Clinical Evaluation of 1,132 Zirconia-Based Single Crowns: A Retrospective Cohort Study from the AIOP Clinical Research Group

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Purpose: The aim of this retrospective cohort study was to gather the outcomes of zirconia single crowns made by 16 members of the Italian Academy of Prosthetic Dentistry (AIOP) over a time period of up to 5 years. ***Materials and Methods:*** A total of 398 patients treated in private practices with 1,132 zirconia-based single-crown restorations made on natural teeth from January 2005 to July 2010 were included. Three hundred forty-three anterior restorations (30.3%) and 789 posterior crowns (69.7%) were made with 16 types of zirconia, using primarily chamfer or knife-edge tooth preparation, and examined according to the esthetic, functional, and biologic criteria. To evaluate the relationship of parafunction with mechanical failure, patients with clenching or bruxism were not excluded from the study group. ***Results:*** The cumulative survival rate of all restorations was 98.1%, while the cumulative success rate was 94.3%. Functional criteria had the highest number of failures. The odds ratio (OR) for all restorations was calculated to clarify the relationship between patients who were subject/not subject to parafunctions and technical complications; the OR was 2.60. An association between parafunction and mechanical failure was found in patients with severe parafunction. ***Conclusions:*** Porcelain-veneered zirconia single crowns with chamfer and knife-edge preparations showed good clinical results over a period of up to 5 years. Technical complications were few and were limited primarily to patients with parafunction. *Int J Prosthodont 2013;26:435–442. doi: 10.11607/ijp.3099*

Conventional metal–ceramic crowns were once the most common restorations for severely compromised, heavily repaired teeth and were used for the replacement of unsuitable prosthetic restorations. Moreover, they still represent the gold standard for comparison with newer metal-free materials.[1] However, the metal framework can reduce translucency, tends to cause a graying of the free gingival margin, and may give rise to allergic or even toxic reactions.[2] Increasing esthetic demands have driven the development of many new ceramic materials for their esthetic properties in terms of translucency, biocompatibility, color stability, wear resistance, and low thermal conductivity[3] and for improving the effectiveness of diagnostic radiographs.[4] Densely sintered alumina has been introduced as a favorable material with increased mechanical properties versus feldspathic ceramics for metal-free restorations in the posterior region.[5] Indeed, in the posterior region, the 5-year survival summary estimates of densely sintered alumina crowns (94.9%) and reinforced glass–ceramic crowns (93.7%) were similar to those obtained for metal–ceramic crowns (95.6%). Furthermore, lower survival rates of 90.4% and 84.4% were seen for In-Ceram crowns and glass–ceramic crowns, respectively, when used for posterior teeth.[6]

Rapid improvements in the properties of these intrinsically brittle materials, combined with the use of computer-aided design/computer-assisted

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manufacture (CAD/CAM), has made all-ceramic systems increasingly popular over the past decade. CAD/CAM systems have been continuously developed and upgraded in prosthetic dentistry in association with zirconium oxide and used primarily for the restoration of single crowns and fixed partial dentures (FPDs) in both the anterior and posterior regions. Zirconia seems to satisfy both esthetic and mechanical needs as a core material for all-ceramic restorations.[7] Its mechanical properties are the highest ever reported for any dental ceramic; indeed, this material can exhibit a toughness higher than 6 MPa and strength greater than 1,000 MPa.[8]

Zirconia dioxide in its pure form is a polymorphic material that occurs in three temperature-dependent forms: monoclinic (room temperature to 1,170°C), tetragonal (1,170°C to 2,370°C), and cubic (2,370°C up to the melting point).[9] However, when stabilizing oxides such as ceria or yttria are added to zirconia, the tetragonal phase is retained in a metastable condition at room temperature, enabling a phenomenon called transformation toughening, which increases its crack-propagation resistance. However, mechanical stress can induce phase transformation, leading to metastable tetragonal grains in the monoclinic phase with volume expansion that induces compressive stresses with sequential crack propagation. Another failure mechanism due to this metastability is low-temperature degradation (also referred to as aging) in the presence of water that causes the progressive tetragonal to monoclinic transformation at the surface, triggered by water molecules, with surface modifications such as roughening and microcracking. These phenomena can influence the performance and reliability of zirconia restorations and reduce their lifetime.[10]

Recently, zirconia dioxide has been used in dentistry, but little information on its clinical performance or behavior as a core material in prosthodontic rehabilitation has been reported. A recent systematic review of zirconia restorations and a clinical long-term evaluation of all-ceramic restorations showed that most studies are performed on FPDs.[11,12]

To date, three studies have reported a small number of restorations and short-term results.[13–15] These studies demonstrated good clinical performance of zirconia as a promising prosthodontic alternative in the premolar and molar regions, with a cumulative survival rate that was about 93% after 3 years of clinical service. However, further randomized controlled trials with a larger number of treatments are needed to evaluate the long-term success of zirconia-based restorations. One of the most commonly reported clinical complications was chipping of the veneering porcelain. Causes of this may include insufficient support of the veneering material by the framework design, changes in the ceramic composition versus conventional feldspathic ceramics, excessive occlusal forces, improper clinical steps/handling, mismatch of the linear coefficient of thermal expansion (CTE), unfavorable surface and heat treatments, and thermal conductivity of the yttrium-stabilized tetragonal zirconia polycrystalline (Y-TZP) (12 times lower than aluminum oxide 99%).[16]

The primary aim of this retrospective cohort study was to evaluate the 1- to 5-year clinical outcome of a large number of zirconia-based single crowns, performed in general dental practice, in an attempt to establish major risk factors that may contribute to zirconia failure and potential risk indicators associated with zirconia failures.

Materials and Methods

This retrospective cohort clinical study was conducted in a private dental practices in Italy by 16 general dentists who are active members of the Italian Academy of Prosthetic Dentistry (AIOP), with a high level of experience in prosthodontics, in collaboration with 15 dental technicians with a deep knowledge of ceramic restorations.

The study design was organized and conducted by two academic teachers in the Department of the Oral Science of the University of Bologna, Italy, who were not involved in the patient treatment. A specific database was created (Access, Office 2003, Microsoft) and used a standardized data-collection form to collect all data recorded for all patients. The two researchers who analyzed all data were blinded with regard to information about the clinician and patient during the period of the analyses.

The clinicians recalled all patients who had received zirconia restorations. In total, 398 patients who received one or more single crowns between January 2005 and July 2010 and who responded to follow-up were recruited and examined. Among them, 261 patients were women (65.6%) and 137 were men (34.4%). The mean age was 48.6 years (range, 18 to 84 years) at the time of crown cementation. In total, 1,132 restorations, 343 on anterior teeth (107 patients: 42 men, 65 women) and 789 on posterior teeth (330 patients: 110 men, 220 women), were checked during the last recall. The data collected from patient records are described in Tables 1 and 2.

All patients were treated according to AIOP guidelines. All patients had moderate to good oral hygiene and low to moderate dental caries. All teeth showed an absence of pain and active periodontal or pulpal disease; they had an occlusogingival dimension of at least 3.0 mm from the interdental papilla to the marginal ridge of the abutment teeth and presented at least 1 mm of ferrule effect.

Of 1,132 tooth elements, 282 restorations were luted on vital teeth while 850 abutments were endodontically treated teeth before prosthetic rehabilitation. Information was also collected regarding the occlusion, and the presence of parafunctions, such as clenching or bruxism, was identified. Among all patients, 273 showed no parafunctions in combination with the absence of wear facets, whereas 67, 33, and 25 patients showed light, moderate, and severe parafunctional habits, respectively. All patients with parafunction (light to severe: 125) were used as a subgroup for comparison with the other patients (control group). For more than half of the abutments (700), a knife-edge preparation was used. A chamfer design was chosen in 419 treatments, whereas only 13 teeth were prepared with a shoulder. The knife-edge finishing line for complete all-ceramic crowns with a zirconia substructure was prepared with 1.5 to 2 mm of occlusal clearance and 6 degrees of axial convergence. The chamfer preparation was performed with 1.5 to 2 mm of occlusal reduction, 0.8 to 1 mm of marginal depth, and almost 6 degrees of axial convergence. The shoulder design was performed with the same characteristics as the chamfer but with 1 to 1.2 mm of marginal depth. A gingival displacement procedure was performed, if necessary, by placement of a gingival cord. Polyether or polyvinyl siloxane impression materials in combination with prefabricated or custom-made trays were used to take impressions. Zirconia substructures were fabricated in differing ways, depending on the brand used. In most cases, a gypsum cast of the prepared tooth was scanned with a laser, and the zirconia core was designed using CAD software. All zirconia substructures were designed anatomically after a traditional or digital wax-up to support each side of the ceramic veneer. The minimum thickness of the core was 0.5 mm. A CAM process was set in relation to the digital information received from the CAD software. The zirconia copings were sintered at different temperatures in the range of 1,450°C to 1,500°C. Sixteen different types of soft milling zirconia were used in this study, and because the distribution was different, five groups of restorations were created based on the number made with each brand (Table 3). This grouping was performed to allow statistical analyses of the restorations to analyze brands using a large number of restorations and identify within a group of experienced clinicians the major systems of zirconia used. Thirteen ceramic veneering materials (Table 4) were used with the zirconia cores in different combinations. In total, 495 restorations were made with veneering ceramics and zirconia cores produced by the same company. In the other patients, the choice of ceramic was made independently of the core, but the linear CTE between the two ceramic materials was matched. Particular attention was paid to the analysis of chipping/delamination of the veneering materials while examining the correlation between zirconia and ceramic veneering of the same versus different brands. Fifteen dental laboratories produced the restorations according to the recommendations of each manufacturer, but in all

Table 1 Distribution of Single Crowns

Tooth position	Maxilla	Mandible	Total
Incisor	207	40	247 (21.8%)
Canine	69	27	96 (8.5%)
Premolar	248	126	374 (33.0%)
Molar	239	176	415 (36.7%)
Total	763 (67.4%)	369 (32.6%)	1132 (100%)

Table 2 Data at Delivery: 39 Patients Received an Anterior and Posterior Crown

Relative data	Anterior	Posterior	Total
Vitality of the abutment and kind of restoration			
Yes	115	167	282
No	228	622	850
Antagonist tooth			
Unrestored tooth	198	250	448
Amalgam/composite restoration	4	133	137
All-ceramic or PFM on natural tooth	134	342	476
PFM or gold/resin on the implant	7	64	71
Type of occlusion*			
Incisal and canine guidance	55	177	232
Canine without incisal	14	63	77
Group function	35	79	114
Other	3	11	14
Type of tooth preparation			
Chamfer	153	266	419
Shoulder	7	6	13
Knife-edge	183	517	700
Clenching and bruxism history*			
No	56	236	292
Light	26	51	77
Moderate	13	27	40
Severe	12	16	28
Use of a night guard*			
No	85	286	371
Yes	22	44	66

PFM = porcelain fused to metal.
* In 39 cases the patients received an anterior and a posterior crown and the total was based on the number of the single restorations.

Table 3 No. of Restorations for Each Zirconia Brand

Group (no. of restorations)	No. of restorations (zirconia brand)
Group 1 (1 to 20)	3 Everest ZS (KaVo) 9 Zirconia dioxide Cara (Heraeus) 19 Biotech (Biotech) 19 New Ancorvis zirconia (New Ancorvis) 17 Echo (Sweden & Martina) 14 Kéramo zirconia (Kéramo) 11 e.max ZirCad (Ivoclar Vivadent)
Group 2 (21 to 50)	32 Byoziram (Cyrtina) 31 Zircodent (Orodent) 27 Ceramill ZI (Amann Girrbach) 30 DD Bio Z (Dental Direkt) 21 Diazir (Diadem) 21 Zenostar (Wieland Dental)
Group 3 (51 to 100)	74 ICE (Zirkonzahn)
Group 4 (101 to 500)	180 NobelProcera zirconia (Nobel Biocare)
Group 5 (> 500)	624 Lava (3M ESPE)
Total	1,132

Table 4 Veneering Materials Used in the Study

Veneering material	No. of restorations
Lava Ceram (3M ESPE)	523
Creation (Jensen)	211
Initial zr-FS (GC Europe)	119
Triceram (Dentaurum)	104
Pulse ZR (Ceramay)	11
NobelRondo (Nobel Biocare)	10
CZR press (Noritake)	9
Duceram (DeguDent)	7
Ceramco3 (Dentsply)	9
ICE (Zirkonzahn)	5
Zirox (Wieland)	8
Natural Zir (Tressis)	31
e.max Ceram (Ivoclar Vivadent)	74
Not specified	11
Total	1,132

crowns, the veneering ceramic was anatomically supported by the zirconia core. A total of 792 restorations used different resin cement systems for the definitive cementation. Two glass-ionomer cements were used for 235 zirconia crowns. Moreover, 77 cases were cemented with zinc phosphate cement and 28 zirconia crowns were luted with temporary cement.

Clinical Evaluation

Bitewing or periapical radiographs were used in most cases to check the radiographic quality of the interface tooth/zirconia restoration. Most of the restorations were placed in the posterior area (n = 789, 69.7%). Fewer than one third of the total restorations were in the anterior area (n = 343, 30.3%).

Esthetic, functional, and biologic United States Public Health Services (USPHS) parameters modified by the FDI World Dental Federation study design[17] were collected at the final recall: surface luster, framework fracture, fracture of the ceramic veneering,[18] marginal discrepancy, crown decementation, patient's view, tooth vitality, postoperative hypersensitivity, secondary caries, and periodontal response. Each parameter was ranked in four subclasses, where 1 and 2 indicated excellent and good, respectively, 3 was clinically sufficient or repairable, and 4 was clinically unsatisfactory or not repairable.

In some cases, the same patient reported a score of 4 for two parameters, such as delamination and patient's view. This situation was calculated as a single failure because of the supposition that if the crown were delaminated, the patient would not be satisfied.

Statistical Analysis

The data for the 1,132 zirconia single-crown restorations were subjected to a life table analysis.

Cumulative Survival Rate (CSR). This analysis calculated the internal survival rate for each time interval and the cumulative survival rate for the entire 5-year period. Treatment with zirconia restorations was considered a failure when the abutment tooth was extracted or the zirconia crowns were no longer performing, reaching a score of 4 for esthetic, functional, or biologic parameters. Chipping fractures of the ceramic veneering (grade 1–2) or decementation were not considered failures because these are at least theoretically repairable.

Cumulative Success Rate (SR). This analysis was stricter than the survival rate analysis because all restorations exhibiting chipping (grade 2–3), decementation, or secondary caries of level 3 at the examination were also considered failures. Although the degree of bruxism or clenching was difficult to recognize, the Mantel–Haenszel odds ratios (ORs) related to parafunction of all restorations and of the subgroups of patients with light, moderate, and severe parafunctions were also calculated.

Table 5 Life Table Analysis of 1,132 Zirconia Crowns with Success Rates (SRs) and Cumulative Survival Rates (CSRs)

	Anterior			Posterior			Total		
Interval	n	Failed and CSR (%)	Failed and SR (%)	n	Failed and CSR (%)	Failed and SR (%)	n (%)	Failed and CSR (%)	Failed and SR (%)
1 y	105	0 (100)	0 (100)	283	2 (99.3)	7 (97.5)	388 (34.3)	2 (99.5)	7 (98.2)
2 y	80	0 (100)	0 (100)	192	3 (98.4)	12 (93.7)	272 (24.0)	3 (98.9)	12 (95.6)
3 y	90	2 (97.8)	13 (85.6)	160	6 (96.2)	20 (87.5)	250 (22.1)	8 (96.8)	33 (86.8)
4 y	40	0 (100)	0 (100)	112	8 (92.9)	11 (90.2)	152 (13.4)	8 (94.7)	11 (92.8)
5 y	28	0 (100)	0 (100)	42	0 (100)	2 (95.2)	70 (6.2)	0 (100)	2 (97.1)
Total	343	2 (99.4)	13 (96.2)	789	19 (97.6)	52 (93.4)	1132 (100)	21 (98.1)	65 (94.3)

Results

The CSR of all zirconia restorations at 1 to 5 years was 98.1%, but if chippings and decementations were considered as failures (not repairable), the SR decreased to 94.3%. Table 5 describes the life table analysis of the number of failures by year, tooth position, and the relative CSR and SR. Results and complications with details regarding esthetic functional and biologic USPHS parameters are shown in Table 6. Additional information related to the five groups of zirconia materials is presented in Table 7.

The OR for all restorations was 2.60 with a 95% confidence interval (CI) of 1.60–4.24. This result indicates a moderate association between parafunction and failure. The OR of the group with light parafunctions was 0.93 (95% CI, 0.40–2.16), with no statistically significant difference between this group and the patients without parafunction. The groups with moderate and severe parafunctions showed ORs of 2.62 (95% CI, 1.38–4.98) and 3.29 (95% CI, 1.62–6.72), respectively, both statistically significant. No strong correlation was found between failure and parafunction, although a tendency to increase the probability of functional breakdown as chipping or delamination was detected (Fig 1). No correlation in terms of functional failures between the coupling of zirconia with the same/different brand of veneering ceramics was found. Moreover, no correlation was observed between the type of finishing line (chamfer, shoulder, or knife-edge) and any kind of failure. Only two decementations occurring a few weeks after the definitive luting procedure were recorded during the screening of the clinical records. Both of the crowns had knife-edge finishing lines and were luted with resin cements.

Discussion

In this retrospective cohort study conducted in a general dental practice of zirconia-based single crown restorations, the short/medium-term results are promising although some results could be of limited scientific value due to the modality of inquiry.

The collected data on a large number of the zirconia-based restorations reported a similar survival rate to metal–ceramic restorations over the same period,[6] but more observations and randomized clinical studies are needed to create a sound basis for the final assessment of the zirconia/ceramic restorations.

The cumulative survival rate of 98.1% and the cumulative success rate of 94.3% after 1 to 5 years reported here were slightly lower than in one recent report of the use of a large number of restorations in which the Kaplan–Meier survival rate was 100% if segregated by tooth number, and ranged from 88% to 99% when failures were analyzed by specific tooth position.[19] Both studies had the same approach to the anatomical design of the framework substructure and had the criterion of not excluding patients with parafunctional habits.

Only one fracture of a zirconia core restored with Procera/Creation and luted with zinc phosphate was found at the 3-year follow-up on a posterior endodontically treated tooth. Thirteen delaminations of the veneering ceramic from the zirconia core (1 anterior, 12 posterior) occurred during the follow-up period. Of 11 restorations, only 2 used zirconia and veneering ceramic of the same brand. No correlation was found between delamination and the finishing line of the tooth preparation, vitality of the abutment, antagonist tooth, or type of occlusion. Cohesive fracture of the veneering ceramic and delamination from the zirconia core have been reported to be the primary complications in various in vivo studies of Y-TZP single crowns and FPDs.[14,15] One of the causes of this phenomenon could be insufficient support of the veneering material by the framework design. A simplistic and nonanatomical modeling of the zirconia core may result in inappropriate support of the veneering ceramic.[11] Upgraded software for the design of the

Table 6 Results and Major Complications of Cemented Zirconia Crowns

Properties	Parameters	Anterior	Posterior	Total
Esthetic properties				
Surface luster	1. Surface luster comparable to enamel	305	709	1,014
	2. Slightly dull, not noticeable if covered with a film of saliva	38	78	116
	3. Dull, cannot be masked by saliva film	0	1	1
	4. Rough surface, unacceptable plaque-retentive surface	0	1	1
Functional properties				
Framework fracture	1. No	343	788	1,131
	2. Yes	0	1	1
Fracture of ceramic veneering	1. No	331	739	1,070
	2. Yes, hairline crack/small chipping (grade 1: polishable)	0	3	3
	3. Yes, chipping (grade 2: repairable)	11	35	46
	4. Yes, severe chipping/delamination (grade 3: replacement)	1	12	13
Marginal discrepancy	1. No gap	342	785	1,127
	2. Yes, < 50 μm	0	4	4
	3. Yes, > 50 < 250 μm	0	0	0
	4. Yes, > 250 μm	1	0	1
Crown decementation	1. No	343	787	1,130
	2. Yes (re-luted "repairable")	0	2	2
Patient's view	1. Entirely satisfied	292	661	953
	2. Satisfied	44	104	148
	3. Minor criticism of esthetics, no adverse effect	7	16	23
	4. Completely dissatisfied and/or adverse effect, including pain	0	8	8
Biologic properties				
Postop sensitivity; tooth vitality	1. No hypersensitivity, normal vitality	106	151	257
	2. Yes, low hypersensitivity for a limited period of time, normal vitality	9	14	23
	3. Yes, premature/intense or in response to the stimulus	0	0	0
	4. Yes, very intense, need for endodontic treatment	0	2	2
Secondary caries	1. No primary or secondary caries	343	788	1,131
	2. Yes, very small and localized	0	1	1
	3. Yes, large area of demineralization, caries with cavitation,	0	0	0
	erosion, or abrasion under the margin of the crown	0	0	0
	4. Yes, deep secondary caries or exposed dentin not repairable			
Periodontal response	1. No plaque, no inflammation, no pockets	308	669	977
	2. Little plaque, no inflammation (gingivitis), no pocket development	35	105	140
	3. Plaque accumulation not acceptable, gingival bleeding on probing	0	14	14
	4. Severe/acute periodontitis	0	1	1

1 = clinically excellent/very good; 2 = clinically good; 3 = clinically sufficient/satisfactory; 4 = clinically unsatisfactory.

zirconia substructure facilitates use of a framework derived from a virtual diagnostic wax-up with a digital cutback procedure. With regard to these failures, the results of this study were encouraging. The design of the zirconia core plays an essential role in preventing crack propagation and fracture of the veneering ceramic. Anatomical support provided by a zirconia core results in uniform thickness of the layering material that may better resist the load during mastication.[20]

Chipping occurred in 46 restorations and was fairly equally distributed in the anterior (3.2%) and posterior (4.4%) regions. Also, the finishing line of the margin had no effect, with a 4.1% failure rate for knife-edge and 3.8% for chamfer preparation. This phenomenon was more common in endodontically treated teeth with fiber reinforced composite (FRC) posts (4.8%) than in vital abutments (1.7%). Of a total of 66 patients using a night guard, 23 of them reported delamination or chipping. One might assume that the use of a night guard could limit the nocturnal stress due to the parafunctions, but these habits cannot be completely controlled during the day. However, a fractographic analysis is always necessary to better evaluate the causes and pattern of fracture.

Chipping could be due to mismatch of the CTE, an unfavorable surface, heat treatment, or the thermal conductivity of the Y-TZP being lower than that of gold, which could generate residual stresses within the porcelain during rapid cooling, contributing to chipping-induced fracturing.[21] Matching the thermal expansion between the porcelain and the underlying framework, metal or ceramic, is critical to avoid

Table 7 Cumulative Survival and Success Rates of All Zirconia Restorations

	Anterior failed		Posterior failed		Total failed	
Groups	CSR (%)	SR (%)	CSR (%)	SR (%)	CSR (%)	SR (%)
All groups (n = 1,132; 100%)	2 (99.4)	13 (96.2)	19 (97.6)	52 (93.4)	21 (98.1)	65 (94.3)
Group 5: LAVA (anterior = 178, posterior = 446, n = 624, 55.1%)	0 (100)	3 (98.3)	10 (97.7)	23 (94.8)	10 (98.4)	26 (95.8)
Group 4: NobelProcera Zirconia (anterior = 75, posterior = 105, n = 180, 15.9%)	2 (97.3)	3 (96.0)	6 (94.3)	13 (87.6)	8 (95.6)	16 (91.1)
Group 3: ICE (anterior = 9, posterior = 65, n = 74, 6.5%)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)	0 (100)
Group 2: Byoziram Cyrtina (32), Zircodent (31), Ceramill ZI (27), DD Bio Z (30), Diazir (21), Zenostar (21) (anterior = 51, posterior = 111, n = 162, 14.3%)	0 (100)	7 (86.3)	0 (100)	9 (91.9)	0 (100)	16 (90.1)
Group 1: Biotech (19), New Ancorvis (19), Echo (17), ZirCad (11), Cara (9), Kéramo (14), Everest (3) (anterior = 30, posterior = 62, n = 92, 8.2%)	0 (100)	0 (100)	3 (95.2)	7 (88.7)	3 (96.7)	7 (92.4)

CSR = cumulative survival rate; SR = cumulative success rate.

Fig 1 Three grades of chipping fracture were assigned depending on the treatment modality. **(a)** Grade 1: fracture surfaces were polishable with rubber cups. **(b)** Grade 2: fracture surfaces were repairable with an adhesive bonding system and composite resin. **(c)** Grade 3: severe chipping or delamination with exposure of the zirconia framework and requiring a crown replacement.

cracking after firing. A great difference in the CTE between core and veneering materials can result in clinical failure; the failure mode, adhesive or cohesive, depends on whether the porcelain has a higher or lower CTE than the framework.[22] Residual stresses that remain after cooling in the veneering ceramic are one possible explanation for the differences in chipping failures between metal and Y-TZP-based all-ceramic restorations. The markedly different thermal conductivities of the different framework materials may be the origin of this special failure mode. In this study, no association was found between the zirconia core and ceramic veneering of the same/different brands and mechanical failure. The Lava zirconia in association with Lava Ceram showed 3.80% mechanical failures versus 3.87% for chippings and delaminations that occurred when sintered with other brands of veneering ceramic.

No secondary caries was detected under the margins of the zirconia restorations, and no adverse soft tissue reaction around the crowns was observed. These results could be associated with the excellent quality of the marginal adaptation of the zirconia core in combination with the CAD/CAM system and the reliable sealing of traditional and resin luting cements. Twenty-three cases of postoperative sensitivity for a limited period of time were recorded in this study. In most, the restorations were luted with temporary cement. Gingival bleeding on probing (level 3 of periodontal response) occurred in only 14 restorations. Patient satisfaction with the zirconia-based crowns was very high, and the few completely dissatisfied people or those with minor criticisms about esthetics or function in most cases coincided with the technical failures.

Half of the zirconia crowns were luted on knife-edge tooth preparations. This type of preparation is supposedly more stressful for all-ceramic restorations, but based on the preliminary results of the present study, the chance to choose the best margin preparation finishing line in relation to the specific clinical situation extends the application of zirconia restorations, especially in esthetically important regions. The historic indication for a knife-edge finishing line is the use of fixed prostheses on teeth with periodontal pathology.[23] An in vitro test showed a significantly higher mean failure load for cemented zirconia copings with knife-edge margins versus chamfer.[24] In addition, the vertical preparation may be a less invasive alternative and could preserve sound tooth structure more effectively than shoulder or chamfer, not only for periodontally treated teeth, but also for endodontically treated teeth to increase the ferrule effect, teeth affected by caries at the cervical third of the clinical crown, and vital teeth in young patients.[25] In addition, a recent clinical study suggests that knife-edge margins in feldspathic porcelain veneered zirconia crowns do not affect the clinical performance of restorations during a short-term observation period.[26]

Conclusions

The level of evidence of the retrospective approach of this cohort study has several limitations compared to randomized controlled trials, and for this reason, the results should be interpreted with caution. Over a period of up to 5 years, porcelain-veneered zirconia single crowns with knife-edge and chamfer preparations showed encouraging clinical results. Technical complications were few and were limited primarily to patients with parafunction, although the degree of bruxism or clenching is a difficult clinical parameter to recognize.

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