# Zirconia-Based Crowns Up to 5 Years in Function: A Retrospective Clinical Study and Evaluation of Prosthetic Restorations and Failures

M. Barış Güncü, DDS, PhD<sup>a</sup>/Umut Cakan, DDS, PhD<sup>b</sup>/ Mehmet Muhtarogullari DDS, PhD<sup>c</sup>/Senay Canay, DDS, PhD<sup>d</sup>

> Purpose: The purpose of this retrospective study was to evaluate the 5-year clinical performance and failure rate of single- or multiple-unit zirconia-based crowns. Materials and Methods: A total of 148 patients (39 men and 109 women, mean age: 46.9  $\pm$ 10.6 years) treated in university and private practices with 618 single- or multiple-unit zirconia-based (Lava) crowns made on natural teeth from January 2007 to December 2008 were included. Two hundred fifty-nine anterior and 359 posterior crowns were examined. A core and/or veneer fracture that required replacement of the restoration was considered to be a failure. The cumulative survival rate (CSR) was described with Kaplan-Meier survival functions. The crowns replaced for other reasons were deemed lost to follow-up, and esthetic, functional, and biologic complications were rated. Results: At the 5-year follow-up, no zirconia core fractures were observed. Twelve veneer fractures that required crown replacement were detected. The CSR was 98.1%. There was a statistically significant difference between survival of the anterior and posterior restorations (P < .001). In total, 116 crowns experienced biologic and technical complications. The most common complications were smooth veneer fracture (4, 0.6%), loss of retention (7, 1%), staining because of smoking (24, 4%), and gingival recession (48, 8%). Conclusions: According to the 5-year CSR (98.1%) observed in this study, zirconia-based single or multiple crowns may be considered an acceptable treatment modality for the replacement of anterior and posterior teeth. Results from the current study should be supported by additional randomized clinical trials. Int J Prosthodont 2015;28:152-157. doi: 10.11607/ijp.4168

Zirconia-based ceramic systems have become an alternative to conventional porcelain-fused-tometal restorations in terms of esthetics, biocompatibility, and structural integrity over the last decade. With the introduction of yttrium oxide  $(Y_2O_3)$ -stabilized tetragonal zirconium dioxide polycrystals (Y-TZP), zirconia-based restorations have a higher flexural strength and fracture toughness value than all other ceramic systems.<sup>1</sup> The addition of  $Y_2O_3$  partially stabilizes the zirconia in a tetragonal crystalline state, which is

<sup>c</sup>Associate Professor, Department of Prosthodontics, Faculty of Dentistry, Hacettepe University, Ankara, Turkey.

responsible for the favorable mechanical properties of Y-TZP materials.<sup>2</sup> Once a crack propagates within the Y-TZP material, the energy supplied by the crack can trigger the tetragon to undergo a monoclinic phase transformation in the surrounding grains. This phase transformation leads to a local compressive stress field that hinders further crack propagation, which is a so-called transformation-toughening mechanism.<sup>3,4</sup> The most recently used processing procedures for Y-TZP with computer-aided design/computer-assisted manufacture (CAD/CAM) technology from a presintered zirconia block provided more predictable anterior and posterior restorations and minimized the complications associated with the framework.<sup>2</sup>

The Lava Zirconia system (3M ESPE) is composed of a Y-TZP ceramic material. The Y-TZP in the Lava system is a polycrystalline material with a small grain size of 0.5  $\mu$ m. The system reportedly has superior flexural strength and fracture toughness values of 1,100 MPa and 5 to 10 MPa·m<sup>1/2</sup>, respectively. A CAM device mills the zirconia core in a prefabricated block. Then, it is sintered for 8 hours at 1,500°C, and feldspathic porcelain is fused to the core according to the manufacturer's recommendations.

<sup>&</sup>lt;sup>a</sup>Assistant Professor, Department of Prosthodontics, Faculty of Dentistry, Hacettepe University, Ankara, Turkey.

<sup>&</sup>lt;sup>b</sup>Assistant Professor, Department of Prosthodontics, Faculty of Dentistry, Istanbul Medipol University, Istanbul, Turkey.

<sup>&</sup>lt;sup>d</sup>Professor, Department of Prosthodontics, Faculty of Dentistry, Hacettepe University, Ankara, Turkey.

**Correspondence to:** Dr M. Barış Güncü, Hacettepe University, Department of Prosthodontics, Faculty of Dentistry, Sihhiye 06100, Ankara, Turkey. Fax: 90 312 310 44 40. Email: barisguncu@hacettepe.edu.tr

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Zirconia has been used in clinical dentistry for over a decade, but there have been a limited number of studies regarding the clinical performance and survival rates of zirconia-based restorations. Previously conducted studies with 2- and 3-year clinical followups presented satisfactory results regarding zirconia-based crowns according to the California Dental Association (CDA) rating criteria.<sup>5-8</sup> Recently, in a 5-year retrospective study, single zirconia crowns in the premolar and molar regions appeared to be an effective clinical solution.<sup>9</sup> Although high survival rates diminish the scarcity of evidence, further investigations with more extensive follow-up periods are necessary. Therefore, the purpose of this retrospective study was to evaluate the 5-year clinical performance of a large number of zirconia crowns that had been placed in patients at private practice and university clinics.

## **Materials and Methods**

### Study Design

This retrospective study on zirconia crowns was conducted by three prosthodontists in collaboration with one dental technician in one dental faculty clinic and two private practice clinics in Turkey. An evaluation of the records of 148 patients who had received single- or multiple-unit zirconia crowns (n = 618) from January 2007 to December 2008 was performed in November 2013 by the authors. Ethical approval for this study was obtained from the Committee on Research Ethics of the University of Hacettepe (GO 14/72-19), and all subjects provided written informed consent. Patient selection was based on the following inclusion criteria: (1) moderate or good oral hygiene and low caries activity; (2) good general health without severe medical or psychologic conditions; (3) no tooth mobility, active bone resorption, furcation involvement, or periapical pathology of the supporting teeth; (4) a residual tooth structure with a restorability index value of  $\leq 2^{10}$ ; and (5) existing crowns requiring replacement. Excessive parafunctional activity was not considered an exclusion criterion.

## Study Procedures and Protocol

Endodontically treated teeth received either prefabricated posts and composite cores or custom-made post-cores as indicated. All tooth preparations were made in a standardized manner with an occlusal/incisal clearance of 1.5 to 2 mm and a circumferential shoulder or chamfer. The axial reduction was 1.5 to 2 mm with an 8- to 10-degree taper. The finish line was located approximately 0.5 mm subgingivally during tooth preparation. Complete arch impressions were made with a polyether impression material (Impregum/Permadyne, 3M ESPE).

Provisional crowns were cemented with a eugenolfree temporary cement (Provicol, Voco). The zirconia crowns were fabricated according to the manufacturer's recommendations, and the zirconia cores were designed using a CAD technique, with an anatomical form and a minimum thickness of 0.5 mm to ensure the veneers were of an appropriate thickness. Feldspathic porcelain (Vita VM 9, Vita Zahnfabrik) was fused to the cores, and the veneering thickness laver was between 1.0 and 2.0 mm. Proximal and occlusal contacts were adjusted as necessary for maximum intercuspation. The same laboratory (Dental Estetik, Ankara, Turkey) manufactured all the crowns, and one company fabricated all the zirconium dioxide cores (Lava, 3M ESPE). A resin-modified glass-ionomer cement (GC Fuji Plus, GC) was used for cementation of 618 crowns. The crowns were provisionally cemented for 2 weeks before definitive cementation. The patients were scheduled for recall appointments after 1 month and 1 year and for annual check-ups thereafter. The patients were asked to contact the clinics if they experienced any problems with their prostheses or abutment teeth.

The following variables were screened and registered on a special form for each patient at annual visits: sex, age at crown delivery, number of crowns cemented, tooth position, vitality, post-core material.

A fractured core or veneering porcelain that required the remake of a crown was considered to be a failure. Chipping of the veneering porcelain, smaller than 1 mm, that could be reshaped and polished was not considered to be a failure. In some cases, for example, tooth extraction due to periodontal problems, the crown was remade, but such cases were recorded as crown replacement without failure.

Clinical findings, including loss of retention and veneer fractures that could be polished, were recorded as prosthodontic complications, whereas color change, staining, loss of vitality, secondary caries, and periodontal problems were recorded as biologic complications.

#### Statistical Analysis

No information was obtained on seven patients (10 crowns) because they did not revisit after crown cementation. The data for the 608 zirconia-based crowns were subjected to statistical analysis. For each tooth, the time to failure and complications were re-corded. Restorations that were replaced but did not fail were considered to be present in the mouth. The survival of the restorations or subsets of restorations



**Fig 1** Kaplan-Meier survivor function of zirconia crowns in men and women. The difference was not statistically significant (P = .82, log-rank test).

| Table 1 | Kaplan-Meier Survival Rates of Zirconia |
|---------|---|
|         | Crowns at 5-Year Follow-up              |

| Tooth           | Units | Failure | Survivor function at<br>5 years (%) |  |  |
|-----------------|-------|---------|-------------------------------------|--|--|
| Maxilla         |       | A STAN  | in the second second                |  |  |
| Central incisor | 75    | 0       | 100.0                               |  |  |
| Lateral incisor | 64    | 0       | 100.0                               |  |  |
| Canine          | 55    | 0       | 100.0                               |  |  |
| First premolar  | 65    | 1       | 98.5                                |  |  |
| Second premolar | 66    | 0       | 100.0                               |  |  |
| First molar     | 60    | 4       | 93.3                                |  |  |
| Second molar    | 28    | 3       | 89.3                                |  |  |
| Mandible        |       |         |                                     |  |  |
| Central incisor | 23    | 1       | 95.7                                |  |  |
| Lateral incisor | 22    | 0       | 100.0                               |  |  |
| Canine          | 20    | 1       | 95.0                                |  |  |
| First premolar  | 27    | 0       | 100.0                               |  |  |
| Second premolar | 38    | 0       | 100.0                               |  |  |
| First molar     | 51    | 0       | 100.0                               |  |  |
| Second molar    | 24    | 2       | 91.7                                |  |  |
| Overall         | 618   | 12      | 98.1                                |  |  |

grouped on the variables of age, sex, and tooth position were displayed using Kaplan-Meier survival curves. The significance of differences between survival curves was determined with the log-rank test.

#### Results

A total of 618 crowns were placed in 148 patients ranging in age from 17 to 72 years, with a mean age of  $46.9 \pm 10.6$  years. Of these 618 crowns, men received 189 (31%) crowns and women received 429 (69%)



**Fig 2** Kaplan-Meier survivor function of zirconia crowns in age groups. The difference was not statistically significant (P = .082, log-rank test).

crowns. The zirconia-based crowns occluded against either the teeth or fixed dental prostheses. Of the 191 endodontically treated teeth, 87 had received a post and core (25 custom-made gold post-core [Degudent U, Degusa], 9 prefabricated titanium posts [Svenska Dentorama], and 53 glass-fiber posts [Cytec Blanco, Hahnenkratt] with composite cores [Filtek Z250 Universal Restorative, 3M ESPE]). No information was obtained on seven patients (10 crowns) because they did not revisit after crown cementation.

There were no core fractures on the 608 zirconiabased crowns. In 12 patients, failure occurred due to non-repairable fracture of veneering porcelain. The cumulative survival rate (CSR) was 98.1% (Table 1). Failure related to sex, age, and tooth position also was computed using Kaplan-Meier survival analysis and significance of differences with the log-rank test. Of the failed 12 crowns, 10 were posterior and 2 were anterior crowns. The difference between posterior and anterior crown failure was statistically significant (P < .001). In terms of sex, the difference between men and women was not statistically significant (P > .05 or P = .82; Fig 1). Also, the difference between age groups was statistically insignificant (P > .05or P = .082; Fig 2).

Twenty-two crowns replaced for other reasons but not because of failure were also recorded, including abutment tooth extraction due to periodontal problem (1, 0.2%), secondary caries (3, 0.5%), pain and hypersensitivity that required endodontic treatment with a new crown fabrication (4, 0.6%), and root fracture (14, 2%).

In fact, of the 574 crowns that were followed up for 5 years, 458 (74%) did not show any complications or

| Table 2 | Number of Prosthetic and Biologic | Complications of | Cemented Zirconia Crowns | (Data Available for 608 Crowns) |
|---------|-----------------------------------|------------------|--------------------------|---------------------------------|
|---------|-----------------------------------|------------------|--------------------------|---------------------------------|

|   | Region                 |                         | Condition           |                            |                     |
|---|------------------------|-------------------------|---------------------|----------------------------|---------------------|
|   | Anterior $(n = 259)^*$ | Posterior<br>(n = 359)* | Vital<br>(n = 427)* | Endo-treated<br>(n = 191)* | Total<br>(n = 618)* |
| Prosthetic complications                          |                        |                         |                     |                            |                     |
| Smooth veneer fracture (reshaped and polished)    | 1                      | 3                       | 4                   | -                          | 4                   |
| Loss of retention (re-cemented)                   |                        | 7                       |                     | 7                          | 7                   |
| Biologic complications                            |                        |                         |                     |                            |                     |
| Staining (smoking)                                | 18                     | 6                       | 14                  | 10                         | 24                  |
| Discoloration around gingival margin (nonvital)   | 7                      | 3                       | -                   | 10                         | 10                  |
| Gingivitis  | 5                      | 12                      | 9                   | 8                          | 17                  |
| Gingival recession                                | 18                     | 30                      | 22                  | 26                         | 48                  |
| Gingival overgrowth (drug induced)                | 3                      |                         | 3                   |                            | 3                   |
| Hypersensitivity and need of endodontic treatment |                        | 3                       | 3                   | -                          | 3                   |

\*Number at baseline.

failure. In total, 116 crowns (19%) showed some type of biologic and technical complications (Table 2). The main recorded complications included gingival recession (48, 8%), staining because of smoking (24, 4%), gingivitis (17, 3%), gray discoloration around the gingival margin of the nonvital tooth (10, 2%), loss of retention (7, 1%), smooth veneer fracture that could be polished (4, 0.6), drug-induced gingival overgrowth (3, 0.5%), and hypersensitivity that required end-odontic treatment without a new crown fabrication (3, 0.5%). Seven crowns that lost retention could be recemented. During the follow-up period, no core material or interdental connector fracture was observed.

## Discussion

In this clinical study, a 5-year follow-up was performed to evaluate the clinical performance of 618 teeth that were supported by zirconia-based crowns. The number of restorations evaluated in this study was larger than that in most of the published short- and longterm follow-up studies.<sup>5,6,8,9,11</sup> During the first-year recall appointments, seven patients were withdrawn from the study because they did not revisit after crown cementation. These patients represented a total of 10 crowns, or 1.6% of the restorations, which was a lower dropout frequency compared to previous studies.8,9 According to the current study results, complications occurred in 116 of the 574 crowns. Although the total incidence of complications was high (19%), it was similar to the complication rates observed in other studies. The most common biologic complications were gingival recession (48; 8%) and gingivitis (17, 3%). However, these data cannot be compared with data from previously published 5-year followup studies because gingival recession or gingivitis was not individually categorized as a complication in those studies. In crowns that were entirely supported by endodontically treated teeth (10, 2%), a gray discoloration around the gingival margin was detected. This result partially contrasted with data reported by Vult von Steyern et al<sup>12</sup> and Çehreli et al,<sup>5</sup> who demonstrated a superior periodontal response in 80% of the crowns involved in their studies that had no clinical sign of a marginal discoloration after 1- and 2-year follow-up periods. On the other hand, regarding the biologic and esthetic complications, those studies had a relatively shorter follow-up period compared to the current study. Although the same finishing and glazing protocols were properly applied during all restoration procedures, nicotine staining was observed on the crowns (24, 4%) of seven patients who smoked cigarettes.

Regarding prosthetic complications, a core material had been previously reported as a frequent complication for all other ceramic systems.<sup>13</sup> Fracture toughness is an inherent material property value that ranges between 5.5 and 7.4 MPa·m<sup>1/2</sup> for zirconia-based core ceramics. Owing to the transformation-toughening mechanism and its contribution to fracture resistance, fracturing of a zirconia core is infrequent.

In the present study, no core material fracture was observed, which was in accordance with the 5-year results of Örtorp et al.<sup>9</sup> This result may be attributed to the high-fracture toughness of the Lava system of up to 10 MPa·m<sup>1/2</sup>, which can be achieved by adhering to the manufacturer's recommendations while designing the coping thickness and connector size. However, this assumption necessitates validation by conducting long-term loading studies with simulated oral conditions.

A fracture of or a chip in the veneering material was considered a major complication in most studies.<sup>14,15</sup> Twelve crowns (1.9%) experienced a veneer fracture at points closer to the interdental connectors, mostly during the second- and third-year follow-up periods.

Ten of the 12 fractured veneers were located on posterior teeth, a finding in line with that of Tartaglia et al.<sup>6</sup> as well as other studies.<sup>14-16</sup> On the contrary, in their review regarding the clinical performance of zirconiabased fixed partial dentures, Triwatana et al<sup>7</sup> reported a veneer fracture rate as high as 25%, remarking that some studies did not include minor chipping in their failure rate.

The bond strength of a zirconia core and veneer ceramic may be affected by the core type and veneering ceramic, core surface finish, application of a liner, method of veneering application, coloring pigments, and thermal incompatibility of the core and veneer materials. In addition, a slow-cooling rate during the sintering of the veneer and liner materials may cause a reduction in the bond strength between the zirconia core and veneer.<sup>17,18</sup> Future research should be conducted to clarify this complex problem and to establish acceptable criteria for a combined coreveneer material. In the current study, minor cohesive veneer fractures were polished, and no further problems were reported; furthermore, seven crowns (1%) lost retention, but each crown could be re-cemented without necessitating replacement. All re-cemented crowns were placed on endodontically treated posterior teeth. The temporary cementation of the crowns for 2 weeks and inadequate removal of the temporary cement from the inner surface prior to definitive cementation might have affected the retention of the zirconia-based crowns. Beuer et al<sup>15</sup> and Schmitt et al<sup>19</sup> also reported the retention loss of zirconia-based restorations that were cemented with a glass ionomer in their 3-year follow-up studies.

In this 5-year follow-up study, an abutment tooth extraction or a crown refabrication was not assumed to be a failure criterion. Replacement of restorations without failure was also recorded and the total rate was 4%, or 22 crowns. The most common reason was root fracture (14, 2%), which had a higher incidence (4 anterior and 10 posterior crowns) in endodontically treated teeth. This can be partly explained by the potential detrimental effect of a post-space preparation on root dentin. Secondary caries and pain were observed in three crowns (0.5%), necessitating endodontic treatment with a new crown fabrication. Hickel et al<sup>20</sup> emphasized that a marginal discoloration might often be misdiagnosed as a sign of secondary caries; therefore, the incidence of secondary caries might have been overstated in some clinical studies. Major adhesive veneer fractures occurred in six crowns (1%) fabricated on endodontically treated molars, and these patients had bruxism. These restorations were immediately replaced, and no other mechanical failures occurred. In this study, a greater percentage of failures was observed in endodontically treated teeth than in vital teeth, which could be attributed to the compromised structure of nonvital and dehydrated dentin.

One major limitation of this study was the absence of a control group. However, this study involved both private practice and university clinics that provided data on a large number of crowns and added diversity to the patient profiles.

## Conclusions

Overall, the observed 5-year CSR was 98.1% in this study, which is in agreement with the results of 4- and 5-year follow-up studies in the literature. The status of patient satisfaction was high and the percentage of failures was limited. With regard to the clinical outcome of this study, zirconia-based single or multiple crowns appeared to be an acceptable treatment modality for the replacement of anterior and posterior teeth. The results of this study should be supported by additional randomized clinical trials.

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#### Literature Abstract

## Can the FRAX tool be a useful aid for clinicians in referring women for periodontal care?

The authors looked at the relationship between FRAX (World Health Organization Fracture Risk Assessment Tool) scores and periodontal health and tooth loss in postmenopausal women. A total of 179 participant charts from the Case/Cleveland Clinic Postmenopausal Wellness Collaboration's 853-sample database, which satisfied the inclusion criteria, were selected. These charts were divided into major osteoporotic fracture risk group (FRAX scores  $\geq$  20%) and control group (FRAX scores < 20%), 90 and 89 charts, respectively. Quantitative signs of periodontitis including plaque score (PS), probing depth (PD), bleeding on probing (BOP), and tooth loss were obtained from the charts. Clinical attachment loss (CAL) was calculated. Alveolar bone height (BH) between teeth was recorded from radiographic records. The authors found that there were significant differences between the two groups in PD (mean  $\pm$  SD: 2.75  $\pm$  0.66 versus 2.2  $\pm$  0.57); CAL (3.15  $\pm$  0.78 versus 2.73  $\pm$  0.66); BH (0.58  $\pm$  0.03 versus 0.60  $\pm$  0.02); and tooth loss (5.6  $\pm$  1.96 versus 3.84  $\pm$  1.94). However, PS and BOP did not differ significantly, which supported the opinion that the significant difference in periodontitis severity is related to a difference in susceptibility in the major osteoporotic fracture risk group. The authors concluded that the FRAX tool might be a useful aid for clinicians in referring postmenopausal women for periodontal care. The article used the data collected from participant charts; it was unknown whether the clinicians were calibrated or whether intraoral radio-graphs were taken in a standardized method.

Alli F, Bhandal GK, Thacker HL, Palomo L. Menopause 2015;22:75–78. References: 31. Reprints: Leena Palomo, Periodontics, Case Western Reserve University, Cleveland, Ohio, USA. Email: leena.palomo@case.edu—Huong Nguyen, Ann Arbor, Michigan, USA

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