A Randomized, Prospective, Open-Ended Clinical Trial of Zirconia Fixed Partial Dentures on Teeth and Implants: Interim Results

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Purpose: The aim of this randomized controlled clinical trial was to compare the outcomes of zirconia crowns and fixed partial dentures (FPDs) supported by teeth or implants. ***Materials and Methods:*** Patients were recruited based on inclusion/exclusion criteria, and 59 eligible subjects were assigned randomly to treatment by one of four zirconia systems (Cercon, ZirkonZahn, Lava, and Katana). One hundred seven single-tooth and 160 three- to six-unit FPDs were fabricated on teeth and implants and cemented using composite resin cement. Californian Dental Association (CDA) quality evaluation, Plaque Index, and Gingival Index scores were recorded, and radiographic assessment of the restorations was performed using periapical and panoramic radiographs at baseline and annually up to 4 years. ***Results:*** Five failures (1.9%) were recorded. The 4-year Kaplan-Meier survival probabilities of FPDs were higher than those of single-tooth restorations (P = .046). The highest survival probability for crowns was observed for Katana and the lowest for Cercon (P < .05). For FPDs, the survival probabilities of Lava restorations were similar to those of Cercon but lower than those of ZirkonZahn and Katana (P < .05). The 4-year survival probabilities of implant- and tooth-supported crowns were comparable (P = .182). Regarding CDA ratings, the slight marginal discrepancy scores for the Cercon restorations were higher than for the other systems at 1 year (P < .05). In FPDs, 94.5% of Katana FPDs had slight or gross color mismatch scores, and the difference between color and surface ratings among zirconia systems was significant (P < .05). FPDs had better periodontal scores than crowns over the 4-year observation period (P < .05). ***Conclusion:*** The 4-year interim results of this study suggest that zirconia systems used to fabricate FPDs have predictably high survival rates on teeth and implants and may exhibit differences, particularly in terms of mechanical failures, marginal adaptation, and color matching.
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In an attempt to solve mechanical failures associated with the use of early all-ceramic systems,[1–3] high-strength yttria-stabilized tetragonal zirconia polycrystalline (Y-TZP) ceramics have been developed. The most prominent advantage of Y-TZP is transformation of tetragonal grains into monoclinic grains at room temperature to inhibit crack propagation.[4] This phase transformation substantially increases the flexural strength and fracture toughness of Y-TZP, approaching those of metal-ceramic restorations.[5–7] In addition, Y-TZP has many advantages as a prosthetic material, such as proven biocompatibility, low thermal conductivity, low corrosion potential, and good radiographic contrast.[7]

Clinical studies on tooth-supported Y-TZP crowns and fixed partial dentures (FPDs) have reported survival rates exceeding 95% for up to 4 years of function.[8–12] At 5 years, three- to five-unit Y-TZP fixed prostheses have been shown to experience negligibly low incidences of framework fracture ranging between 0.0% and 0.1%,[13,14] although the success rate may decrease to 74% when other complications are considered.[13] Indeed, apart from the promising

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mechanical durability of the framework, a systematic review reported that zirconia restorations might suffer veneering porcelain chip-off at a rate 7% higher than that of traditional metal-ceramic prostheses in 3 years of function.[15] Chip-off or defects in veneering porcelains might not always be solved by polishing, and impairment of esthetics or function may necessitate replacement of the restoration. In addition to mechanical problems, biologic complications such as secondary caries, root canal therapy, and tooth extraction also have been reported for Y-TZP, but these are reasons similar to those for failure of traditional metal-ceramic fixed prostheses.[16]

In terms of biologic and mechanical complications, particularly chipping of the veneering porcelain, the significance of reporting on both tooth- and implant-supported prostheses has been emphasized.[14] The purpose of this study was to compare the clinical outcomes of different zirconia systems on crowns and FPDs supported by teeth and implants since comparative studies on different zirconia systems or veneering ceramics[11,14] as well as studies on teeth and implants are relatively sparse.[17–19] It was hypothesized that the survival probability and biologic and prosthetic outcomes of crowns and FPDs made from different zirconia systems would be comparable. In addition, it was surmised that survival probability and prosthetic complications of FPDs supported by teeth and implants would also be similar.

Materials and Methods

A convenience sample of 59 consecutive patients (20 men, mean age: 36.8 years; 39 women, mean age: 38.64 years) were selected based on the following inclusion criteria: *(1)* excessive loss of tooth structure requiring full veneer crowns, crowns/FPDs needing replacement, and missing tooth or teeth requiring tooth- or implant-supported crowns and/or FPDs; *(2)* no history of periodontal or implant surgery; *(3)* periodontal pocket depth < 3 mm; *(4)* good oral hygiene and low caries activity; *(5)* absence of tooth mobility; *(6)* absence of excessive parafunctional activity and abfraction lesions; *(7)* absence of local inflammation and oral mucosal diseases; and *(8)* absence of removable dentures. In patients with implant treatment, the aforementioned criteria were used except for absence of tooth mobility. In addition, patients to receive implant surgery must have met the following inclusion criteria: presence of residual bone volume sufficient to receive at least 4×10-mm implants, low-span partial edentulism, no requirement for guided bone regeneration during surgery, and implant surgery at least 8 weeks postextraction.

Patients who had a history of alcohol or drug abuse and/or life-threatening diseases (American Society of Anesthesiologists classification[20]), radiotherapy in the head or neck region, severe intermaxillary skeletal discrepancy, excessive parafunctional activity, untreated periodontitis, unhealed extraction sites, or physical disability hindering adequate oral hygiene were excluded from this study.

Study Design

This was a randomized, single-blind (prosthodontist) clinical trial on zirconia single-tooth crowns and FPDs without cantilevers on teeth and implants. The zirconia systems used were Cercon (DeguDent), Lava (3M ESPE), ZirkonZahn (Zirkonzahn), and Katana (Noritake) (Fig 1). Of these, Cercon, Lava, and Katana systems are based on computer-aided design/computer-assisted manufacture technology, and fixed prostheses made from the ZirkonZahn system were made using the copy-milling technique. Patients were screened following the inclusion/exclusion criteria, and eligible subjects were assigned to one of the four zirconia groups between October 2005 and May 2010. Allocation of patients was accomplished randomly as described by Meijer et al.[21] The primary outcome measure was prosthetic assessment of crowns and FPDs by the California Dental Association (CDA) quality evaluation index[22] (Table 1) at baseline and annually and treatment needs of biologic and prosthetic complications, if any. Secondary outcomes were Plaque Index[23] and Gingival Index[24] scores around teeth and implants at baseline and annually, as well as assessment of survival and success of the restorations and implants. Survival of an implant was defined as the implant still being in place at the annual checkup; success was defined according to Buser et al.[25] Success criteria for FPDs was defined as presence of optimum function without adverse soft tissue response, tooth/implant mobility, persistent and enduring pain, or need for porcelain polish or repair resulting from veneer porcelain chip-off.

Study Procedures

For both single-tooth restorations and FPDs, teeth were prepared with a 2-mm occlusal/incisal clearance and 1.5-mm rounded shoulder. The finish line was located approximately 0.5 mm subgingivally on the buccal aspect and at the gingival crest level on the mesial, distal, and oral aspects during tooth preparation. No bevel was incorporated into the finish line preparation. Both nonvital and vital prepared teeth had a more than 2-mm ferrule. For implant-supported

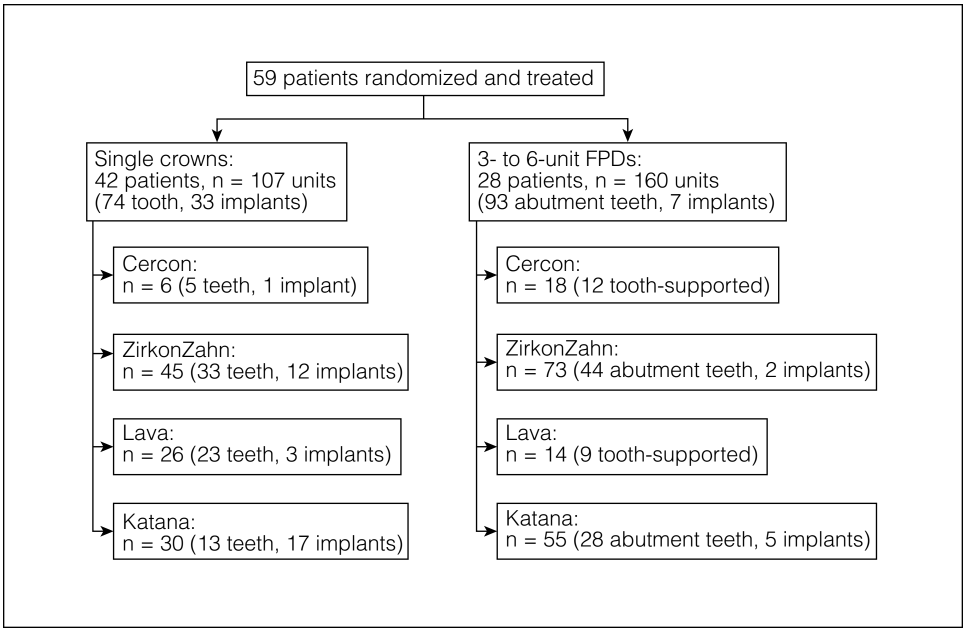


Fig 1 Flowchart of patients and restorations.

restorations, the implants (predominantly MKIII TiUnite, Nobel Biocare) were placed following the standard two-stage surgical protocol. Standard postoperative treatment comprised analgesics and chlorhexidine 0.2% mouthrinses, as well as antibiotics and nonsteroidal analgesics postoperatively for 3 consecutive days. Upon stage-two surgery at 4 to 5 weeks, healing abutments were connected. Implants were subjected to an early loading protocol at 8 weeks postsurgery.

For both tooth- and implant-supported prostheses, full-arch impressions were taken using a condensational polymerization silicone impression material (Speedex, Coltène), and irreversible hydrocolloid impressions (Blueprint cremix, Dentsply DeTrey) were taken of the opposing arch. The zirconia restorations were fabricated following the manufacturers' instructions. Zirconia restorations on implants were supported by titanium abutments (Esthetic Abutment, Nobel Biocare). The crowns and FPDs were cemented using dual-cured composite resin cement (Panavia F 2.0, Kuraray). At delivery (baseline) and annually thereafter, each restoration was evaluated according to the CDA quality evaluation index, and Plaque Index and Gingival Index scores were also recorded. Any change relative to the initial rating (delivery) was recorded at recalls, ie, a crown having a color and surface rating of SMM (slight color mismatch) was rated SMM at the recall appointment in the event that only a clinically discernable slight mismatch was still present. In addition, radiographic assessments of teeth, implants, and surrounding bone were undertaken using periapical radiographs obtained by a paralleling device (Dentsply Rinn) or panaromic radiographs.

Statistical Analysis

For the comparison of prosthetic outcomes, the first incidence of any complication indicating replacement of a crown/FPD was taken into account, and the timing was referred to as a failure period. A restoration was considered failed when any of the following were detected: porcelain chipping; catastrophic fracture of the crown/FPD, supporting tooth/implant, or both; secondary caries; endodontic therapy followed by replacement of the prosthesis; and excessive breakdown of supporting tissues indicating extraction of the tooth or removal of the implant. Excluding the indication for extraction, replacement of a crown was undertaken upon detection of any of these complications. A crown/FPD was considered as survived when any of the aforementioned problems were not detected. During statistical assessment, absence of the complication was referred to as censored. Survival of the crowns was evaluated using the Kaplan-Meier estimator, and comparative evaluations between groups regarding survival probabilities (maximum time in function without experiencing any complications) were undertaken using the log-rank test at a 95% confidence level. Since the number of implants supporting FPDs was very low in this interim report, survival and the clinical outcome of crowns

Table 1 Criteria for California Dental Association Rating[22]

Category	Score: Acceptable	Score: Unacceptable	Criteria
Marginal integrity	Excellent		No visible evidence of crevice along margin that explorer would penetrate; no evidence of ditching along margin
	SCR		Visible evidence of slight marginal discrepancy with no evidence of decay, repair possible but perhaps unnecessary; explorer gets stuck in one direction
		TFAM	Faulty margins cannot be properly repaired
		TPEN	Penetrating discoloration along margin of restoration in pulpal direction
		TCEM	Retained excess cement
		VMO	Mobile restoration
		VFR	Fractured restoration
		VCAR	Caries continuous with margin of restoration
		VTF	Fractured tooth structure
Anatomical form	Excellent		Restoration contour in functional harmony with adjacent teeth and soft tissues within good individual anatomical form
	SOCO		Restoration slightly overcontoured
	SUCO		Restoration slightly undercontoured
	SOH		Occlusion not completely functional
	SMR		Margin ridges slightly undercontoured
	SCO		Contact slightly open
	SFA		Facial flattening present
	SLG		Lingual flattening present
		TUCO	Restoration grossly undercontoured
		TOCO	Restoration grossly overcontoured
		TET	Occlusion affected
		TOC	Contact faulty
		TOV	Marginal overhang present
		VTO	Traumatic occlusion
		VUO	Gross underocclusion
		VPN	Restoration caused unremitting pain in tooth or adjacent tissue
		VDM	Damage to tooth, soft tissue, or supporting bone
Color and surface	Excellent		No mismatch in color shade or translucency between restoration(s) and adjacent teeth; restoration surface smooth; no irritation of adjacent tissue
	SMM		Slight mismatch between shade of restoration(s) and adjacent tooth or teeth
	SRO		Restoration surface slightly rough but can be polished
		TGI	Grossly irregular surface not related to anatomy and not subject to correction
		TMM	Mismatch between restoration(s) and adjacent tooth or teeth outside normal range of color, shade, or translucency
		VSF	Fractured surface
		VGP	Gross porosities in crown material
		VSD	Shade in gross disharmony with adjacent teeth

supported by teeth and implants were compared. CDA criteria were categorized into "excellent" and "other," with reference to Table 1. Likewise, Plaque Index and Gingival Index scores were grouped (ie, 0 and other [scores 1 and 2]). Between-group comparisons of CDA ratings and Plaque Index and Gingival Index scores were performed using the chi-square test, Fisher exact test, and McNemar binomial test at a 95% confidence interval for baseline, 1-year, 3-year, and 4-year data.

Fig 2a Fractured three-unit Lava FPD.

Fig 2b Veneering porcelain chip-off in a single crown.

Results

Patients and Survival Probabilities of the Restorations

Among the 59 patients, no dropouts were recorded during the maximum 4-year observation period, although 4 patients were not able to attend every recall appointment. Thirty-five patients received dental cleanings (59.3%) and 3 patients had gingivectomy procedures (5.08%) prior to prosthetic treatment. Seven patients (11.8%) were treated with muscle-relation splints because of nocturnal bruxism. Nine patients (15.2%) were smokers. The reasons for fabrication of restorations or renewal of the preexisting restorations were excessive tooth substance loss, secondary caries with or without periapical lesions, marginal discrepancy of preexisting restorations, gingival recession with secondary caries, tooth fracture or loss, or a combination of these. Among the restored prosthetic retainers (n = 167), a total of 40 teeth (23.9%) were nonvital (32 in crowns, 8 in FPDs), and 2 retainers in the FPD group were restored with post-and-core restorations.

During the observation period, no tooth fractures were observed, and presence of secondary caries or periapical lesions was not detected in the radiographs. All implants survived over the course of the observation period, and the success rate was 100%. Of the 267 unit restorations, 5 failures (1.9%) were recorded (4 crowns, 1 FPD) (Figs 2a and 2b); 4 failures were noted in the first year and 1 in the second year. Among crown failures, 3 failures were observed in the first year of function (1 fracture of core and veneering porcelain, 1 root canal therapy, and 1 veneering porcelain fracture). The tooth with a fractured and replaced restoration experienced a second catastrophic fracture of the new restoration in the second year that was again replaced. The tooth with root canal therapy and a renewed restoration was extracted in the second year. The failure of the FPD was observed at the retainer/connector region in the first year of function. The overall success rate of all restorations (n = 267) was 98.13% at the 3- and 4-year recall appointments.

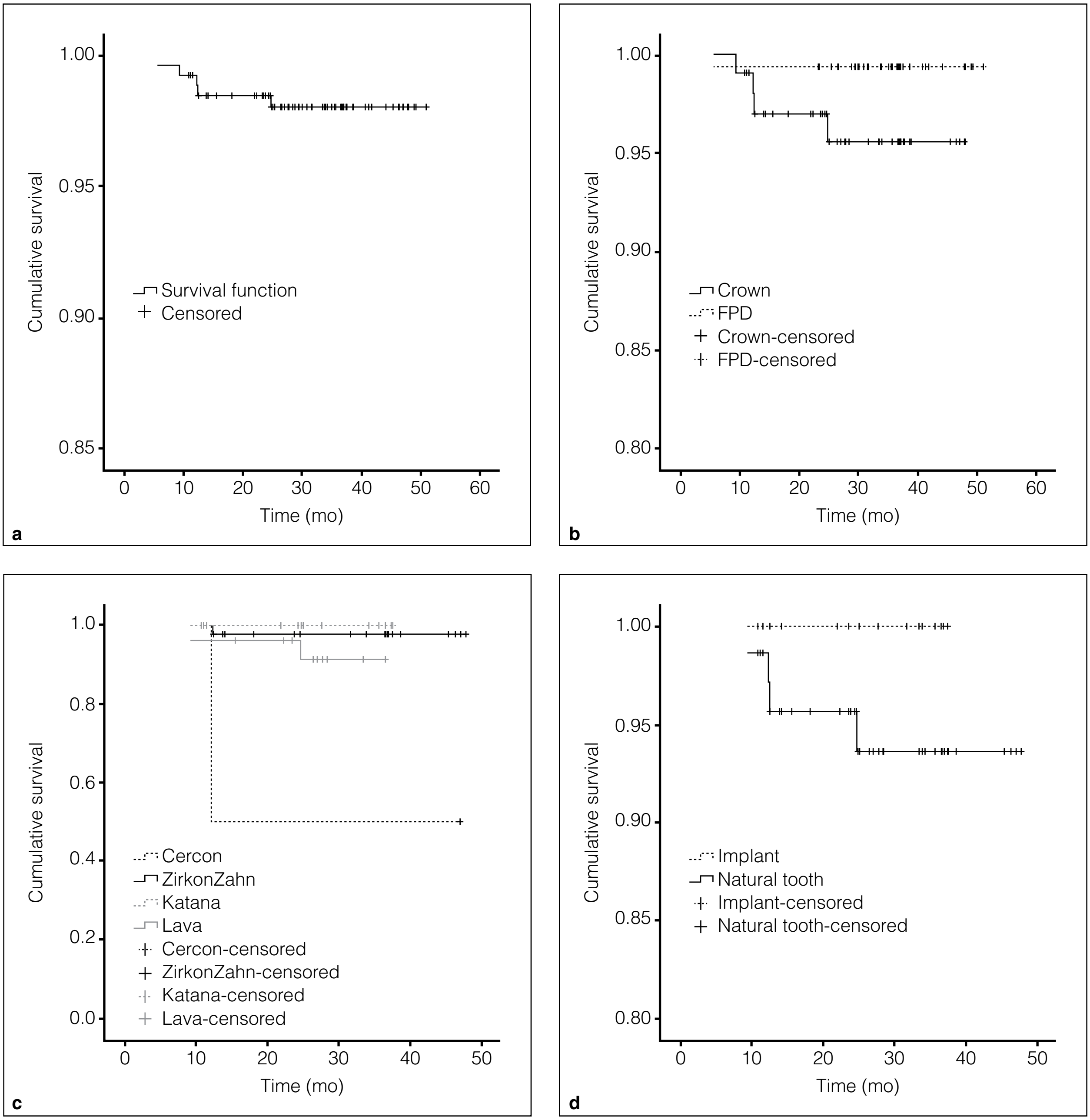
Kaplan-Meier analysis showed that the mean survival time for all restorations was 50.1 ± 0.3 months, with 1- to 4-year survival probabilities of 0.99, 0.985, 0.98, and 0.98, respectively. The mean survival time for single-tooth restorations (n = 107, 4 failures) was 46.3 ± 0.7 months, with survival probabilities of 0.991 (1 year), 0.97 (3 years), and 0.956 (4 years). The mean survival time for FPDs (n = 160 units, 1 three-unit FPD failure) was 50.6 ± 0.2 months, with a 4-year survival probability of 0.994. The 1- to 4-year survival probabilities of FPDs were higher than those of crowns ($P = .046$).

Kaplan-Meier survival estimates of the restorations are presented in Table 2 and Figs 3a to 3d. Considering crowns (40.1%), the difference between groups was significant ($P = .017$). The highest survival probability was observed for Katana restorations.

Table 2 Frequency and Distribution of Restorations (n = 267) and Kaplan-Meier Survival Probabilities for Different Zirconia

	Crown			FPD		
	Total	Within-group %	Observation period (mo)†	Total	Within-group %	Observation period (mo)†
Cercon	6	5.6	24.36 ± 21.10	18	11.3	46.18 ± 4.15
ZirkonZahn	45	42.1	29.50 ± 12.51	73	45.6	39.28 ± 4.48
Lava	26	24.3	28.16 ± 4.35	14	8.8	29.18 ± 0.52
Katana	30	28.0	26.73 ± 9.83	55	34.4	32.47 ± 4.88

*Considering single crowns, differences in survival probabilities between ZirkonZahn and Lava and Katana restorations were insignificant (P = .317 and
†Mean ± standard deviation.



Figs 3a to 3d Kaplan-Meier survival estimates of **(a)** all restorations, **(b)** crowns and FPDs, **(c)** zirconia systems, and **(d)** prostheses supported by teeth or implants.

Systems on Single Crowns and FPDs*

Kaplan-Meier estimates							
1 y		2 y		3 y		4 y	
Crown	FPD	Crown	FPD	Crown	FPD	Crown	FPD
1.000	1.000	0.500	1.000	0.500	1.000	0.500	1.000
1.000	1.000	0.978	1.000	0.978	1.000	0.978	1.000
0.962	0.929	0.962	0.929	0.913	0.929	0.913	0.929
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

P = .475, respectively). The difference between Lava and Katana restorations was insignificant (P = .138).

Cercon restorations had lower survival probabilities than ZirkonZahn, Lava, and Katana restorations (P = .00, P = .001, and P = .018, respectively). For FPDs (59.9%), the differences between groups were also significant (P = .015), and the survival probabilities of Lava restorations were similar to those of Cercon (P = .257) but lower than those of ZirkonZahn and Katana FPDs (P = .022 and P = .047, respectively). The 4-year Kaplan-Meier survival probability of implant-supported crowns was 1.00; for tooth-supported crowns, it was 0.957 for 1 to 2 years and 0.936 for 3 to 4 years. The difference between groups was insignificant (P = .182).

CDA Ratings and Soft Tissue Outcome

Frequency and percentage distribution of CDA ratings of the restorations are presented in Table 3. P values of between-group comparisons are presented in Table 4. Comparisons between crowns and FPDs showed that baseline and 1-year color and surface excellent scores of FPDs were higher than those for crowns (P = .03) (Table 4). FPDs also had better Plaque Index and Gingival Index scores than crowns during the 4-year observation period ($P < .05$) (Fig 4). Comparisons of single-tooth zirconia restorations showed that baseline and 1-year excellent scores for Cercon and Lava restorations were higher than those for the other systems ($P < .05$). At 1 year, SCR (slight marginal discrepancy) scores for the Cercon group were higher than in other systems ($P < .05$). For FPDs, the difference between color and surface ratings between systems was significant ($P < .05$) because 94.5% of Katana FPDs had SMM (slight color mismatch) or TMM (gross color mismatch) scores, while the other systems predominantly had excellent scores. Excellent ratings for anatomical form of Cercon restorations were lower than those of the other groups ($P < .05$). Between-group comparisons showed that CDA ratings and periodontal scores for tooth- and implant-supported crowns were comparable over 3 years of follow-up, although the 3-year margin rating for tooth-supported restorations and color and surface ratings for implant-supported restorations were better ($P < .05$) (Table 4).

Discussion

The 3- to 4-year interim results of this prospective open-ended study suggest that the long-term outcome of zirconia restorations may not always be similar, although similar survival probabilities were obtained for tooth- and implant-supported crowns. At the outset, the authors hypothesized that the outcomes of different zirconia systems would be comparable because of the high-strength core ceramics[4–7] and the fact that even all-ceramic alumina crowns strengthened by 25% zirconia can sufficiently withstand functional loads in the posterior zone.[26] Failure of the crowns was not only dependent on mechanical complications but on the low incidence of biologic complications as well. Chipping of the veneering porcelain was extremely infrequent in the present study (0.003%), which is in contrast to previous reports.[9–13,27] Indeed, chipping of veneering porcelain is a frequent problem with Y-TZP restorations on teeth as well as implants[12,14] and sometimes cannot be solved by routine porcelain polishing techniques. Porcelain chipping is attributed to mechanically defective microstructural regions in the porcelain, including porosities, agglomerates, inclusions, and large-grained zones.[28] Poor bond strength between the core and veneering ceramic may be another reason for chip-off fractures. In the present study, chip-off failure was observed at the core–veneering ceramic interface of one Lava crown. Because Lava is a densely sintered zirconia material with no glass phase, it might be difficult to achieve a superior bond between the core and veneering ceramic. The chip-off fracture necessitated replacement because contact with the neighboring tooth was lost.

In a larger patient population (161 patients and 204 crowns) than that in this study, Ortorp et al[11] did not observe any catastrophic fracture of Procera (Nobel

Table 3 Frequency and Distribution of CDA Ratings of All Restorations*

		CDA rating	Frequency	%
Marginal integrity	Baseline	Excellent	166	62.2
		SCR	43	16.1
		No data	58	21.7
	1 y	Excellent	164	61.4
		SCR	43	16.1
		VFR	2	0.7
		No data	58	21.7
	2 y	Excellent	143	53.6
		SCR	32	12.0
		VFR	1	0.4
	3 y	Excellent	120	44.9
		SCR	28	10.5
		No data	119	44.6
	4 y	Excellent	35	13.1
		SCR	6	2.2
		No data	226	84.6
Anatomical form	Baseline	Excellent	239	85.9
		SCO	3	1.1
		SFA	4	1.5
		SLG	4	1.5
		SMR	4	1.5
		SOCO	4	1.5
		SOH	1	0.4
		SUCO	2	0.7
		VPN	6	2.2
	1 y	Excellent	246	92.1
		SCO + SFA + SLG + SMR + SOCO + SUCO†	21	7.9
	2 y	Excellent	219	82.0
		SLG + SMR + SOCO + SUCO†	14	5.2
		VPN	1	0.4
	3 y	Excellent	193	72.3
		SMR + SOCO + SUCO†	10	3.7
		SLG	3	1.1
	4 y	Excellent	48	18.0
		SLG + SMR + SOCO + SUCO†	11	4.1
Color and surface	Baseline	Excellent	174	65.2
		SMM	93	34.8
	1 y	Excellent	174	65.2
	2 y	SMM	92	34.5
		VSF	1	0.4
		Excellent	148	55.4
		SMM	76	28.5
		TMM	9	3.4
		VSF	1	0.4
	3 y	Excellent	130	48.7
		SMM	67	25.1
		TMM	9	3.4
	4 y	Excellent	41	15.4
		SMM	9	3.4
		TMM	9	3.4

No data = observation period < 3 years, patient did not attend recall appointment, or pontic tooth.
*See Table 1 for explanation of CDA rating acronyms.
†Same frequency as previous year.

Biocare) single crowns in a 3-year observation period, but the rate of biologic complications was 9% excluding minor problems, such as temporary pain after cementation, excess of cement detected at the following check-up, and loosened crowns that could be easily recemented. In the present study, biologic complications were extremely low, although the 3- to 4-year periodontal scores suggested that patients,

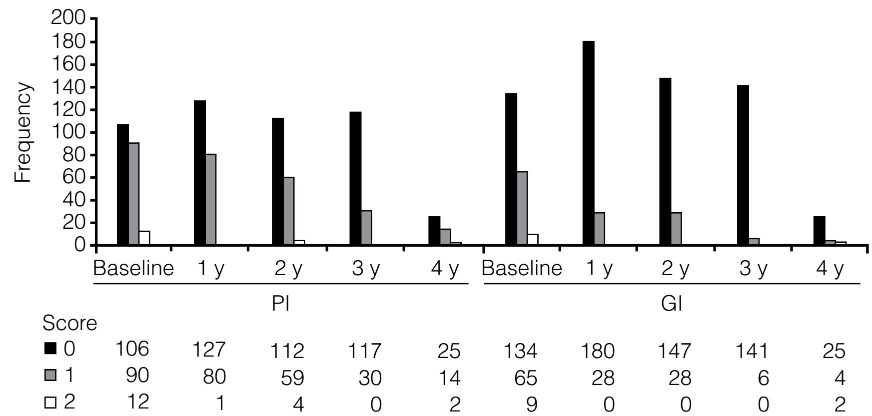


Fig 4 Time-dependent distribution of the frequency of Plaque Index (PI) and Gingival Index (GI) scores.

Table 4 *P* Values of Between-Group Comparisons of CDA Ratings and Periodontal Scores

	Baseline	1 y	3 y	4 y
Crown vs FPD				
Marginal integrity	.497	.319	.893	.622
Anatomical form	.468	.096	.492	.079
Color and surface	.030*	.030*	.085	.054
Plaque Index	.327	.003*	.004*	.007*
Gingival Index	.022*	.062	.377	.024*
Zirconia systems (crowns)				
Marginal integrity	.096	.040*	–	1.000
Anatomical form	–	–	–	1.000
Color and surface	.001*	.003*	–	.133
Plaque Index	.206	.505	–	.378
Gingival Index	.787	–	–	.467
Zirconia systems (FPDs)				
Marginal integrity	.174	.174	.174	.002*
Anatomical form	.000*	–	–	.000*
Color and surface	.000*	.000*	.000*	.000*
Plaque Index	.260	.573	–	.012*
Gingival Index	.265	–	–	.051
Tooth vs implant				
Marginal integrity	.764	.993	.042*	NA
Anatomical form	> .999	> .999	.004*	NA
Color and surface	.150	.150	.288	NA
Plaque Index	.594	.394	.421	NA
Gingival Index	.616	.241	.541	NA

– = Analysis cannot be performed; NA = data not available for implants (no statistical analysis).
*Statistically significant difference.

especially those with crowns, needed improvement in oral hygiene maintenance habits. In a 4-year study on Cercon FPDs, Wolfart et al[27] reported biologic complications (21%) including endodontic treatment, apicoectomy, recementation, and secondary caries. Unlike previous studies, recementation was not required in this study, and secondary caries was not observed in any tooth including those supporting

Cercon restorations with higher SCR (slight marginal discrepancy) scores. The Kaplan-Meier survival probability of single crowns was 0.956 including the biologic complications. The fracture of the Cercon restorations, which decreased its survival probability in comparison to the other systems, was probably a result of insufficient seating of the intaglio surface. Indeed, the SCR scores for Cercon restorations were higher than those for other groups after 1 year. Although it was beyond the scope of this study to compare quantitatively the chair time for adjustment of the internal fit of restorations, it was generally observed that Cercon crowns and FPDs required relatively more time than Lava and Katana restorations. Including the fracture of the three-unit Lava FPD, the Kaplan-Meier survival probability of the restorations was 0.98 at the end of the 4-year period, which is in agreement with previous findings of survival probabilities between 94% and 100%.[9–12] Contrary to these findings, Sailer et al[13] observed a survival rate of 73.9% for five-unit FPDs after a mean observation period of 53 months. The main reason for failure in that study was secondary caries, and only one framework fracture was observed, leading to a framework survival rate of 97.8%.

In terms of comparisons between tooth- and implant-supported restorations, this 4-year interim report included a relatively low number of implants, and the distribution of implants and natural teeth supporting crowns was not homogenous because of randomization. In the present study, the periodontal parameters of teeth and implants supporting crowns were comparable. All implants supporting zirconia crowns survived, and the crowns did not experience any mechanical complications. In an earlier report on a series of zirconia restorations on teeth and implants, Kollar et al[17] observed 100% survival of supporting implants but two tooth fractures supporting zirconia crowns. They also observed chipping of the veneering porcelain in five implant-supported crowns, which is in contrast with the present findings. The impact of zirconia as a prosthetic material on the biologic outcome of osseointegrated implants could be considered negligible since there is consensus that prosthetic materials have little or no influence on the biomechanics and clinical success of implants.[29]

In comparison with traditional feldspathic porcelain, high-strength ceramics tend to be more opaque and pose a challenge when trying to match natural tooth color in the esthetic zone. With regard to CDA ratings, one of the most striking clinical observations was that color match with the Katana restorations was frequently a challenging task. Among the zirconia systems used, Katana crowns and FPDs had significantly poorer color and surface CDA ratings (94.5% SMM or TMM [slight or gross color mismatch]) than other groups. This was a result of the opaque appearance of the core and/or veneering porcelain at the cervical as well as middle thirds of the restorations. Because there are not published clinical reports on Katana crowns and FPDs, it is currently not possible to make comparisons between studies.

It is important to acknowledge this study's limitations, which inlude small and unequal sample sizes, as well as the risk of overinterpreting individual observations derived from a multifactorial design. Since the number of implants supporting FPDs was very low, survival and the clinical outcomes of crowns supported by teeth and implants were compared. Fractographic analyses of the failed prostheses could have been performed, but it was beyond the scope of this study. The results of this study should be interpreted as short-term outcomes of FPDs and crowns supported by teeth and implants. Long-term studies are required to comprehensively understand the outcome of such treatments.

Conclusions

The 4-year clinical outcomes of zirconia single-tooth crowns and three- to six-unit FPDs showed differences in survival rates with regard to the porcelain systems used. The outcomes of zirconia restorations on teeth and implants were comparable, although differences were observed in terms of fracture rates, marginal adaptation, and color matching.

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Literature Abstract

Tooth tissue engineering: Optimal dental stem cell harvest based on tooth development

Human tooth development using anatomical, histologic, and radiographic methods has been inconclusively characterized to correlate with tooth serial growth and chronologic development. Small bioengineered tooth crowns from harvested pig and rat postnatal dental stem cells (DSCs) were successfully generated with the use of tissue-engineered approaches in previous studies. Eventual replacement of human tooth therapies can be accomplished through the generation of a bioengineered tooth structure of specified size and shape in the future. The purpose of this study was to introduce a new radiographic classification method to accurately correlate the human third molar tooth developmental stage with cultured harvested DSC numbers. The results showed that higher initial human DSC numbers were obtained from less developed teeth in stages 1 (mean: 14×10^6) and 2 (mean: 11.1×10^6) but lower in more developed teeth in stage 3 (mean: 10×10^6). Based on the capabilities of colony-forming units (CFUs), teeth in stage 1 contained the highest DSC numbers at 2 and 3 weeks compared to teeth in stages 2 and 3. The authors concluded that there was a close correlation between donor chronologic age and developmental stage of harvested human mandibular third molar teeth, consistent with prior published reports. The authors also concluded that data from cone beam computed tomography could accurately assess the developmental stage of extracted teeth in future dental tissue engineering.

Duailibi MT, Duailibi SE, Duailibi Neto EF, et al. *Artif Organs* 2011;35:E129–135. **References:** 25. **Reprints:** Pamela C. Yelick, Division of Craniofacial and Molecular Genetics, Department of Oral and Maxillofacial Pathology, Tufts University, Boston, Massachusetts, USA. Email: pamela.yelick@tufts.edu—*Arthur S. Sham, Hong Kong*