Zirconia Versus Metal: A Preliminary Comparative Analysis of Ceramic Veneer Behavior

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Purpose: Clinical studies have revealed a high rate of fracture for porcelain-veneered zirconia-based restorations that varies between 6% and 15% over a 3- to 5-year period. These are high values compared to the 4% fracture rate shown by conventional metal-ceramic restorations over 10 years. To date, little in vitro research has been carried out on the fracture resistance of the new generation of ceramic crowns. The aims of this study were to develop preliminary research on the mechanical failure behavior of three types of porcelain-veneered crowns with zirconia cores when subjected to static compressive loading and to analyze fracture characteristics using scanning electron microscopy (SEM). ***Materials and Methods:*** Eighty individual full-coverage crowns were studied: 60 crowns with a zirconia core and 20 with a metal core (control). ***Results:*** Values obtained in compressive testing were as follows: ZirPress: 1,818.01 N, ZirCAD: 1,773.92 N, Lava: 2,210.95 N, and metal-ceramic (control): 2,310.49 N. SEM analysis revealed that 71.66% of zirconia-based restoration mechanical failures were cohesive, while 100% of mechanical failures for metal-ceramic restorations were adhesive. ***Conclusions:*** The mechanical behavior of the porcelain veneering on a zirconia core is more fragile than that on metal-ceramic crowns, and when load forces exerted on these restorations lead to mechanical failure, this will occur in the interior of the porcelain veneering. *Int J Prosthodont 2012;25:294–300.*

Treatment outcomes are subject to increasing social and cultural expectations resulting from the ongoing development of dental technologies. Restorative dentistry can no longer satisfy expectations by fulfilling functional objectives; it must also achieve optimum esthetics. This forces dental practitioners to provide treatments that also consider the canon of beauty, which is why clinicians have welcomed the introduction of a new generation of materials that help to meet this difficult objective.

Hegel defines beauty as the result of the imagination and feelings, and therefore not as an exact science.[1] Generally speaking, the relationship between esthetics and dentistry is complicated, given that esthetics refers to the study and perception of beauty.

Dental porcelain has undergone major advances in recent times. New-generation porcelains (high-resistance feldspathic porcelain and ceramic oxides) offer improved esthetics previously unobtainable with conventional metal-ceramic restorations, although the strength of the latter is greater. This is a problem that presents itself on a daily basis in dental practice: whether to opt for good esthetic results by sacrificing maximum resistance or to opt for resistance while compromising esthetics.

The most frequent complication associated with zirconia-based restorations is the fracture of the veneering porcelain.[2] Clinical studies have revealed a high fracture rate that fluctuates between 6% and 15% over a 3- to 5-year period.[3,4] These are high values compared to the 4% fracture rate shown by conventional metal-ceramic restorations over 10 years.[5–7] To date, little in vitro research has been carried out on the fracture resistance and mechanical failure rate of the veneering ceramic.

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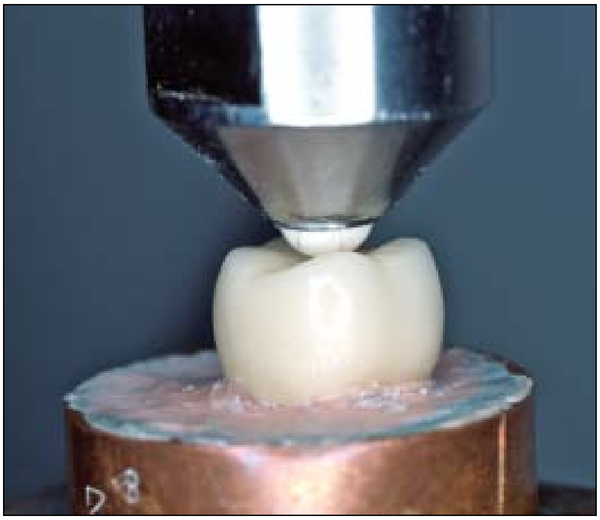


Fig 1 Load applicator establishing three-point contact with the internal slopes of the vestibular and palatine cusps of the crown.

The objectives of this study were to carry out compressive testing to the point of fracture of porcelain-veneered zirconia restorations and to study the mechanical failure and surface changes produced using scanning electron microscopy (SEM).

Materials and Methods

Restorations used in this study were designed on the basis of a fabricated master cast, which took the form of a maxillary first molar shaped in the conventional manner to obtain a full-coverage fixed crown. Eighty impressions were taken from the master cast using addition silicone (polyvinyl siloxane) of heavy consistency and silicone fluid (Putty and Light Elite HD, Zhermack) using the double-mix technique. Each impression was then cast in epoxy resin (Exakto-Form, Bredent). After a 45-minute polymerization, the epoxy resin specimen was removed from the mold and mounted in a 2.2-cm-diameter copper cylinder, setting the specimen in type IV dental plaster (Vel-Mix Classic Die Stone, Kerr).

Eighty crowns were fabricated and divided into four groups: group 1 = 20 Ivoclar IPS e.max ZirCAD crowns (core: IPS e.max ZirCAD, Ivoclar Vivadent; porcelain veneer: IPS e.max Ceram, Ivoclar Vivadent), group 2 = 20 Ivoclar IPS e.max ZirPress crowns (core: IPS e.max ZirCAD; porcelain veneer: IPS e.max ZirPress, Ivoclar Vivadent), group 3 = 20 Lava crowns (core: Lava Frame Zirconia, 3M ESPE; porcelain veneer: Lava Ceram, 3M ESPE), and group 4 (control) = 20 metal-ceramic crowns with porcelain stratification layering (core: Rexillium V nickel-chromium alloy, Pentron Laboratory Technologies; porcelain veneer: IPS d.SIGN ceramic, Ivoclar Vivadent).

Characteristics of Ceramic Veneer Morphology Design

The occlusal anatomy of each crown was designed using the wax-up technique so that the load applicator of the Instron machine used for the compression tests (a 4-mm aluminum ball) made contact in the fossa of the restoration with three-point contact on the internal slopes of the vestibular cusps and palatine cusp. To do this, a reproduction of the active part (antagonist) of the load applicator was fabricated by taking an impression using addition silicone (Elite HD), which was then cast in acrylic resin (Trim II, Bosworth).

Bonding Crowns to the Casts

Once fabricated, the crowns were bonded using a dual-polymerization composite resin cement. A 1-kg force was applied for 5 minutes to ensure correct distribution of the bond material and to seat the crowns properly.

Compression Testing

The compression test was carried out using an Instron 4202 testing machine (Instron) (Fig 1). The load applicator descended onto the sample exercising continuous vertical force with a crosshead speed of 0.5 mm/s, moving vertically downward perpendicular to the occlusal zone. The load force applicator's aluminum ball established three-point contact with the internal slopes of the crown's vestibular cusps and palatine cusp. The machine was stopped once the layering ceramic had fractured, and the force that had provoked the fracture was measured in Newtons.

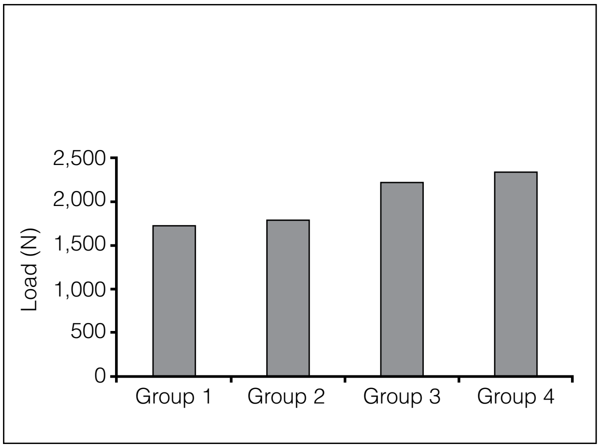


Fig 2 Results of the porcelain veneer compression test for each group.

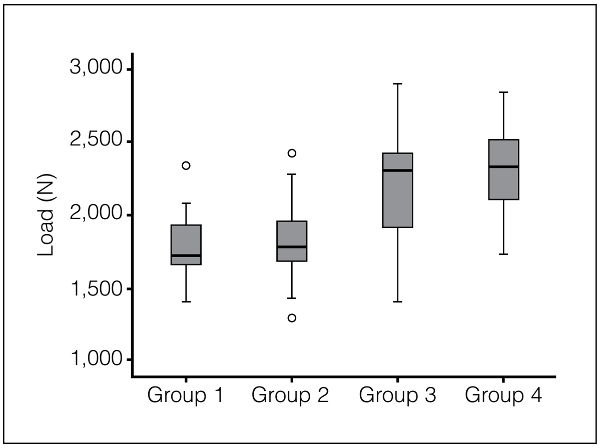


Fig 3 Box plot values obtained from the porcelain veneer compression test.

Image Processing of Test Samples

Samples in all groups were examined using SEM to identify the type of fracture, which was classified as either cohesive (fracture situated within the internal structure of the porcelain veneering [chipping]), adhesive (at the porcelain veneer–zirconia interface), or complete (complete fracture of the crown). Complete fractures were excluded from the study. Samples were examined on the external surface as well as within the fracture to examine its internal structure.

Sample dimensions were conditioned to analyze their external surfaces. The copper cylinder that held the stump of each sample was sectioned to leave a ring with a depth of 4 mm using an Accutom-5 machine (Struers) at 3,000 rpm and progression of 0.25 mm/min, with refrigeration by low-velocity water to avoid damaging samples with a 50 A15 Struers diamond cutting disk.

To analyze the internal structures of the fractures, samples were embedded in slow-setting epoxy resin (Epofix Kit, Electron Microscopy Sciences) in a small polypropylene mold. Samples were cut transversally using a precision cutter of 0.3-mm-diameter diamond wire at low velocity. The surfaces were then roughened and polished with a series of disks of different granulometry (reducing granulometry in stages to 0.05 μm) to obtain a uniform flat section of the area to be examined. Polishing was carried out with a Struers LaboPol-21 machine. Each sample was then placed in a metallic support designed for electron microscopic image capturing equipped with a microprobe for energy-dispersive x-ray (EDX) emission analysis (Jeol JSM 6300, Oxford Instruments).

Statistical Analysis

Descriptive and bivariant analysis contrasts were made by means of parametric statistical methods (Student *t* test and Mann-Whitney nonparametric test). The significance level established for bivariate analysis was 5% ($P = .05$).

Results

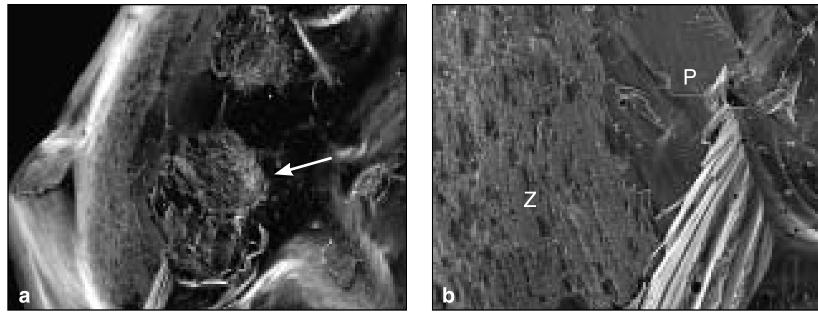
The results were divided into two groups: *(1)* compressive test results and the statistical analysis of them and *(2)* SEM examination.

Compression Test Results and Statistical Analysis

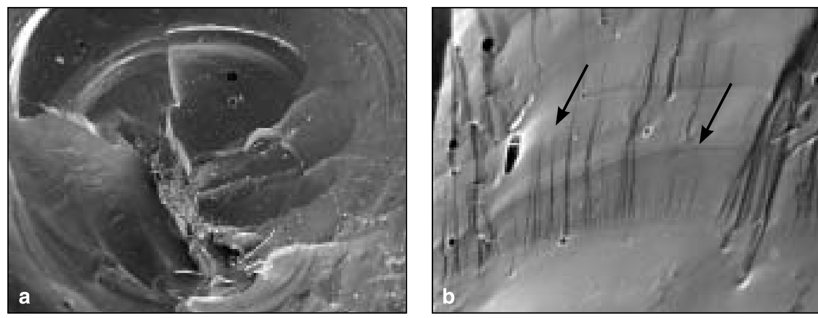
In the porcelain veneer compression test, group 4, the control group, achieved the highest values (2,310.49 N), closely followed by group 3 (2,210.95 N). Groups 2 (1,818.01 N) and 1 (1,773.92 N) came in third and fourth place, respectively (Fig 2).

When values were displayed as a box plot, the similarity between groups 3 and 4 (control) was clearly visible (boxes of similar height) compared to the lower values obtained in groups 1 and 2 (Fig 3).

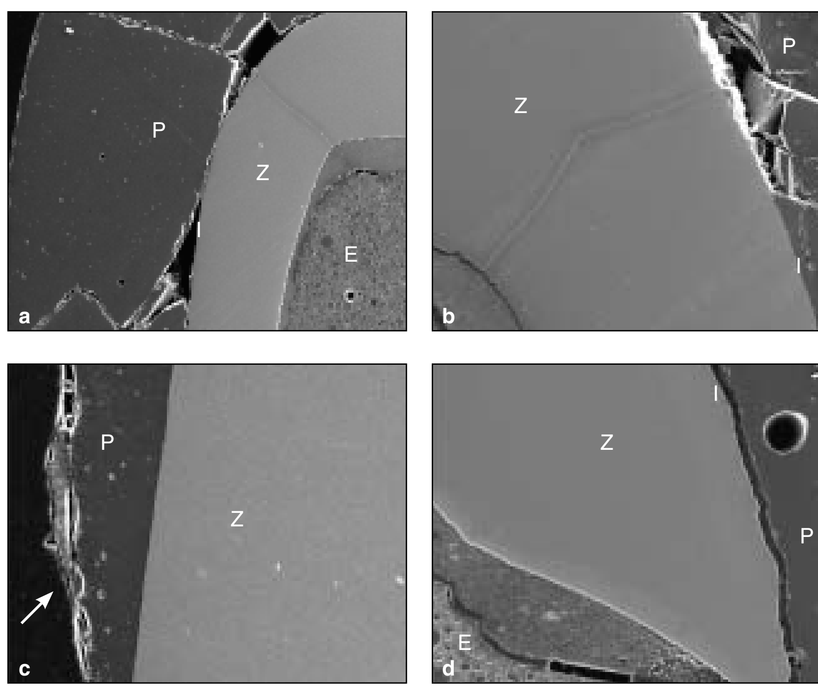
The different groups were compared to the control group by applying Mann-Whitney nonparametric tests (group 1 vs group 4: $P = .000$; group 2 vs group 4: $P = .000$; group 3 vs group 4: $P = .565$), taking a significance level of 5% ($P = .05$). When the resistance of different porcelains was compared, there were statistically significant differences between group 3 and groups 1 and 2 (group 3 vs group 2: $P = .002$;



Figs 4a and 4b Fracture zone surface images for Lava crowns (group 3). **(a)** Contact zone showing the fracture's radial pattern *(arrow)* (original magnification ×25). **(b)** Adhesive fracture exposing the zirconia core (original magnification ×100). Z = zirconia; P = porcelain veneering.



Figs 5a and 5b Surface images for ZirCAD crowns (group 1). **(a)** Cohesive fracture zone with characteristic radial pattern (original magnification ×50). **(b)** Porcelain veneering showing fracture lines *(arrows)* and porosities (original magnification ×500).



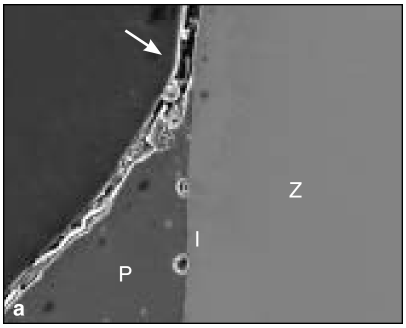
Figs 6a to 6d Transverse sections of ZirCAD crowns (group 1). **(a)** Adhesive fracture at the porcelain-core interface (original magnification ×50). **(b)** Deconstruction of the zirconia-porcelain union affecting the zirconia core (original magnification ×250). **(c)** Cohesive failure of the porcelain veneer *(arrow)* (original magnification ×100). **(d)** Adhesive fracture showing failure of the porcelain-zirconia union with separation of the two structures (original magnification ×150). P = porcelain veneering; I = porcelain-zirconia interface; Z = zirconia; E = epoxy resin.

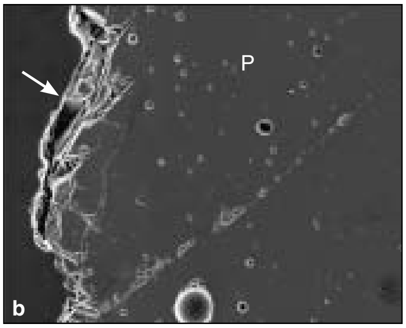
group 3 vs group 1: P = .001; group 2 vs group 1: P = .553), which showed that groups 1 and 2 were statistically less resistant than groups 3 and 4 (control).

SEM

External Surface of Fracture. In all crowns studied, fractures followed a radial or peripheral pattern. Deformation of the veneer material was produced in the occlusal zone, with fractures occurring at and around the point of occlusal contact (Figs 4 and 5).

Restoration Cross Section/Internal Structure. The interface between the zirconia and porcelain is mainly a result of micromechanical retention. The zirconia surface area presents microscopic convexities and concavities that facilitate interlocking with the veneering porcelain. No type of chemical bond was found.





Figs 7a and 7b Transverse zone of Zir-Press crowns (group 2). **(a)** Adhesive fracture of the porcelain veneering *(arrow)* (original magnification ×100). **(b)** Cohesive fracture showing great porosity of the porcelain veneer *(arrow)* (original magnification ×300). P = porcelain veneering; I = porcelain=zirconia interface; Z = zirconia.

Analysis of Cross Section Showing Internal Fracture. Of the 80 crowns studied, 43.75% underwent adhesive fracture, 53.75% cohesive fracture, and 2.5% complete crown fracture. In group 1, 65% of crowns underwent cohesive fracture, 25% adhesive fracture, and 10% complete crown fracture (Figs 6a to 6d). In group 2, 80% of crowns underwent cohesive fracture while 20% suffered adhesive fracture (Figs 7a and 7b). In group 3, 70% of crowns underwent cohesive fracture while 30% suffered adhesive fracture. In group 4, all fractures were adhesive, exposing the metal core.

Relating fracture type to static load value for all groups, it was noted that adhesive fractures occurred in response to higher load values than cohesive fractures (2,125.3 ± 381.4 N).

Statistical analysis (Student *t* test, $P < .05$) showed that mechanical failure through adhesive fracture occurred as a result of higher load values than mechanical failure through cohesive fracture.

Zirconia-based porcelain veneering (groups 1, 2, and 3) showed a higher incidence of cohesive fracture (71.66%) in comparison to metal-ceramic crowns (0%). This result demonstrates that differences in porcelain veneering behavior are dependent on the core material the vener covers. Satisfactory mechanical behavior was found to be nonexistent for the porcelain-zirconia complex, and the static loads exerted provoked mechanical failure within the veneering material. Microscopy examination revealed a lack of chemical union between the porcelain veneer and zirconia core.

Discussion

To date, little in vitro research has been carried out regarding the strength of porcelain veneered on zirconia-based ceramic restorations. Even among the scant research that does exist, there are few references to zirconia core restorations compared to studies of the mechanical resistance of metal-ceramic crowns.

The choice of compressive test type and its specific design were based on CRA recommendations for compressive testing for the study of the resistance of ceramic materials.[8] These have been substantiated by numerous authors[9–12]; compressive testing would therefore appear to be an adequate method for evaluating resistance to fracture of crowns or fixed partial dentures.[13] Furthermore, the crosshead speed (0.5 mm/min) and static compressive load (5 KN) were established in light of a literature review dealing with these variables.[11,14,15]

Despite the many disadvantages of in vitro studies, it is important to evaluate isolated mechanical properties under standardized conditions and limited influencing parameters.[13] Although compressive testing does not reproduce conditions in the oral environment as faithfully as in vitro cyclic studies, the results of this type of test provide valid information, which can then be extrapolated in clinical practice.

Zahran et al[10] used the same type of morphology design in their research study of resistance to fracture of surface porcelain, comparing 20 single-piece Vita Mark II (VITA Zahnfabrik) feldspathic crowns and 20 crowns with a zirconia core. Moreover, Bindl et al[12] studied resistance to fracture of different crowns of the same size and shape as those included in the present study.

An important factor for the fabrication of zirconia crowns is the anatomy of the internal zirconia jacket. For the design purposes of this study, the authors referred to earlier work to ensure that the porcelain veneer was of even thickness.[9] It is important to avoid the occurrence of areas with too little or too great a veneer thickness, which might reduce the restoration's resistance and bring about unwanted but all-too-frequent porcelain delamination.[9,16–22]

Pospiech studied four different groups of Ivoclar ceramic crowns and showed that the load required to fracture the porcelain coating of the IPS e.max ZirCAD crown was significantly greater than that needed to fracture the other restorations, which showed mean values of 1,750 N.[23] This result was similar to that found in the present study.

Chapman and Bulot[24] compared fracture resistance of three types of porcelain veneering on ceramic crowns: Procera AllCeram (Nobel Biocare), Procera AllZirkon (Nobel Biocare), and Lava Zirconia (3M ESPE). Lava Zirconia showed statistically greater resistance than the other crowns.[24] In this study, the Lava group also achieved the best results. Brukl and Ocampo[25] studied resistance to fracture of porcelain veneering on metal-ceramic crowns subjected to static loading and obtained mean fracture values that were similar to those of the present study (1,895 ± 317 N).

Fischer et al[26] studied zirconia-porcelain interfaces on zirconia crowns subjected to static loading to the point of fracture of the surface porcelain, carrying out an SEM analysis of elemental composition and distribution. To date, no scientific evidence for a chemical bond between zirconia and the veneering ceramic has been found. The two materials appear to bond as a result of mechanical interlocking and through the formation of compressive strength resulting from thermal contraction during cooling following sinterization.[27] In accordance with the authors' findings, Fischer et al showed that in zirconia restorations, the most frequent type of fracture occurs within the porcelain veneer rather than at the porcelain–zirconia core interface.[26]

From the present in vitro study, it may be confirmed that porcelain veneers with the same characteristics behave in response to static loading differently depending on the type of core they cover. Zirconia restorations fracture at lower static load values, and these fractures occur more frequently in the interior of the porcelain veneer. Porcelain veneer over a metal-ceramic core resisted higher static loading, and fracture always occurred at the metal core–porcelain interface.

These results can be extrapolated to clinical practice given that, according to the literature, zirconia restorations fracture with greater frequency than metal-ceramic ones, with the main failure type being cohesive (chipping).[26]

Conclusions

Veneering ceramics covering zirconia core restorations fracture at lower load values than metal-ceramic restorations. Groups 1 and 2 (1,773.92 N and 1,818.01 N, respectively) were found to be significantly less resistant than groups 3 (2,210.95 N) and 4 (2,335.17 N), with a P value of .05. No statistically significant differences were found between groups 3 and 4. All samples studied resisted compressive forces far greater than those exerted during normal mastication, as established by ISO 6872. SEM examination showed that 71.66% of porcelain veneered to zirconia restoration fractures were cohesive (chipping).

In the treatment of patients with malocclusions or parafunctions and in cases not requiring high esthetic standards, conventional metal-ceramic restorations are to be recommended for their better mechanical behavior. For patients with normal or favorable occlusion, any of the zirconia-based restorations studied are to be recommended; the Lava system achieved the best results.

The results of this preliminary study must be interpreted with caution since it is difficult to extrapolate in vivo clinical results from the static loading test alone. Further fatigue fracture testing in a wet environment needs to be carried out. To confirm the results of this study, other clinical investigations are needed.

Acknowledgments

The authors would like to thank Juan Badal, Luis Casado, and Justo Rubio for their technical support throughout the development of this study. They also thank 3M ESPE and Ivoclar Vivadent for their help.

References

1. Hegel GF. Phänomendogie des Geistes. Würzburg: Erster Theil, 1807.
2. Roediger M, Gersdorff N, Huels A, Rinke S. Prospective evaluation of zirconia posterior fixed partial dentures: Four-year clinical results. Int J Prosthodont 2010;23:141–148.
3. Koutayas S, Vagkopoulou T, Pelekanos S, Koidis P, Strub JR. Zirconia in dentistry: Part 2. Evidence-base clinical breakthrough. Eur J Esthet Dent 2009;4:348–380.
4. Sailer I, Fehér A, Filser F, Gauckler LJ, Lüthy H, Hämmerle CH. Five-year clinical results of zirconia frameworks for posterior fixed partial dentures. Int J Prosthodont 2007;20:383–388.
5. Walton TR. An up to 15-year longitudinal study of 515 metal-ceramic FPDs: Part 2. Modes of failure and influence of various clinical characteristics. Int J Prosthodont 2003;16:177–182.
6. Anderson RJ, Janes GR, Sabella LR, Morris HF. Comparison of the performance on prosthodontic criteria of several alternative alloys used for fixed crown and partial denture restoration: Department of Veterans Affairs Cooperative Studies project 147. J Prosthet Dent 1993;69:1–8.
7. Creugers NH, Käyser AF, van't Hof MA. A meta-analysis of durability data on conventional fixed bridges. Community Dent Oral Epidemiol 1994;22:448–452.
8. Desensitizer use with restorative procedures. NW: Evaluators Report and Clinical Tips. CRA Newletter 2002;26(8):1.
9. Mori K. Influence of the design of zirconia framework on the fracture strength of veneering porcelain [in Japanese]. Kokubyo Gakkai Zasshi 2010;77:67–70.

10. Zahran M, El-Mowafy O, Tam L, Watson PA, Finer Y. Fracture strength and fatigue resistance of all-ceramic molar crowns manufactured with CAD/CAM technology. J Prosthodont 2008; 17:370–377.
11. Snyder MD, Hogg KD. Load-to-fracture value of different all-ceramic crown Systems. J Contemp Dent Pract 2005;6 (4):54–63.
12. Bindl A, Lüthy H, Mörmann WH. Thin-wall ceramic CAD/CAM crown copings: Strength and fracture pattern. J Oral Rehabil 2006;33:520–528.
13. Blatz MB, Bergler M, Ozer F, Holst S, Phark JH, Chiche GJ. Bond strength of different veneering ceramics to zirconia and their susceptibility to thermocycling. Am J Dent 2010;23:213–216.
14. Román-Rodríguez JL, Roig-Vanaclocha A, Fons-Font A, et al. In vitro experimental study of bonding between aluminium oxide ceramics and resin cements. Med Oral Patol Oral Cir Bucal 2010;15:e95–e100.
15. AL-Makramani B, Razak AA, Abu-Hassan MI. Comparison of the load at fracture of Turkom-Cera to Procera AllCeram and In-Ceram all-ceramic restorations. J Prosthodont 2009;18:484–488.
16. Kim B, Zhang Y, Pines M, Thompson VP. Fracture of porcelain-veneered structures in fatigue. J Dent Res 2007;86:142–146.
17. Edelhoff D, Sorensen J. Light transmision through all-ceramic framework and cement combinations. J Dent Res 2002;81 (Spec Iss A):1779.
18. Hofstede TM, Ercoli C, Graser GN, Tallents RH, Moss ME, Zero DT. Influence of metal surface finishing on porcelain porosity and beam failure loads at the metal-ceramic interface. J Prosthet Dent 2000;84:309–317.
19. Luthardt RG, Holzhüter MS, Rudolph H, Herold V, Walter MH. CAD/CAM-machining effects on Y-TZP zirconia. Dent Mater 2004;20:655–662.
20. Granell-Ruiz M, Fons-Font A, Labaig-Rueda C, Martínez-González A, Román-Rodríguez JL, Solá-Ruiz MF. A clinical longitudinal study 323 porcelain laminate veneers. Period of study from 3 to 11 years. Med Oral Patol Oral Cir Bucal 2010;15:e531–e537.
21. Sundh A, Sjögren G. A comparison of fracture strength of yttrium-oxide- partially-stabilized zirconia ceramic crowns with varying core thicknesses, shapes and veneer ceramics. J Oral Rehabil 2004;31:682–688.
22. Sundh A, Molin M, Sjögren G. Fracture resistance of yttrium oxide partially-stabilized zirconia all-ceramic bridges after veneering and mechanical fatigue testing. Dent Mater 2005; 21:476–482.
23. Pospiech P. All-ceramic crowns: Bonding or cementing? Clin Oral Investig 2002;6:189–197.
24. Chapman JL, Bulot DA. Flexural strength of high strength ceramics after sandblasting. J Dent Res 2005;84(Spec Iss A): 1757.
25. Brukl CE, Ocampo RR. Compressive strengths of a new foil and porcelain-fused-to-metal crowns. J Prosthet Dent 1987; 57:404–410.
26. Fischer J, Grohmann P, Stawarczyk B. Effect of zirconia surface treatments on the shear strength of zirconia/veneering ceramic composites. Dent Mater J 2008;27:448–454.
27. Ban S, Sato H, Suehiro Y, Nakanishi H, Nawa M. Biaxial flexure strength and low temperature degradation of Ce-TZP/Al2O3 nanocomposite and Y-TZP as dental restoratives. J Biomed Mater Res B Appl Biomater 2008;87:492–498.

Literature Abstract

Relationship between bone fragility of the mandibular inferior cortex and tooth loss related to periodontal disease in older people

The authors evaluated the relationship between bone fragility of the mandibular inferior cortex and tooth loss as well as periodontal disease and bone metabolism markers in older adults. One hundred seventy-seven subjects aged 77 years of age who did not take medication for bone disorders and did not have bone fractures were included in this study. The mandibular inferior cortex classification (MICC) was used to evaluate the condition of the mandibular inferior cortex from dental panoramic radiographs (C1 = normal, C2 = mild/moderate erosion, C3 = severe erosion). The number of remaining teeth, probing pocket depth, clinical attachment level (CAL), and serum osteocalcin level (S-OC, ng/mL) were also evaluated. This study showed that subjects with MICC C1 had more teeth, a lower level of CAL, and a lower level of S-OC than subjects with MICC C2 or C3. A significantly higher percentage of women than men had MICC C2 or C3. The authors suggested that higher S-OC levels, which indicated higher bone turnover, suggested a relationship between the mandibular inferior cortex and general bone metabolism. Estrogen deficiency and osteopenia/osteoporosis might also influence the progression of oral bone loss following menopause in women. There appeared to be a relationship between the fragility of the mandibular inferior cortex and tooth loss related to periodontal disease. However, longitudinal studies are needed to provide better evidence for routine clinical use of the MICC.

Yosihara A, Deguchi T, Miyazaki H. *Community Dent Health* 2011;28:165–169. **References:** 25. **Reprints:** Dr A. Yoshihara, Division of Preventive Dentistry, Department of Oral Health Science, Graduate School of Medicine and Dental Sciences, Niigata University, 2-5274 Gakkocho-Dori, Chuo-ku, Niigata 951-8514, Japan. Email: akihiro@dent.niigata-u.ac.jp—*Teo Juin Wei, Singapore*