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Measurement of mechanical properties for veneered zirconia in dental application based on finite element analysis

Khawla H Rasheed,[1] Auns Qusai Al-Neami,[2] Mohammed Q Shabban[3]

[1]College of Dentistry Ibn Sina University of Medical and Pharmaceutical Sciences. Iraq

[2]Biomedical Engineering Department/College of Engineering, Al-Nahrain University, Iraq

[3]Ibn Sina University of Medical and Pharmaceutical Sciences, Iraq

Correspondence: Khawla H Rasheed, College of Dentistry Ibn Sina University of Medical and Pharmaceutical Sciences. Iraq, Email eng.khawlarasheed@gmail.com

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Abstract

Purpose: Because the failure due to tensile stresses is the dominant case in many clinical trials, the combination of strength property of zirconia and the weaker veneer aesthetic porcelain results in stronger and more reliable restoration. The purpose of the current study is to investigate the mechanical properties of veneered zirconia in different thickness configurations obtained from simulated bending tests.

Materials and methods: To simulate the biomechanical behavior of porcelain veneered yttria- stabilized zirconia three points bending test based on finite element analysis performed on eight beams, eight three dimensional models of different thicknesses of veneer to zirconia created by Auto Cad 16 program. Geometric models imported to Ansys 17.1 program to perform static structural analysis.

Results: The results show that veneered zirconia is stronger in compression than in tension and increasing the veneer layer thickness weakens the restoration.

Conclusion: it is better to reduce the veneer layer thickness, as it is possible also to place the zirconia layer in the areas of compression.

Keywords: zirconia, veneer, three-points bending test, finite element analysis

Abbreviations: CAD, computer-aided design; CAM, Computer-aided manufacturing, FEA, finite element analysis

Introduction

The science of dental biomaterials is an important field for studying its biological and physical properties. Ceramics is one of the important biomaterials. Among all types of dental ceramics, it's evident that zirconia is the material of choice in recent restorative materials in dentistry.[1] Zirconia is expectable restorative dental material for its high success rate in a clinical trial and its translucency.[2,3] Compared with metal, the zirconia ceramic crown has less fracture rate.[4] It offers several advantages as aesthetic restorative materials, so it's the first choice in the premolar region and the anterior teeth.[5,6] To achieve the structural demand zirconia is doped frequently with stabilizers to attain high fracture toughness and strength.[7] The structural ceramics used in military armor and aerospace were modified to fit the biocompatibility requirements.[8,9]

The use of zirconia as restorative materials is increasing, leading to the presentation of Computer-Aided Design/Computer-Aided Manufacturing (CAD/CAM) that helps in the production of complex restorations with high dimensional accuracy.[10,11] Since they have toughening capabilities among the dental materials, the zirconia is very common.[12,13]

Mostly three-points bending tests and four-points bending tests used for the prediction of flexural strength of materials,[14] they are model tensile and compression stress on specimens.[15] Finite Element Analysis is one of the common methods used to solve complex stress analysis problems, and now it becomes easier to use FEA with the aid of much available software.[16]

This study aims to determine flexural strength using a simulation of three points bending test of the zirconia Core material and Two-Layered with different thicknesses of Core/Veneer Specimens to determine their mechanical behavior. This test was simulated using FEA using Ansys 17.1.

Material and method

The production of porcelain veneered yttria-stabilized zirconia crowns and bridges with CAD/CAM technique, analyzed by simulated three points bending test to investigate the flexural strength using Ansys 17.1 program. the specimen was created using (AutoCAD 16) program, core/veneer specimens with eight different configurations to show the effect of zirconia to veneer ratio and the effect of applying force from veneer or zirconia side.

Core veneer specimens with 8 different configurations: Eight three dimensional models of different thicknesses of veneer to zirconia created by Auto Cad 16 program. The specimens created with 44 mm

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in length and 4 mm width and 4 mm thickness.[17,18] The specimens were divided into four fourths and labeled as VZZZ, VVZZ, VVVZ, VVVV, ZVVV, ZZVV, ZZZV, and ZZZZ. As shown in Figure 1, Where V represents veneer and Z is Zirconia, as shown in Figure 1. The test span was 40mm to achieve a span to depth ratio of 10:1,[19] and the translation rate of 0.25 mm per minute.[20]

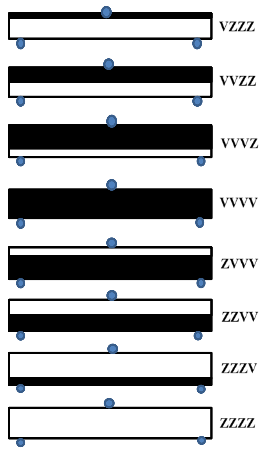

Figure 1 The eight specimens with different configurations.

The constructed models were meshed to attain the Finite Element Model (FEA) as shown in Figure 2. The FEM models involve many nodes and tetrahedral elements. The number of nodes and elements is shown in Table 1, Flexural strength was determined by performing simulated three-point bending test using ANSYS 17.1 program. The load was applied to each finite element model following boundary conditions shown in Table 2.[21]

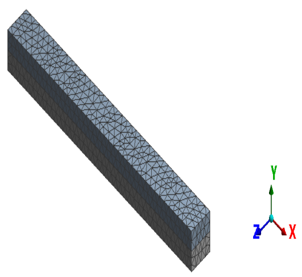

Figure 2 The meshed specimen.

Table 1 The number of nodes and elements in each model.

Design	Nodes	Elements
VZZZ	30779	19056
VVZZ	28095	17458
VVVZ	21686	13956
VVVV	33243	21431
ZVVV	30779	19056
ZZVV	28095	17458
ZZZV	21686	13956
ZZZZ	33243	21431

Table 2 Boundary conditions.

Material properties	Porcelain veneer	Core (Yattria stabilized Zirconia)
Density ρ gm/cm^3	2.53	6.22
Elastic modulus (E) (Gpa)	64	196
Poisson's ratio	0.27	0.34

Flexural strength, the minimum force required to cause failer, and strain energy obtained for each model. No statistical analysis was required for current work and the results were analyzed numerically using the software (ANSYS 17.1).

Results and discussion

The results regarding the simulated tests are illustrated in this section. The maximum principal stresses are reached when it exceeds the ultimate tensile stress of that material. The ultimate tensile strength of zirconia is about 1200 MPa and porcelain is about 290 MPa in tension and about 340 MPa in compression.[22,23]

The crack initiation and tensile frailer are the predominant cases in all specimens. Because veneering porcelain said to be the weakest link in many reconstructions, the specimens with zirconia core material facing the tensile stresses withstand higher stresses reaches eight folds than the specimens with porcelain facing the tensile stresses side, these results show that the materials on the bottom determine the flexural strength and failure mode.[24,25] it's clear from Figure 3 increasing the thickness of zirconia core material will lead to increasing the fracture load.

Figure 3 Fracture loads.

Veneered zirconia core recorded higher moduli of fracture (786-794MPa) in comparison to glass –alumina- porcelain (340-520MPa).[17,18] So it's reasonable that the zirconia-based prosthesis has a lower clinical failure and a wider range of clinical applications.

According to FEA, the flexural strength of any specimen is directly proportional to the elastic modulus of material under tension.[26,27] Because higher tensile stresses concentrated at the bottom of the specimen there for a higher flexural strength is attained when zirconia be under tension in any part of the prosthesis. Figure 4 shows the distribution of maximal principal stresses in all specimens. it's clear that the stresses concentrated in the lower or tension side in most specimens except in specimen ZVVV that composed of three-quarters

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of porcelain and one lower fourth of zirconia, in this specimen the stresses concentrated at the lower fourth of porcelain.

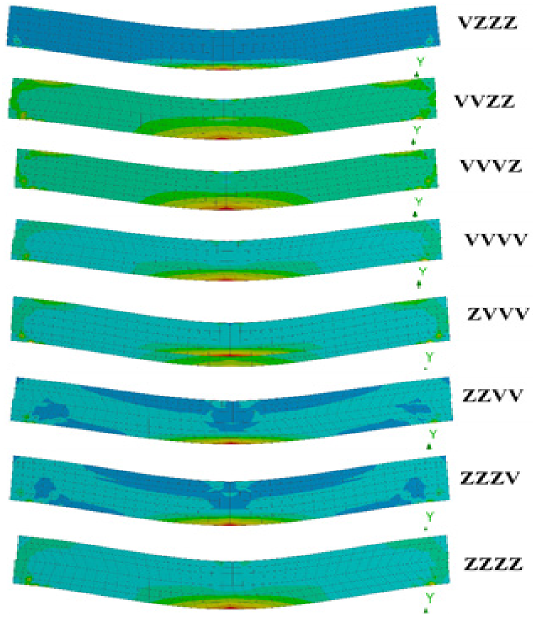

Figure 4 Maximal principal stresses distribution in all specimens.

So whether the zirconia was placed facing tensile or compressive stresses, the strong zirconia core should be as thick as possible, and veneer be as thin as it's possible. The complex shape of partial dentures and the complexity of human masticatory forces could cause the prosthesis loaded in many different ways.[28] So increasing the thickness of core zirconia in all areas of high stresses is highly recommended. Also because the material facing tensile stresses is very important it's better to make the stronger zirconia from tensile stresses side as it's possible.

An increasing zirconia proportion will increase the capacity of load-bearing of beams with the same dimensions (Figure 5). The VZZZ shows the best mechanical behavior and specimens ZVVV and VVVZ show approximate values of two energies (Figure 6).

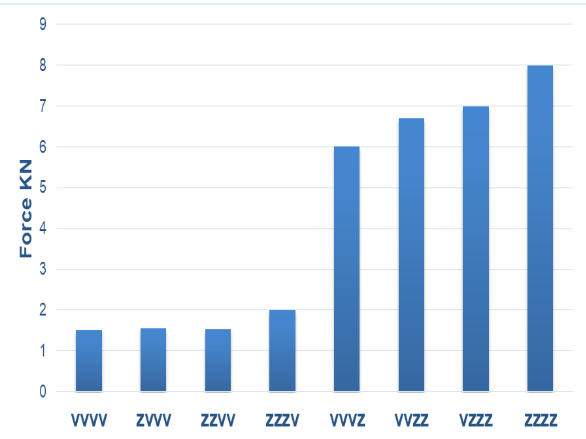

Figure 5 Failure force of each specimen.

This study shows that the investigation of dental biomechanics is more easily by finite element analysis by creating a three dimensional veneered zirconia bars models.

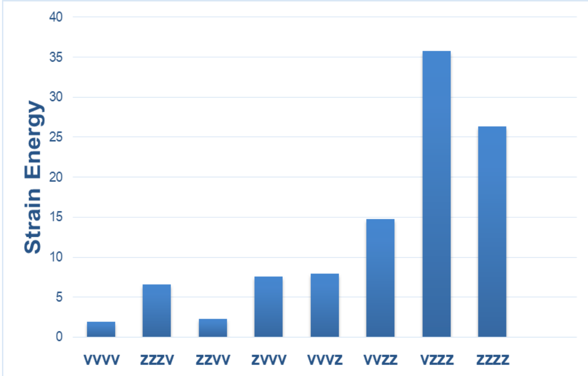

Figure 6 Strain energy at the failure point of each specimen.

Acknowledgments

None.

Conflicts of interest

This study has no conflict of interest to be declared by any author.

References

1. Alvaro Della Bona, Oscar E Pecho, Rodrigo Alessandretti, et al. Zirconia as a Dental Biomaterial. *Materials (Basel)*. 2015;8(8):4978–4991.
2. Lohbauer U, Reich S. Antagonist wear of monolithic zirconia crowns after 2 years. *Clin Oral Investig*. 2017;21(4):1165–1172.
3. PO. Bona A.D. Alessandretti R. Zirconia as a dental biomaterial. Materials. 2015;8:4978–4991.
4. Stawarczyk B, Keul C, Eichberger M, et al. Three generations of zirconia: From veneered to monolithic. Part I. *Quintessence Int*. 2017;48(5):369–380.
5. Baldissara P, Wandscher VF, Marchionatti AME, et al. Translucency of IPS e.max and cubic zirconia monolithic crowns. *J Prosthet Dent*. 2018;120(2): 269–275.
6. Nassary Zadeh P, Lümkemann N, Sener B, et al. Flexural strength, fracture toughness, and translucency of cubic/tetragonal zirconia materials. *J Prosthet Dent*. 2018;120(8):948–954.
7. Kelly JR, Denry I. Stabilized zirconia as a structural ceramic: An overview. *Dent Mate*. 2008;24(2):289–298.
8. Jeffrey Y Thompson, Brian R Stoner, Jeffrey R Piascik. Ceramics for restorative dentistry: Critical aspects for fracture and fatigue resistance. *J Mat Science Eng*. 2006;27(3):565–569.
9. Vagkopoulou T, Koutayas SO, Koidis P, et al. Zirconia in Dentistry: Part 1. Discovering the nature of an upcoming bioceramic. *Eur J Esthet Dent*. 2009;4(2):130–151.
10. Manicone PF, Rossi Iommetti P, Raffaelli L. An ojverview of zirconia ceramics: basic properties and clinical applications. *Journal of Dentistry*. 2007;35(11):819–826.
11. J Robert Kelly, Isabelle Denry. Stabilized zirconia as a structural ceramic: an overview. *Dent Mater*. 2008;24(3):289–298.
12. Massimiliano Guazzato, Kaarel Proos, Linda Quach, et al. Strength,reliability and mode of fracture of bilayered porcelain/zirconia(Y-TZP) dental ceramics. *Biomaterials*. 2004;25(20):5045–5052.

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13. Nima Rahbara, Yong Yang, Winston Soboyejo. Mixed mode fracture of dental interfaces. *Materials Science and Engineering*. 2008;488(12):381–388.

14. M Kumar, V Murthy. Effect of Specimen Dimensions on Flexural Modulus in a 3-Point Bending Test. *International Journal of Engineering Research & Technology*. 2012;1(8):1–6.

15. P Chitchumnong, SC Brooks, GD Stafford. Comparison of three- and four-point flexural strength testing of denture-base polymers. *Dental Mate.*1989;5(1):2–5.

16. M Ramesh, P Sudharsan. Experimental and Finite Element Analysis of Flexural Strength of Glass Fiber Reinforced Polymer Composite Laminate. *Journal of Material Science and Mechanical Engineering*. 2016;3(2):50–53.

17. SN White, AA Caputo, FM Vidjak, et al. Moduli of rupture of layered dental ceramics. *Dent Materials*.1994;10(5):2–8.

18. SN White, AA Caputo, ZC Li. Modulus of rupture of the Procera All-Ceramic System. *J Esthet Dent*. 1996;8(12):3–6.

19. SR Woelfel JB. Dental anatomy: its relevance to dentistry. Philadelphia: Lippincott, 2002.

20. D WH. Precise tensile properties of ceramic bodies. *J Am Ceramics*. 1951;34(1):1–9.

21. Taskonak B, Borges GA, Mecholsky JJ, et al. The effects of viscoelastic parameters on residual stress development in a zirconia/glass bilayer dental ceramic.US National Library of Medicine National Institutes of Health. 2008;24(9):11149–1155.

22. Paolo Francesco Manicone, Pierfrancesco Rossi Iommetti, Luca Raffaelli. An overview of zirconia ceramics: basic properties and clinical applications. *J Dent*. 2007;35(11):19–26.

23. OW Johnston WM. The shear strength of dental porcelain. *Dent Res.*1980;59(11):9–11.

24. Bona AD, Anusavice KJ, DeHoff PH. Weibull analysis and flexural strength of hot-pressed core and veneered ceramic structures. *Dental Mate.* 2003;19(7):2–9.

25. Yilmaz H, Nemli SK, Aydin C, et al. Effect of fatigue on biaxial flexural strength of bilayered porcelain/zirconia (Y-TZP) dental ceramics. *Dental Mate*. 2011;27(8):786–795.

26. Kelly JR. Perspectives on strength. *Dental Materials.*1995;11(2):3–10.

27. Kaiyang Zeng. A Odén, David Rowcliffe. Evaluation of mechanical properties of dental ceramic core materials in combination. *Int J Prosthodont*. 1998;11(2):183–189.

28. Van Eijden TM. Three-dimensional analyses of human bite-force magnitude and moment. *Arch Oral Biol*. 1991;36(7):535–539.

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