the pattern of stress distribution, which can be an indicator of crack propagation and future chances of failure. There are various methods for testing the stresses in dental structures, such as brittle coating analysis, strain gauges, two-dimensional and three-dimensional photoelasticity, and other numerical methods. A more recent method of stress analysis is FEA. FEA can be used to solve complex problems involving intricate structures (e.g., bone, teeth, etc.) under any kind of loading and boundary conditions. Previous literature reveals that FEA can be applied to understand the pattern of stress distribution in anterior laminate veneers [11]. Knowledge of the intensity and distribution of stresses may aid in predicting the failure patterns of veneers with different types of preparations [12].

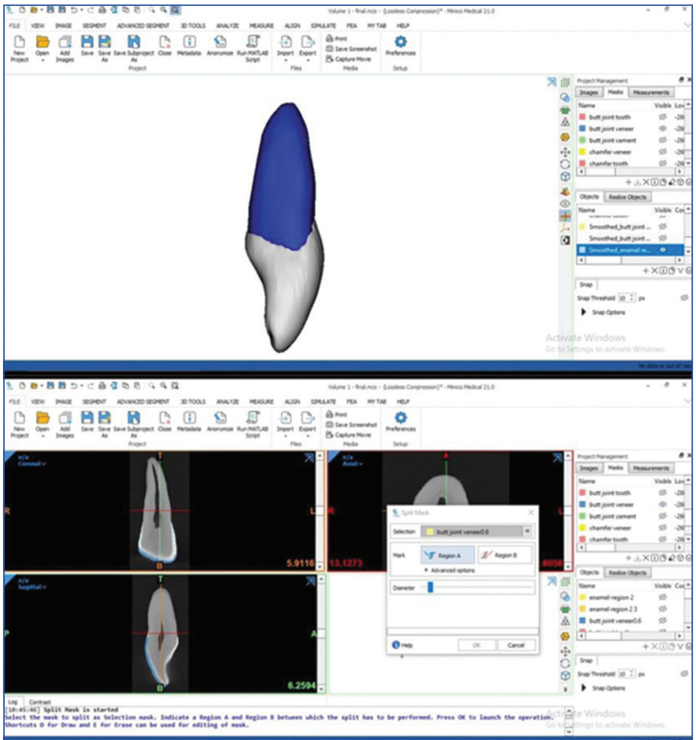
In this study, an attempt has been made to evaluate the maximum principal stresses generated on the model of a maxillary central incisor tooth prepared according to two different designs: incisal preparation with a butt-joint and incisal preparation with a palatal mini-chamfer. The study considered veneers made from two different materials, namely lithia disilicate and zirconia, which were cemented with resin cement. The study was based on a null hypothesis that there is no difference in the stress distribution of veneers between the "mini-chamfer" and "butt-joint" designs, as well as the two ceramic materials.

MATERIALS AND METHODS

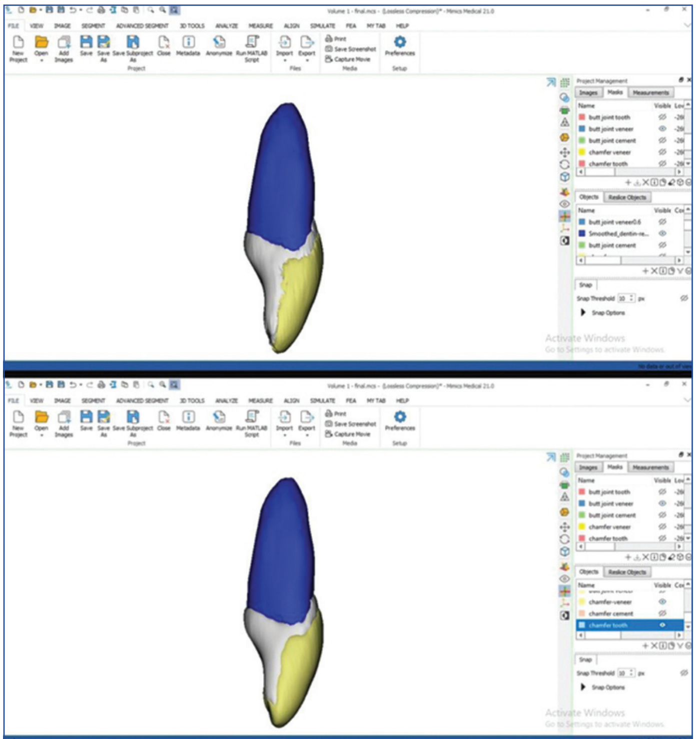
This was an in-vitro study conducted in the Department of Prosthodontics and Crown and Bridge at Guru Nanak Institute of Dental Science and Research, Kolkata, India between March 2018 and June 2019. The study presents a comparative evaluation of the maximum principal stresses obtained on a computer-generated model of a maxillary central incisor, which was virtually prepared to receive a veneer and simulated to be cemented with resin cement after the virtual application of a single static force at two different angles. There were two types of preparation designs for the virtual veneer, and each of these was simulated to be fabricated from two different materials.

Study Procedure

A non carious cadaveric maxillary central incisor tooth was scanned using a micro CT machine (GE phoenix v|tome|x L240), resulting in 578 images with a voxel size of 50 μm for optimum clarity, which were saved in the Digital Imaging and Communications in Medicine (DICOM) format. The micro CT images were assembled in the Materialise Interactive Medical Image Control System (MIMICS) software (MIMICS Medical 21.0.0.406; Materialise, Leuven, Belgium) using a laboratory computer. Two masks were created corresponding to the layers of enamel and dentine, and two three-dimensional objects were generated from these masks. The assembled three-dimensional objects resembled the scanned tooth [Table/Fig-1]. A second modelling step was performed to obtain the veneers, cement layer, and remaining crown structure [Table/Fig-2]. One model was created for each of the four groups: "Lithia disilicate-reinforced porcelain using butt-joint design"; "Lithia disilicate-reinforced porcelain using palatal mini-chamfer design"; "Yttria-stabilised zirconia using butt-joint design"; and "Yttria-stabilised zirconia using palatal mini-chamfer design."

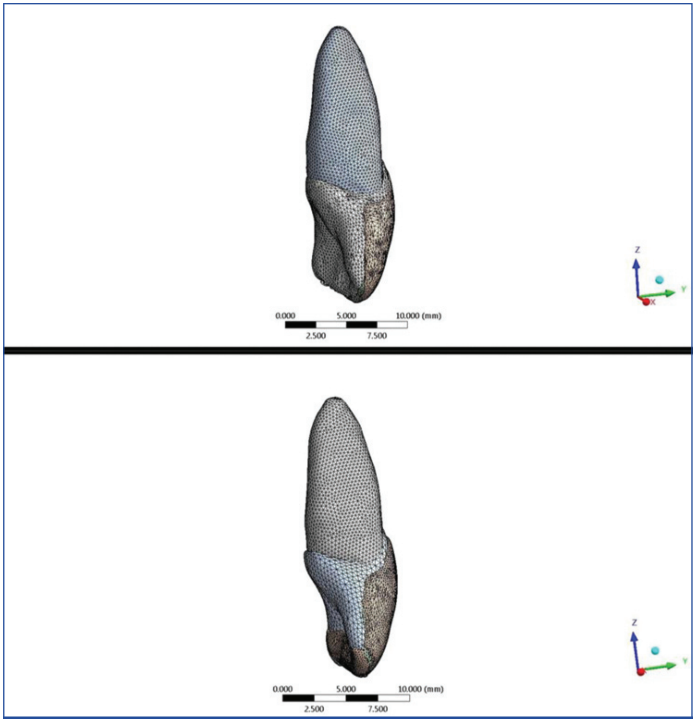


[Table/Fig-1]: Virtual model of tooth using Materialise Interactive Medical Image Control System (MIMICS) software (MIMICS Medical 21.0.0.406; Materialise, Leuven, Belgium).



[Table/Fig-2]: Virtual model of veneer preparations using Materialise Interactive Medical Image Control System (MIMICS) software (MIMICS Medical 21.0.0.406; Materialise, Leuven, Belgium).

The three-dimensional objects corresponding to the veneer, cement layer, and the reduced tooth structure were meshed in the 3-MATIC software [Table/Fig-3]. Each model was meshed by elements defined by 20 nodes and three degrees of freedom in tetrahedral bodies. The tooth, veneer, and cement layer were considered homogeneous, isotropic, and linearly elastic [11]. The Poisson's ratio and Young's modulus of elasticity were incorporated, as the structures were considered homogeneous, isotropic, and linearly elastic for simplification purposes. These properties are shown in [Table/Fig-4] [13-16] and were used for calculating the maximum principal stresses. A single static load of 150 N, consistent with the incisal bite force in natural dentition [17], was applied to the tooth in the incisal third on the palatal surface at two angles: 135° and 60°, which were symbolically represented as F1 and F2, respectively. The models of the tooth were constrained in all six degrees of freedom, and the maximum principal stresses were calculated for the individual layers. The maximum principal stresses were calculated in three areas: incisal third, middle third, and cervical third for each of the three layers - Veneer (V), Cement layer (C), and Remaining tooth structure (T). Mean values for V, C, and T were obtained from the averages of the incisal, middle, and cervical thirds. Master data tables for mean maximum principal stresses for V, C, and T were created. This data has been used for statistical analysis.



[Table/Fig-3]: Mesh models using 3-MATIC software.

Tissues and materials	Young's modulus of elasticity (MPa)	Poisson's ratio
Enamel	84,100 [12]	0.33 [12]
Dentine	14,700 [13]	0.31 [12]
Yttria-stabilised zirconia	205000 [14]	0.19 [14]
Lithia disilicate	96000 [14]	0.23 [14]
Resin cement	6000 [15]	0.3 [15]

[Table/Fig-4]: Young's Modulus of elasticity (MPa) and Poisson's ratio of tissues and materials [12-15].

STATISTICAL ANALYSIS

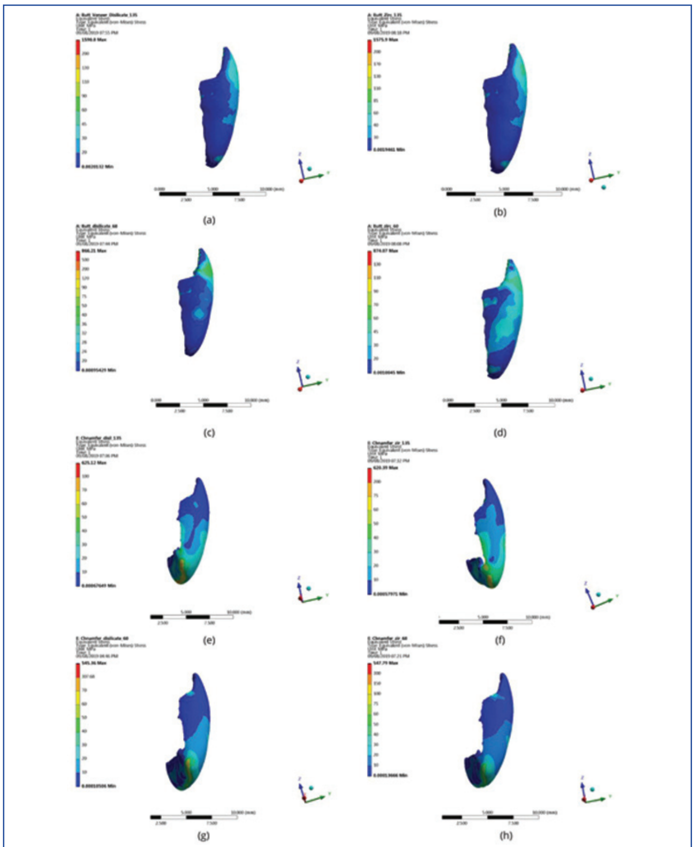
For statistical analysis, data were entered into a Microsoft Excel spreadsheet and subsequently analysed using Statistical Package for Social Sciences (SPSS) version 24.0 and GraphPad Prism version 5. The data were summarised as means and standard deviations for numerical variables. Student's t-test was used for the comparison of two group means. In this study, a p-value of ≤0.05 was considered statistically significant.

RESULTS

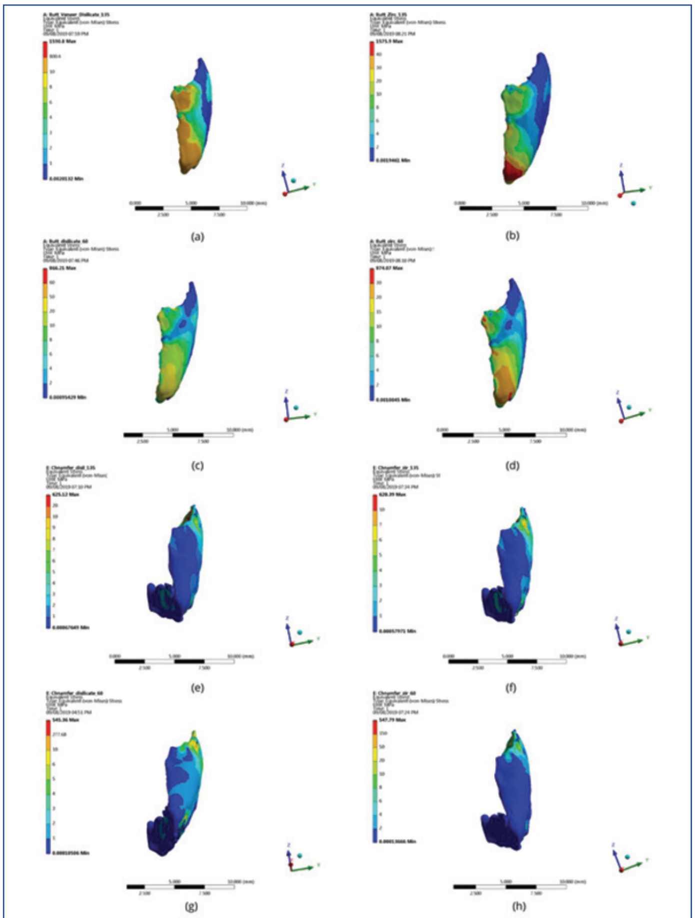
The pattern of stress distribution was depicted using different colours [Table/Fig-5-7]. Areas of greatest stress were represented in red, while areas of least stress were depicted in blue. There was a gradation of values shown in the increasing array of stress distribution, represented by bluish green, green, greenish yellow, and yellowish red. The maximum principal stress values of the veneer, cement layer, and underlying remaining tooth structure were calculated and grouped in three separate tables. The maximum principal stresses were calculated at the incisal, middle, and cervical thirds for V, C, and T. The mean values for each layer were obtained by averaging the values from each third.

In [Table/Fig-8], the maximum principal stress values of the different structures have been compared irrespective of the materials used. The maximum principal stresses on V and C with butt-joint preparation under the forces F1 and F2 were lower than those with palatal mini-chamfer preparation. However, the stress values on T were higher with the butt-joint preparation than with the palatal mini-chamfer preparation.

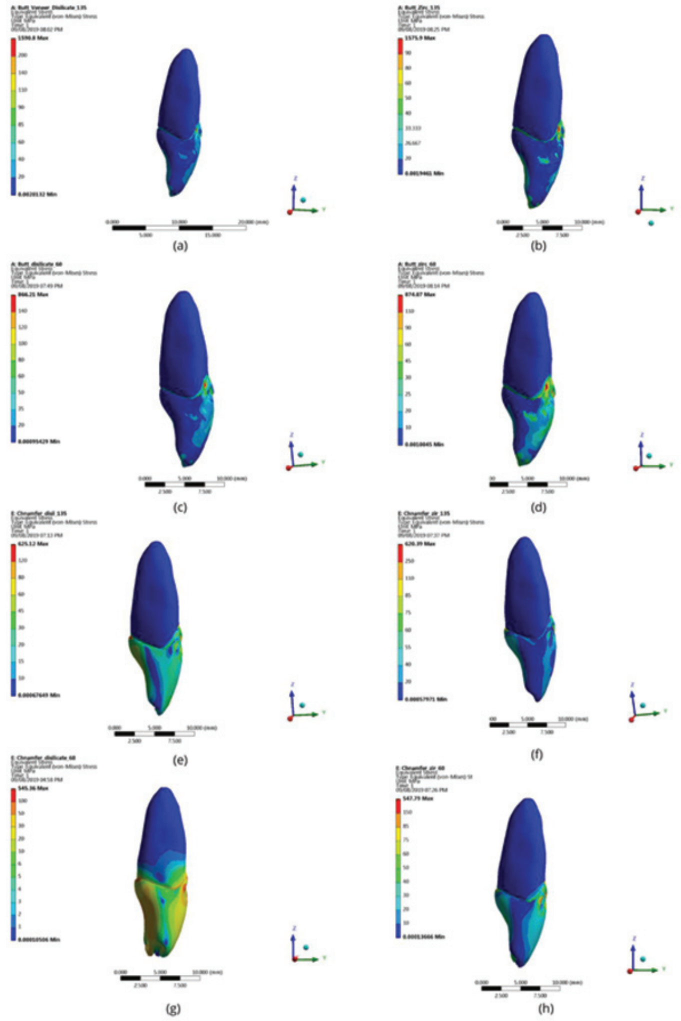
[Table/Fig-9] shows the comparison of the maximum principal stress on the veneer, cement layer, and remaining tooth structure under



[Table/Fig-5]: Distribution of the maximum principal stresses on the veneer: (a) butt joint with lithium disilicate under 150º; (b) butt joint with zirconia under 150º; (c) butt joint with lithium disilicate under 60º; (d) butt joint with zirconia under 60º; (e) palatal chamfer with lithium disilicate under 150º; (f) palatal chamfer with zirconia under 150º; (g) palatal chamfer with lithium disilicate under 60º; (h) palatal chamfer with zirconia under 60º.



[Table/Fig-6]: Distribution of the maximum principal stresses on the cement layer: (a) butt joint with lithium disilicate under 150º; (b) butt joint with zirconia under 150º; (c) butt joint with lithium disilicate under 60º; (d) butt joint with zirconia under 60º; (e) palatal chamfer with lithium disilicate under 150º; (f) palatal chamfer with zirconia under 150º; (g) palatal chamfer with lithium disilicate under 60º; (h) palatal chamfer with zirconia under 60º.



[Table/Fig-7]: Distribution of the maximum principal stresses on the remaining tooth structure: (a) butt joint with lithium disilicate under 150º; (b) butt joint with zirconia under 150º; (c) butt joint with lithium disilicate under 60º; (d) butt joint with zirconia under 60º; (e) palatal chamfer with lithium disilicate under 150º; (f) palatal chamfer with zirconia under 150º; (g) palatal chamfer with lithium disilicate under 60º; (h) palatal chamfer with zirconia under 60º.

Structure	Force	Butt-joint (MPa) (n=6)		Palatal chamfer (MPa) (n=6)		p-value
Veneer	F1	Mean	93.46	Mean	104.36	0.51
		SD	27.03	SD	28.26	
	F2	Mean	80.27	Mean	115.39	0.01*
		SD	23.77	SD	13.39	
Cement layer	F1	Mean	1.46	Mean	2.30	0.0007*
		SD	0.29	SD	0.31	
	F2	Mean	1.42	Mean	2.38	0.0004*
		SD	0.35	SD	0.27	
Remaining tooth structure	F1	Mean	61.51	Mean	54.88	0.40
		SD	16.30	SD	9.47	
	F2	Mean	64.86	Mean	58.72	0.47
		SD	14.81	SD	14.85	

[Table/Fig-8]: Maximum Principal Stress values of Veneer (V), cement (C) and remaining tooth structure (T) irrespective of material of the veneer under F1 (150 N force at 135º) and F2 (150 N force at 60º).
unpaired t-test

the zirconia veneers and lithium disilicate veneers with incisal butt-joint preparation, according to the respective loading conditions. The maximum principal stresses under forces F1 and F2 on V and C with butt-joint preparation restored by lithium disilicate were found to be greater than those restored by yttria-stabilised zirconia. In the present study, the maximum principal stresses on T with the lithium disilicate-restored veneers were less than those with the zirconia-restored veneers.

Structure	Force	Lithium disilicate (n=3)		Zirconia (n=3)		p-value
Veneer	F1	Mean	110.58	Mean	76.33	0.12
		SD	20.15	SD	23.27	
	F2	Mean	97.77	Mean	62.77	0.05*
		SD	19.81	SD	10.06	
Cement layer	F1	Mean	1.55	Mean	1.37	0.51
		SD	0.28	SD	0.32	
	F2	Mean	1.68	Mean	1.17	0.06*
		SD	0.30	SD	0.17	
Tooth structure	F1	Mean	66.74	Mean	56.30	0.49
		SD	10.42	SD	21.76	
	F2	Mean	74.97	Mean	54.76	0.08*
		SD	12.21	SD	9.65	

[Table/Fig-9]: Maximum Principal Stress values of Veneer (V), cement (C) and remaining tooth structure (T) with butt-joint preparation under F1 (150 N force at 135º) and F2 (150 N force at 60º) under zirconia veneers vs lithium disilicate veneers.
unpaired t-test

The mean values for V, C, and T were obtained from the maximum principal stress in the incisal, middle, and cervical thirds.

In [Table/Fig-10], the maximum principal stresses on the three layers under the lithium disilicate veneers with palatal chamfer preparation have been compared according to the corresponding loading conditions. The maximum principal stresses under forces F1 and F2 on V and C with palatal mini-chamfer preparation restored by lithium disilicate were found to be greater than those restored by yttria-stabilised zirconia. In the present study, the maximum principal stresses on T with the lithium disilicate-restored veneers were less than those with the zirconia-restored veneers.

Structure	Force	Lithium disilicate (n=3)		Zirconia (n=3)		p-value
Veneer	F1	Mean	125.14	Mean	83.58	0.05*
		SD	19.70	SD	17.70	
	F2	Mean	116.95	Mean	113.82	0.80
		SD	13.58	SD	16.01	
Cement layer	F1	Mean	2.43	Mean	2.16	0.34
		SD	0.32	SD	0.28	
	F2	Mean	2.14	Mean	2.61	0.008*
		SD	0.08	SD	0.14	
Tooth structure	F1	Mean	56.40	Mean	53.35	0.73
		SD	9.96	SD	10.86	
	F2	Mean	57	Mean	60.43	0.80
		SD	14.74	SD	16.56	

[Table/Fig-10]: Maximum Principal Stress values of Veneer (V), cement (C) and remaining tooth structure (T) with palatal chamfer preparation under F1 (150 N force at 135º) and F2 (150 N force at 60º) under zirconia veneers vs lithium disilicate veneers.
Mean- unpaired t-test; p-value- t-test

DISCUSSION

The oral environment is a complex biomechanical system in which a multitude of forces acts on the teeth and restorations, interacting in an extremely complicated manner [11]. Due to these complex forces, it is challenging to comprehend the interplay of all factors through in-vivo studies. For this reason, most biomechanical aspects of oral forces are researched using in-vitro methods. FEA is a commonly employed mathematical analysis that has been successfully applied in technical fields of engineering for a long time. This method has also been used in dentistry to determine the biomechanical behaviour of oral structures [11].

The observations in [Table/Fig-8] for the veneers (V) with butt-joint and palatal mini-chamfer preparations align with the results obtained by Üstün O and Öztürk AN (2018), where the highest value of the maximum principal stresses was recorded with the palatal chamfer preparation [18]. The outcome of the current study can further corroborate the findings from studies conducted by Castelnuovo J, Tjan AHL, Phillips K et al., (2000) [19], and Mirra AG and El-Mahalawy S (2009), which demonstrated higher fracture loads for veneers with butt-joint preparation compared to those with palatal chamfer preparation [20]. These observations may be linked to the fact that the palatal chamfer represents the weakest portion of the veneer, due to unsupported ceramic in the chamfer extension [19].

The maximum principal stresses on the lithium disilicate veneers with butt-joint and palatal mini-chamfer preparations were greater than those on the zirconia veneers [Table/Fig-9,10]. These findings can be substantiated by results obtained by Zhang Y et al., in a study investigating edge chipping and flexural resistance of crowns fabricated using monolithic high-translucency zirconia and monolithic lithium disilicate, which indicated higher flexural strength for monolithic zirconia than for monolithic lithium disilicate [21]. Another study by Zhang Y et al., showed that the fracture loads recorded for monolithic zirconia, determined by in-vitro methods and by Extended Finite Element Method (XFEM), were greater than those determined for monolithic lithium disilicate ceramics [22]. A plausible explanation for these findings could be related to the greater Young's modulus of elasticity of zirconia (205,000 MPa) compared to that of lithium disilicate ceramics (96,000 MPa). The higher modulus of elasticity could render zirconia a stronger material in comparison to lithium disilicate ceramics.

The findings presented in [Table/Fig-8] for the cement layer (C) with butt-joint and palatal mini-chamfer preparations indicate that the butt-joint preparation reduced the stresses on the cement layer more effectively than the palatal mini-chamfer preparation. This finding is consistent with the observations made by Castelnuovo J, Tjan AHL, Phillips K et al., (2000) [19], where failure of the veneers due to debonding was noted only in the case of palatal chamfer preparation and not with the butt-joint preparation. However, the study by Li Z et al., indicated that there was no significant difference in stresses generated in the cement layer between the butt-joint preparation and the palatal chamfer preparation [11]. This discrepancy may be attributed to differences in the loading conditions and material properties used in the two studies.

The maximum principal stresses on the cement layer (C) underneath the lithium disilicate veneers were greater than those for the zirconia veneers with both butt-joint and palatal mini-chamfer preparations. Collectively, these results imply that fabricating the veneers with zirconia helped to reduce the stresses on the underlying cement layer more effectively than with lithium disilicate. This is supported by the study conducted by Zhang Y et al., which observed a "stress shielding" effect on the underlying structures by monolithic zirconia crowns compared to monolithic lithium disilicate crowns [22]. This effect could be explained by the fact that zirconia possesses a greater modulus of elasticity than lithium disilicate, making it a stronger material.

When comparing the maximum principal stresses on the remaining tooth structure, it was found that these stresses were higher with the butt-joint preparation than with the palatal mini-chamfer preparation. This suggests that a greater proportion of the stresses in the palatal mini-chamfer preparation were absorbed by the veneer itself, resulting in less stress generation in the tooth structure compared to the butt-joint preparation, where less stress was absorbed by the veneer, leading to more stress in the tooth structure. This observation could be validated by the findings of a study conducted by Arora A et al., where the authors noted more veneer fractures with palatal chamfer preparation than with butt-joint preparation, along with fewer coronal fractures for the palatal chamfer preparation compared to the butt-joint preparation [23].

The maximum principal stresses on the remaining tooth structure (T) in the butt-joint and palatal mini-chamfer groups with lithium disilicate-restored veneers were less than those for zirconia-restored veneers. A probable explanation for this observation could also be related to the "stress shielding" effect of zirconia, as noted by Zhang Y et al., [22].

Limitation(s)

Although this study is comprehensive, it has certain limitations. The load applied was a static load and was directed to a specific point on the palatal surface. However, in intra-oral conditions, veneers are typically subjected to cyclic loads applied over a broad area on the palatal surface of the teeth. In the present study, enamel and dentine were regarded as isotropic structures, whereas natural human enamel and dentine are anisotropic in nature. Additionally, the periodontal ligament and alveolar bone were considered rigid structures, whereas, in natural human dentition, they possess elastic properties. Therefore, further research in this field is required.

CONCLUSION(S)

Considering the constraints of this study, certain conclusions can be drawn. Among the butt-joint and palatal mini-chamfer preparations, the butt-joint preparation can be regarded as providing the veneer with better mechanical properties, while the palatal mini-chamfer preparation resulted in greater strength for the remaining tooth structure. Among the restorative materials, yttria-stabilised zirconia proved to be superior for fabricating veneers compared to lithium disilicate-reinforced ceramic. The results of this study can serve as a guideline for future preparations of veneers for maxillary incisor teeth, aiding in the decision of the type of preparation design and material used for fabricating the veneers.

REFERENCES

[1] Albashaireh ZS, Alhusein AA, Marashdeh MM. Clinical assessments and patient evaluations of the esthetic quality of maxillary anterior restorations. Int J Prosthodont. 2009;22(1):65-71.
[2] Sabri R. The eight components of a balanced smile. J Clin Orthod. 2005;39(3):155-67.
[3] Ferro KJ, Morgano SM, Driscoll CF, Freilich MA, Guckes AD, Knoernschild KL, et al. The glossary of prosthodontic terms. J Prosthet Dent. 2017;117(5S):c1-e105.
[4] Radz GM. Minimum thickness anterior porcelain restorations. Dent Clin North Am. 2011;55(2):353-70.
[5] Toh CG, Setcos JC, Weinstein AR. Indirect dental laminate veneers—an overview. J Dent. 1987;15(3):117-24.
[6] Peumans M, Van Meerbeek B, Lambrechts P, Vanherle G. Porcelain veneers: A review of the literature. J Dent. 2000;28(3):163-77.
[7] Alothman Y, Bamasoud MS. The success of dental veneers according to preparation design and material type. Open Access Maced J Med Sci. 2018;6(12):2402-08.
[8] Weinberg LA. Tooth preparation for porcelain laminates. N Y State Dent J. 1989;55(5):25-28.
[9] Highton R, Caputo AA, Matyas J. A photoelastic study of stresses on porcelain laminate preparations. J Prosthet Dent 1987;58(2):157-61.
[10] Hui KKK, Williams B, Davis EH, et al. A comparative assessment on the strengths of porcelain veneers for incisor teeth dependent on their design characteristics. Br. Dent. Jr. 1991;171:51-55.
[11] Li Z, Yang Z, Zuo L, Meng Y. A three-dimensional finite element study on anterior laminate veneers with different incisal preparations. J Prosthet Dent. 2014;112(2):325-33.
[12] Srirekha A, Bashetty K. Infinite to finite: An overview of finite element analysis. Indian J Dent Res. 2010;21(3):425.
[13] Farah JW, Craig RG, Meroueh KA. Finite element analysis of three-and four-unit bridges. J Oral Rehabil. 1989;16(6):603-11.
[14] Sano H, Ciucchi B, Matthews WG, Pashley DH. Tensile properties of mineralized and demineralized human and bovine dentin. J Dent Res. 1994;73(6):1205-11.
[15] Lin J, Shinya A, Gomi H, Shinya A. Finite element analysis to compare stress distribution of connector of lithia disilicate-reinforced glass–ceramic and zirconia-based fixed partial denture. Odontology. 2012;100(1):96-99.
[16] Kuo WC, Chang CY, Lin CL. Mechanical interactions of cuspal-coverage designs and cement thickness in a cusp-replacing ceramic premolar restoration: A finite element study. Med Biol Eng Comput. 2009;47(4):367.
[17] Helkimo E, Carlsson GE, Helkimo M. Bite force and state of dentition. Acta Odontol Scand. 1977;35(6):297-303.
[18] Ustun O, Ozturk AN. The evaluation of stress patterns in porcelain laminate veneers with different restoration designs and loading angles induced by functional loads: A three-dimensional finite element analysis study. Niger J Clin Pract. 2018;21(3):337.
[19] Castelnuovo J, Tjan A.H.L, Phillips K, Nicholls J. I, Kohls J C. Fracture load and mode of failure of ceramic veneers with different preparations. J. Prosthet. Dent. 2000;83:171-181.

[20] Mirra A, El-Mahalawy S. Fracture strength and microleakage of laminate veneers. Cairo Dent J. 2009;25:245-54.
[21] Zhang Y, Lee JJ, Srikanth R, Lawn BR. Edge chipping and flexural resistance of monolithic ceramics. Dent Mater. 2013;29(12):1201-08.
[22] Zhang Y, Mai Z, Barani A, Bush M, Lawn B. Fracture-resistant monolithic dental crowns. Dent Mater. 2016;32(3):442-49.
[23] Arora A, Upadhyaya V, Arora SJ, Jain P, Yadav A. Evaluation of fracture resistance of ceramic veneers with different preparation designs and loading conditions: An in vitro study. J Indian Prosthodont Soc. 2017;17(4):325.

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