Modern processing technologies of all-ceramic dental crowns with various zirconia frameworks

Sorin Porojan, Liliana Porojan, and Cristina Savencu

***Abstract*—**CAD/CAM (computer aided design/computer aided manufacturing) processing or zirconia frameworks and overpressing of the veneer are modern methods available to achieve all-ceramic bilayered crowns. Besides materials strength, other factors affect restorations' clinical longevity, such as prosthesis design and technological steps. The aim of the study is to display alternative modern technologies for the fabrication of all-ceramic molar crowns with various zirconia frameworks. The individual processing procedures could cause structural flaws. The structural flaws may be located in the framework, at the veneer–core interface, at the surface, in the bulk of the veneering material, and lead to stress concentration as well as act as fracture initiation sites. An innovative modality for the improvement of all-ceramic restorations in the posterior areas might be the possibility to use glass ceramics as veneering material for zirconia cores and to adjust framework designs. Individual processing procedures are responsible for structural flaws.

***Keywords*—**CAD/CAM, framework design, molar crowns, overpressing ceramics.

I. Introduction

STUDIES on all-ceramic crowns over the last two decades are focused on different processing methods, improving the properties of the materials, and analyzing clinical failures. In practice all-ceramic crowns are fabricated as monolithic full anatomic restorations or into layer structures with a veneer porcelain on a zirconia core [1]. Current ceramic materials are considered sufficiently strong to produce reliable all-ceramic restorations. CAD/CAM (computer aided design/computer aided manufacturing) processing or zirconia frameworks and overpressing of the veneer are modern methods available to achieve all-ceramic bilayered crowns. The lower intrinsic strength of veneering porcelain may still determine the longevity in spite of a strong substrate, as the flexural resistance of a bilayered structure is dependent upon the veneering external layer of the structure. Delamination and chipping of veneering porcelain from the underlying ceramic substrates have been reported for bilayered all-ceramic restorations [2-7]. However, from a fracture mechanic perspective of material failure, flaw size is a critical structural variable that determines the strength [2]. As a consequence the conventional layering process with veneering materials is more technically sensitive. The variability due to the individual veneering procedures could cause structural flaws. There are various types of structural flaws which may be located at the surface, in the bulk of the material, or at the veneer–core interface, and lead to stress concentration as well as act as fracture initiation sites [2, 3].

Veneered structures have inferior lifetime characteristics relative to monoliths, partly because the weak porcelain is more susceptible to surface cracking and partly because the cracks have a smaller thickness to traverse to an interface. An important requirement in design is to maintain the lifetime trendlines above the range of natural bite forces, with maxima estimated variously between 100 N and 600 N [8].

Fracture (chipping) of the veneer has been reported as the major clinical reason for technical complications of zirconia-supported restorations in the posterior region [9, 10]. While combined fracture of the veneer and core is rare, efforts to reduce chipping represent a chief concern in the use of zirconia restorations [11].

Besides materials strength, other factors affect restorations' clinical longevity, such as prosthesis design. However, the effects of changes in design have not been thoroughly evaluated [11, 12].

II. Aim

The aim of the study is to display alternative modern technologies for the fabrication of all-ceramic crowns with various zirconia frameworks.

III. Materials and methods

An upper first molar was prepared for all-ceramic crown restoration, with a rounded 1 mm deep chamfer finish line, a convergence angle of the axial walls of 6 degree, an axial reduction of 1.5 mm and an occlusal reduction of 1.5-2 mm. The bilayered crowns were fabricated with a zirconia core of 0.5 mm thickness, respectively with an anatomical framework, using the cut-back design. The framework was obtained by CAD/CAM technology using Cercon System (Degudent,

This work was supported by a grant of the Romanian National Authority for Scientific Research and Innovation CNCS-UEFISCDI, project number PN-II-RU-TE-2014-4-0476.

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Hanau, Germany). The master die, the antagonist stone cast, and bite-registration were scanned using the Cercon Eye scanner. Scanned data were computed and then the framework for all-ceramic crowns was designed using the Cercon Art 3.2 software (Fig. 1, 2).

Fig. 1. CAD of the crown framework with uniform thickness of 0.5 mm.

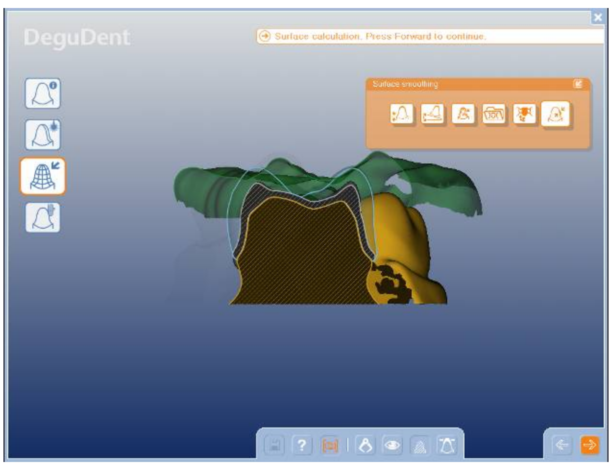

Fig. 2. CAD of the crown framework with cutback design.

Specific steps have been completed for each type of framework modeling. Cercon Art easily allows obtaining these frameworks for lateral aesthetic single crowns due to the continuous improvements of the software. Thus the control over all parameters of designs both the framework and the future veneer can be achieved.

Presintered zirconia blocks were milled with Cercon brain and after that sintered at 1350°C (Fig. 3). After sandblasting with 110-125 µm aluminum oxide, at 3,5 bar, veneering steps have been succeeded.

The veneer was achieved to occupy the space between the framework and the external surface of the unprepared tooth, with a nonuniform thickness in the first case and with a thickness of 1 mm in the second case.

The veneers of the bilayered crowns were obtained by hot pressing of Vita PM9 ceramics (Vita Zahnfabrik, Bad Säckingen, Germany) (Fig. 4, 5). All the crowns were glazed and fired in the furnace Multimat 2 Touch and Press (Degudent, Hanau, Germany).

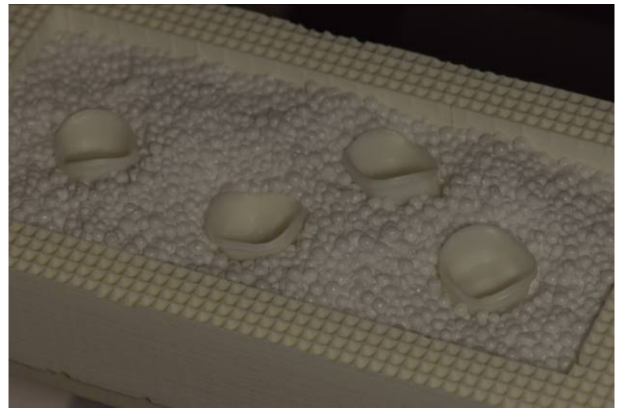

Fig. 3. Frameworks after sintering.

Fig. 4. Wax patterns prepared for investing.

Fig. 5. Zirconia frameworks and bilayered all-ceramic finished crowns.

IV. Results and Discussions

An innovative modality for the improvement of all-ceramic restorations in the posterior areas might be the possibility to use glass ceramics only as veneering material for zirconia cores (Fig. 3). All these involve modern technologies and proper endowment.

Displaying differences in various designs for veneered zirconia frameworks with glass ceramic crowns for posterior areas was the main objective of the studies.

The individual processing procedures could cause structural flaws. The structural flaws may be located in the framework, at the veneer–core interface, at the surface, in the bulk of the veneering material, and lead to stress concentration as well as act as fracture initiation sites. Some of them are obvious, other are macroscopic visible, other are overlooked, but may create problems in time. Some of the flaws occurred during the technological stages are reflected in the Fig. 6-8, like cleavage of a veneer fragment, cracks in the framework, cracks in the veneer.

Fig. 6. Cleavage of a veneer fragment and cracks in the veneer thickness.

Fig. 7. Cracks in the framework.

Fig. 8. Cracks in the veneer.

Literature concerning the clinical performance of all-ceramic systems is inconclusive regarding the relative performance of different materials and physical configurations.

Anatomical shaped crown specimens with simpler geometries were used in strength determination of layered dental ceramics [13]. Although anatomical specimens have their main advantages as being in similar geometry to that of real prosthesis, the major drawbacks are the difficulty to prepare specimens with reproducible dimensions, difficulty in comparing data, and the need of finite element analyses. Laboratory tests such as finite element analysis may help to predict the behaviour of different restorations during biomechanical simulation [14-17]. Also, the comparison of observations between these studies is complicated by differences in tooth preparation, core or framework design, material thickness at the areas of high tensile stress, and veneer/core ratio [18-23].

V. Conclusions

Given to the brittleness of ceramics, different failures may occur in the framework or veneer. Ceramics with most desirable aesthetics has the lowest resistance to crack propagation. Tougher ceramics, like zirconia is not so aesthetic. Glass ceramics occupy a middle ground. An innovative modality for the improvement of all-ceramic restorations in the posterior areas might be the possibility to use glass ceramics as veneering material for zirconia cores and to adjust framework designs. Individual processing procedures are responsible for structural flaws.

Acknowledgment

This work was supported by a grant of the Romanian National Authority for Scientific Research and Innovation CNCS-UEFISCDI, project number PN-II-RU-TE-2014-4-0476.

References

[1] D. Zhang, C. Lu, X. Zhang, S. Mao, D. Arola, "Contact fracture of full-ceramic crowns subjected to occlusal loads", *J Biomech*. 2008 Oct 20;41(14):2995-3001.

[2] K. Zhao, Y. Pan, P.C. Guess, X.P. Zhang, M.V. Swain, "Influence of veneer application on fracture behavior of lithium-disilicate-based ceramic crowns", *Dent Mater*. 2012;28(6):653-6.

[3] P.V. von Steyern, P. Carlson, K. Nilner, "All-ceramic fixed partial dentures designed according to the DC-Zirkon technique: a 2-year clinical study", *J Oral Rehabil* 2005;32:180–7.

[4] A.J. Raigrodski, G.J. Chiche, N. Potiket, J.L. Hochstedler, S.E. Mohamed, S. Billiot, et al., "The efficacy of posterior three-unit zirconium-oxide-based ceramic fixed partial dental prostheses: a prospective clinical pilot study". *J Prosthet Dent* 2006;96:237–44.

[5] J. Tinschert, G. Natt, N. Mohrbotter, H. Spiekermann, K.A. Schulze, "Lifetime of alumina- and zirconia ceramics used for crown and bridge restorations", *J Biomed Mater Res B: Appl Biomater* 2007;80:317–21.

[6] I. Sailer, A. Feher, F. Filse, "Prospective clinical study of zirconia posterior fixed partial dentures: 3-year follow up", *Quintessence Int* 2006;37:685–93.

[7] I. Sailer, J. Gottnerb, S. Kanelb, C.H. Hammerl, "Randomized controlled clinical trial of zirconia–ceramic and metal–ceramic posterior fixed dental prostheses: a 3-year follow-up". *Int J Prosthodont* 2009;22(6):553–60.

[8] Y. Zhang, I. Sailer, B.R..Lawn, "Fatigue of dental ceramics", *J Dent*. 2013;41(12):1135-47.

[9] I. Sailer, B.E. Pjetursson, M. Zwahlen, C.H. Hammerle, "A systematic review of the survival and complication rates of all-ceramic and metal-ceramic reconstructions after an observation period of at least 3 years. Part II: Fixed dental prostheses". *Clin Oral Implants Res* 2007b 18(Suppl 3):86-96.

[10] A. Della Bona, J.R. Kelly, "The clinical success of all-ceramic restorations". *J Am Dent Assoc* 2008;139(Suppl):8S-13S.

[11] N.R. Silva, E.A. Bonfante, B.T. Rafferty, R.A. Zavanelli., E.D. Rekow, V.P. Thompson, P.G. Coelho, "Modified Y-TZP core design improves all-ceramic crown reliability". *J Dent Res*. 2011 Jan;90(1):104-8.

[12] D. Rekow, V.P. Thompson, "Engineering long term clinical success of advanced ceramic prostheses". *J Mater Sci Mater Med* 2007 18:47-56.

[13] H. Yilmaz, S.K. Nemli, C. Aydin, B.T. Bal, T. Tıraş, "Effect of fatigue on biaxial flexural strength of bilayered porcelain/zirconia (Y-TZP) dental ceramics". *Dent Mater*. 2011 Aug;27(8):786-95.

[14] C. Baudin, J. Gurauskis, A.J. Sanchez-Herencia, V.M Orera, "Indentation damage and residual stress field in alumina-Y2O3-stabilized zirconia composites". *J Am Ceram Soc* 2009;92:152–60.

[15] A.R. Studart, F. Filser, P. Kocher, H. Lüthy, L.J. Gauckler, "Mechanical and fracture behavior of veneer-framework composites for all-ceramic dental bridges". *Dent Mater* 2007;23:115–23.

[16] L. Porojan, F. Topală, C. Savencu, "Influence of the veneering thickness on stresses in all-ceramic crowns". *Applied Mechanics and Materials* 2016, Vol. 835, pp 97-102.

[17] L. Porojan, F. Topală, S. Porojan "Biomechanical behaviour of all-ceramic crowns with variable thicknesses of zirconia frameworks". *Applied Mechanics and Materials* 2016, Vol. 835, pp 91-96.

[18] P.G. Coelho, N.R. Silva, E.A. Bonfante, P.C. Guess, E.D. Rekow, V.P. Thompson, "Fatigue testing of two porcelain–zirconia all-ceramic crown systems". *Dent Mater* 2009;25:1122–7.

[19] A.R. Studart, F. Filser, P. Kocher, L.J. Gauckler, "Fatigue of zirconia under cyclic loading in water and its implications for the design of dental bridges". *Dent Mater* 2007;23:106–14.

[20] P. Kohorst, M.P. Dittmer, L. Borchers, M. Stiesch-Scholz. "Influence of cyclic fatigue in water on the load-bearing capacity of dental bridges made of zirconia". *Acta Biomater* 2008;4:1440–7.

[21] P. Kohorst, T.J. Herzog, L. Borchers, M. Stiesch-Scholz "Load-bearing capacity of all-ceramic posterior four-unit fixed partial dentures with different zirconia frameworks". *Eur J Oral Sci* 2007;115 (2):161–6.

[22] A.R. Studart, F. Filser, P. Kocher, H. Lüthy, L.J. Gauckler "Mechanical and fracture behavior of veneer-framework composites for all-ceramic dental bridges". *Dent Mater* 2007;23:115–23.

[23] M.N. Aboushelib, N. de Jager, C.J. Kleverlaan, A.J. Feilzer "Effect of loading method on the fracture mechanics of two layered all-ceramic restorative systems". *Dent Mater* 2007;23:952–9.