Computer-Aided Designed/Computer-Assisted Manufactured Composite Resin Versus Ceramic Single-Tooth Restorations: A 3-Year Clinical Study

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Purpose: No clinical evidence has been provided to suggest that metal-free all–composite resin indirect restorations are a functional and esthetic alternative to all-ceramic restorations. The aim of this study was to evaluate the clinical performance of single-tooth computer-aided design/computer-assisted manufacturing (CAD/CAM)–generated all–composite resin and all-ceramic crowns after 3 years of function. ***Materials and Methods:*** In a prospective trial, 200 all–composite resin and all-ceramic crowns were rated over a 3-year period. Restorations were evaluated at 3 weeks and 1 and 3 years after insertion by the California Dental Association quality evaluation index, the patient's self-assessment, marginal fit, periodontal parameters, volume loss, and wear patterns of the veneering material. Statistical analysis was performed using *t* tests ($\alpha = .05$). ***Results:*** Cumulative survival and success rates after 3 years were 87.9% and 55.6% for all–composite resin and 97.2% and 81.2% for all-ceramic crowns, respectively ($P < .05$ for success rates). Restoration loosening occurred exclusively for all–composite resin crowns cemented on a cast post. All-ceramic restorations demonstrated satisfactory esthetic results. All–composite resin crowns resulted in significantly more mean total volume loss and mean vertical wear at occlusal contact areas after 6 months and 3 years of function. The clinical performance of the CAD/CAM-generated all-ceramic crowns used in this study was similar to that of other all-ceramic CAD/CAM systems. ***Conclusion:*** For up to 3 years of function, all–composite resin single-tooth restorations have inferior success rates compared to all-ceramic restorations. Due to the inferior esthetics and wear resistance of all–composite resin crowns, all-ceramic crowns remain the preferred treatment for CAD/CAM-generated metal-free single-tooth restorations. *Int J Prosthodont 2010;23:223–230.*

Advances in adhesive dentistry and technologic developments with computer-aided design/computer-assisted manufacturing (CAD/CAM)–generated restorations have provided alternatives to conventional laboratory-processed restorations. All-ceramic restorations, with high-strength ceramic copings and feldspathic veneering porcelain offering good esthetics, fracture resistance, and accuracy of fit,[1–3] have been used as an alternative to metal-ceramic restorations in anterior and posterior sites for many years. Fradeani and Aquilano[4] estimated the cumulative survival rate for IPS-Empress (Ivoclar Vivadent) complete restorations to be 95.4% after 5.5 years. A 92% and 97.5% 5-year survival rate for In-Ceram Alumina[5] and In-Ceram Spinell[6] (VITA) core restorations, respectively, was reported. All-ceramic Procera alumina (Procera) restorations showed a cumulative survival rate of 98.4% after 5.5 years[7] and 93.5% after 10 years,[8] and an overall survival rate of 96.7% after 5 years.[9] Their clinical success was found to be irrespective of tooth position, cement type (composite resin or glass-ionomer cement), or core design with reduced or conventional margins.[10] Titanium copings did not provide

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a true alternative for the metal-ceramic restorations, primarily because of their inferior esthetic outcome.[11,12] Promising alternatives for all-ceramic restorations are those with zirconium oxide copings because of their high load-to-fracture value[13] and all–composite resin (ie, coping + veneering) crowns because of their noninvasiveness to the opposing enamel, ease of use, ability to bond, and resilience. However, the occlusal wear of composite resin restorations is inferior to that of metal-ceramic ones.[14] Moreover, the fracture resistance of composite resin restorations depends significantly on the occlusal thickness of the restorations and the type of cement used.[15] The fracture load of composite resin and feldspathic ceramic CAD/CAM restorations with different luting agents was investigated by Attia et al.[16] A significant influence of the cyclic loading and the luting agent on the fracture load of both restoration types was found, whereas the restoration material itself had no significant influence. Adhesive cementation significantly increased the fracture load. Compared to methyl methacrylate–based resin cement, composite resin for cementation of a polymer-based restoration resulted in a more favorable von Mises stress distribution at the cervical root area during function.[17] Moreover, composite resin cements are characterized by a specific pore volume and a lower porosity compared to conventional luting cements such as zinc-phosphate, polycarboxylate, or glass-ionomer cement,[18] rendering these cements less soluble,[19] and thereby reducing the microleakage.

Initial results from a clinical study on conventionally manufactured composite resin complete restorations were reported by Rammelsberg et al.[20] The authors found that composite resin crowns exhibit an acceptable survival rate of 96% after 3 years. An estimated overall survival rate at 17 years of only 53% ± 14% at the restoration level and 79% ± 11% at the tooth level was reported by Fokkinga et al[21] in a controlled clinical trial for composite resin core-crown restorations.

The objective of this originally randomized controlled clinical trial was to evaluate survival and success rates of single-tooth all–composite resin and all-ceramic complete restorations manufactured with a CAD/CAM system (GN-1, GC) after 3 years of function. The null hypothesis to be tested was that there were no differences between both restoration types.

Materials and Methods

A 3-year prospective clinical study was performed evaluating 200 GN-1 restorations in 130 patients. Patients between 18 and 70 years of age were included based on the clinical need of restoring single teeth with full-coverage restorations. Randomized allocation to the all–composite resin and all-ceramic restoration groups occurred for the first 120 restorations (59 composite resin, 61 ceramic restorations). Due to early occurring complications and inferior results with the composite resin restorations, only all-ceramic crowns were placed thereafter until the required number of restorations for the study was achieved (n = 200).

Inclusion criteria required patients to be in good health, have a maxillomandibular relationship with neutro-occlusion, and have a stable occlusion guaranteed by a sufficient number of natural or artificial teeth. Exclusion criteria were the inability of the patient to provide informed consent for participation, administrative difficulties preventing the 3-year follow-up period, an oral status that did not permit a long-term prediction of stable periodontal and endodontic status, medical conditions that might conflict with the treatment itself or with the follow-up, insufficient interarch space to provide the patient with restorative substitutions for hard tooth tissues, and alcohol or drug abuse.

This study was approved by the ethical committee of the University Hospitals of the K. U. Leuven, in accordance with the Declaration of Helsinki.[22]

The GN-1 system manufacturing tool is composed of three devices: a measuring unit, a CAD software, and a CAM milling device. The composite resin copings were milled out of premanufactured blanks characterized by high compressive and flexural strength, whereas aluminum-oxide ceramic blanks were used for the ceramic copings. After milling, the ceramic coping was infiltrated with (leucite) glass at a temperature of 1,120°C for 20 minutes. Composite resin copings were veneered with GC Gradia (GC), a composite resin characterized by, according to the manufacturer, high wear and abrasion resistance. A veneering feldspathic porcelain (GC Initial AL, GC) was developed for application on the ceramic copings.

Abutment teeth were prepared according to the guidelines used for all-ceramic restorations, with a labial reduction of 1.3 to 1.5 mm, an incisal or occlusal reduction of 1.5 to 2.0 mm, and a chamfer outline design. The copings were designed and manufactured by the GN-1 CAD/CAM device operating at the University Hospitals Dental Laboratories, Leuven, Belgium. The firing of porcelain and the veneering of the resin coping was done by dental technicians at the same laboratory after they had received training guided by the manufacturer. Both restorations were luted with a dual-polymerizing adhesive composite resin cement (Linkmax, GC). The restorations were placed by graduate staff of the department of prosthetic dentistry K. U. Leuven, and supervised by a senior staff prosthodontist.

Evaluation was performed at several levels. The marginal fit was rated on a three-point scale (0 = no corrections needed, 1 = small corrections needed, 2 = large corrections needed and restoration rejected)

Table 1 Distribution of All-Ceramic and All–Composite Resin Crowns According to Tooth Position*

	17	16	15	14	13	12	11	21	22	23	24	25	26	27
Ceramic	2	1	14	7	7	12	15	12	12	5	11	10	3	1
Composite resin	–	–	6	3	3	5	2	3	4	2	7	3	5	1
	47	46	45	44	43	42	41	31	32	33	34	35	36	37
Ceramic	–	4	8	4	1	–	–	–	–	1	4	4	3	–
Composite resin	–	4	1	3	–	–	–	–	–	–	–	1	5	1

*FDI tooth-numbering system.

before and after veneering at the dental laboratory. After cementation and at recall sessions, the marginal fit was rated at facial, lingual, mesial, and distal locations by means of a sharp probe (EXS54, Hu-Friedy) using a three-point scale (0 = optimal fit, 1 = light overhang, 2 = probe is hooking). The subjective appreciation for esthetics and function by the patient was rated by means of a visual analog scale (VAS). Scores were given between 1 (unsatisfactory) and 10 (very good). A clinical and radiologic examination was performed by two independent investigators after 3 weeks (baseline) and 1 and 3 years, evaluating *(1)* color, surface texture, and anatomical form; *(2)* restoration margin edge location and periodontal conditions; and *(3)* possible adverse effects. Color, surface texture, and anatomical form were evaluated based on the California Dental Association quality evaluation system.[23] Periodontal parameters such as the presence or absence of plaque and bleeding after gentle probing (0 = absence, 1 = presence) were recorded at the test and contralateral control sites. Finally, wear and changes to the occlusal surface were quantified over time on replicas made of every tenth restoration. The baseline replica was made 3 weeks after cementation; the following ones after 6, 12, 24, and 36 months. Two impressions were made (Exaflex and Examix NDS, GC). The first impression was poured in type 4 dental die stone (Fujirock EP, GC) for evaluation by laser scanning of the amount of lost veneering material and of the vertical wear at occlusal contact areas (Laserscan 3D-Pro system, Willytec). The second impression, cast in epoxy resin (Araldite DRL-HY, Huntsman Group), served to evaluate changes in the occlusal morphology by means of morphometric assessments (Image Pro Plus, Media Cybernetics) on stereomicroscope images (Wild-Heerbrugg).

A restoration was considered as having survived when the original restoration was present at the last recall. A restoration was considered successful if it not only had survived, but if it did not have one or a combination of shortcomings, such as anatomical form changes or excessive veneer chipping, that seriously compromised the esthetics (CAD score[23] Sierra or Tango); loss of integrity at the restoration margins (score $>$ 1); or loosening or fracture (ie, micro- or macroscopic cleavage in the core and veneering portions of the crown) of the restoration. When calculating the cumulative success rates, loosening was considered only the first time, even when the same restoration came loose more than once. The original restoration was always used for reluting. The same applied for loss of marginal integrity. This was considered only at the last recall. If the restoration fractured or needed renewal, this was considered as the endpoint for survival and success calculation. All events that occurred in between recall visits were noted in the patients' files and regrouped in 6-month intervals.

Statistical Analysis

Baseline data were compared with those at 1 and 3 years within test and control teeth by means of a one-sample *t* test. When comparing the status between all-ceramic and all–composite resin restorations, a two-sample *t* test was used. A modified standard lifetime table analysis was constructed to perform survival and success analyses.[24] Non-normality sampling distribution could not be confirmed by a normality test (Shapiro-Wilk), permitting the calculation of approximate confidence intervals for these values. The level of significance was set at $\alpha = 5\%$.

Results

The distribution of the all-ceramic and all–composite resin crowns according to tooth position is shown in Table 1. Of the 200 restorations originally placed, 138 restorations were left at risk after 3 years of function (34 all–composite resin and 104 all-ceramic), leading to a dropout rate of 25.4% at the restoration level. Patients who did not attend their appointment were reminded both in writing and by phone. The main reasons for missing appointments were no interest or no time to come. Four patients mentioned dissatisfaction with the restoration, although they reported the restoration was still in place. Baseline data between dropout patients and those participating in the study did not differ significantly from each other. Of the 138

Table 2 Reasons for Restoration Failure and Unsuccessful Scoring in Relation to Loading Time

Restoration type/ loading time (mo)	No. of failed restorations	No. of unsuccessful restorations
Composite resin		
0–6	1 fracture 1 unacceptable color 1 perforation of veneering material due to excessive occlusal wear	5 restoration loosenings 2 excessive occlusal wear of veneering material
7–12	–	4 restoration loosenings 1 excessive occlusal wear of veneering material
13–18	1 fracture	2 restoration loosenings
19–24	1 fracture	2 restoration loosenings 1 excessive occlusal wear of veneering material
25–30	1 fracture	2 restoration loosenings
31–36	–	2 restoration loosenings 1 probe hooking 1 excessive occlusal wear of veneering material
Ceramic		
0–6	2 fractures	–
7–12	–	–
13–18	–	–
19–24	–	3 probe hooking
25–30	1 fracture	2 probe hooking
31–36	–	5 probe hooking 1 chipping of veneering material

– = no failures or unsuccessful restorations.

restorations at risk, 4 all–composite resin and 3 all-ceramic crowns fractured and were replaced by conventional metal-ceramic restorations, in line with the protocol. Another composite resin restoration was replaced after 4 months by a ceramic GN-1 restoration because of excessive wear of the veneering material, but it was kept in its original allocated group according to the Intent-to-Treat principle.[25] The reasons for restoration failure and unsuccessful scoring are reviewed in Table 2. Cumulative survival and success rates for all–composite resin restorations after 3 years were 87.9% and 55.6%, respectively. For all-ceramic restorations, the corresponding data were 97.2% and 81.2% (Table 3). The outcome for successful all–composite resin and all-ceramic restorations was significantly different ($P < .05$), while the survival outcome was not ($P = .059$).

The margin of the ceramic copings was rated too short (score 2) after milling for 58% of restorations. Those restorations were rescanned and remade until a score of 0 was obtained. Three composite resin copings, three ceramic copings, and two veneered ceramic restorations were rejected by the treating clinician at delivery and remade. Overall, there was a decrease of fit after veneering for both restoration types. After cementation, both restorations had the same degree of clinical fit. At the last recall, the marginal fit was mostly affected in the composite resin restorations, with 23.5% of these rated as displaying a light overhang (score 1) or probe hooking (score 2). For the ceramic restorations, the corresponding figure was 16.7% ($P > .5$).

Subjectively rated VAS scores for esthetics and function are shown in Table 4. At the 3-year recall, 64.6% and 61.7% of the all–composite resin crowns were rated > 7 for esthetics and function, respectively. Although the corresponding figures for all-ceramic crowns were 97% and 95%, respectively, they were not significantly different from the results of the all–composite resin restorations.

A significant difference ($P < .05$) for objectively rated color, surface texture, and anatomical form was found between all–composite resin and all-ceramic restorations at baseline and after 1 and 3 years (Table 5). Presence of plaque was detected at the last recall in 63.5% and 73.5% ($P < .05$) and bleeding on gentle probing in 62.5% and 87.1% ($P > .5$) for all–composite resin and all-ceramic restorations, respectively (Table 6). Significant differences between test and control teeth for the presence of plaque ($P < .05$) were found at the 1- and 3-year recalls for both all–composite resin and all-ceramic crowns. Two teeth provided with an all-ceramic restoration showed signs of a recurrent apical infection and were endodontically retreated through an occlusal vent in the restoration. Both teeth and restorations functioned well at the last recall.

Excessive occlusal wear of all–composite resin restorations after 3 years of function was observed (Fig 1). Mean total volume loss (composite resin: n = 8, ceramic: n = 10) after 3 years was 0.57 mm^3 and 0.49 mm^3 ($P = .003$) and mean vertical wear at occlusal contact areas was 174.1 μm and 92.5 μm ($P = .001$) for composite resin and ceramic restorations, respectively (Table 7).

Table 3 Modified Life Table Analysis Reviewing the No. of Restorations at the Beginning of Each Interval, No. of Restorations Lost Due to Dropout, No. of Investigated Restorations for Each Interval, No. of Failed/Unsuccessful Restorations, and Resulting Cumulative Success and Survival Rates

Restoration type/ loading time (mo)	No. of restorations at the beginning of interval	No. of restorations lost due to dropout	No. of restorations at risk	No. of failed (unsuccessful) restorations	Cumulative success rate (%)*	Cumulative survival rate (%)
Composite resin						
0–6	59	6	53	3 (7)	81.1	94.3
7–12	55	4	51	0 (5)	80.5	94.3
13–18	55	4	51	1 (2)	75.7	92.4
19–24	55	5	50	1 (3)	69.7[a]	90.6
25–30	54	20	34	1 (2)	63.5[b]	87.9
31–36	51	17	34	0 (4)	55.6[c]	87.9
Ceramic						
0–6	141	11	130	2 (0)	98.5	98.5
7–12	139	11	128	–	98.5	98.5
13–18	138	35	104	–	98.5	98.5
19–24	137	34	104	0 (3)	95.6[a]	98.5
25–30	112	34	78	1 (2)	92.0[b]	97.2
31–36	86	35	51	0 (6)	81.2[c]	97.2

*Values with the same letter are significantly different from one another ($P < .05$).

Table 4 Distribution (%) of Patient Satisfaction Based on Ordered VAS Scores for Esthetics and Function at Baseline and at 3 Years

Time point/ score*	Esthetics		Function	
	Composite resin	Ceramic	Composite resin	Ceramic
Baseline				
> 9	35.0	33.8	34.7	34.6
> 8	52.0	35.4	45.3	37.8
> 7	7.0	20.0	15.0	20.8
≤ 7	6.0	10.8	5.0	6.8
3 years				
> 9	8.8	5.8	2.9	5.8
> 8	38.2	55.3	41.2	57.2
> 7	17.6	35.9	17.6	32.0
≤ 7	35.4	3.0	38.3	5.0

*VAS scores: 1 = unsatisfactory, 10 = very good.

Table 5 Clinical Rating of Color, Surface, and Anatomical Form According to the CDA Index[23]

Restoration type/ outcome measure/ observation period	No. of observations	CDA values*		
		Romeo	Sierra	Tango
Composite resin				
Color and surface				
3 wk	53	35.7[a]	64.3[b]	–
1 y	51	31.4[c]	68.6[d]	–
3 y	34	32.4[e]	64.7[f]	2.9
Anatomical form				
3 wk	53	35.7[g]	64.3[h]	–
1 y	51	29.4[i]	70.6[j]	–
3 y	34	26.5[k]	70.6[l]	2.9
Ceramic				
Color and surface				
3 wk	130	72.2[a]	27.8[b]	–
1 y	128	84.3[c]	16.7[d]	–
3 y	51	96.0[e]	4.0[f]	–
Anatomical form				
3 wk	130	72.2[g]	27.8[h]	–
1 y	128	84.3[i]	16.7[j]	–
3 y	51	96.0[k]	3.1[l]	0.9

Romeo = range of excellence; Sierra = range of acceptability; Tango = replace or correct.
*Values with same letter are significantly different from one another ($P < .05$).

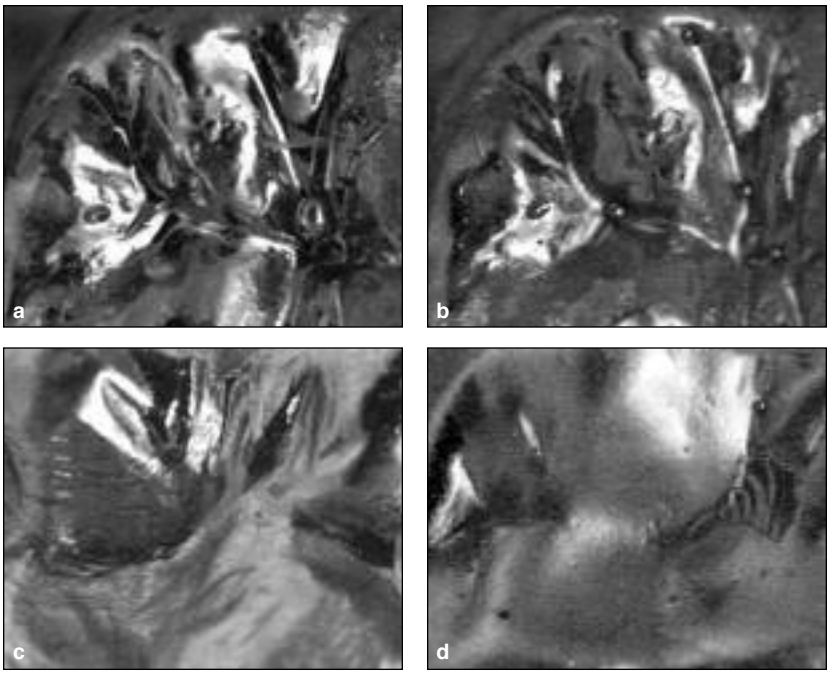

Fig 1 Detailed view of a randomly selected ceramic restoration at **(a)** baseline and **(b)** after 3 years of function, and a randomly selected composite resin restoration at the same time points **(c and d)**. The results of excessive occlusal wear on the all–composite resin crown after 3 years of function are illustrated, with a disappearance of teeth pits and fissures and a flattened occlusal morphology. Only minor changes were observed for the all-ceramic crowns (magnification ×12).

Table 6 Positive Scores* for Plaque and Gingival Indexes at Baseline and After 1 and 3 Years for Restorations and Contralateral Control Teeth

	Composite resin restorations (%)				Ceramic restorations (%)			
	Test		Control		Test		Control	
	PI	GI	PI	GI	PI	GI	PI	GI
3 wk	66.0	59.0	52.8	45.3	27.1	39.6	29.2	28.5
1 y	74.5[a]	68.6	29.4[a]	37.3	47.7[b]	61.7	39.8[b]	43.0
3 y	87.1[c,d]	73.5	32.7[d]	39.7	62.5[c,e]	63.5	37.0[e]	38.6

PI = Plaque Index; GI = Gingival Index.
*Values with same letter are significantly different from one another ($P < .05$).

Table 7 Mean (SD) of Total Volume Loss and Vertical Loss at Occlusal Contact Areas*

	Composite resin restorations				Ceramic restorations			
	6 mo	12 mo	24 mo	36 mo	6 mo	12 mo	24 mo	36 mo
Volume loss (mm^3)	0.1413 (0.0429)	0.2505 (0.0437)	0.4010 (0.036)	0.5657[a] (0.044)	0.09115 (0.0255)	0.1664 (0.0238)	0.3326 (0.0299)	0.4904[a] (0.0463)
Vertical loss (μm)	34.02 (4.77)	55.40 (6.89)	103.2 (14.2)	174.1[b] (36.8)	27.05 (4.38)	42.94 (5.04)	66.60 (18.2)	92.5[b] (34.5)

SD = standard deviation.
*Values with same letter are significantly different from one another (P < .05).

Discussion

Although this study was originally designed as a randomized controlled clinical trial, too many early complications with the composite resin crowns occurred and the last composite restoration was placed at month 22, after agreement of the manufacturer. It is clear that although the ethical committee had given approval for the study, the principal investigator remains the only individual responsible for the study. The potential of bias due to this change in study design is high. However, it is evident from Table 3 that after 24 months (randomized allocation), the success of composite resin restorations (69.7%) significantly differed from ceramic (95.6%) ($P < .05$). This consideration tempers this concern.

Recent studies have indicated that for an esthetic single-tooth replacement in anterior as well as posterior locations, all-ceramic restorations compete with metal-ceramic ones.[4–10] The cumulative survival rate of 97.2% after 3 years for all-ceramic restorations found in this

study is similar to the results of previously mentioned studies, keeping in mind that the present study has a shorter follow-up time. However, much less favorable results were found for all–composite resin restorations, with a survival rate of only 87.9% after 3 years.

Three and four fractures were observed in the ceramic and composite resin groups, respectively. The authors hypothesize that the application of identical tooth preparation protocols resulted in similar curved occlusal surfaces with the same thickness (inter- and intraoperator variability not taken into account). Moreover, there was the prerequisite for inclusion in the study of a stabilized neutro-occlusion for both groups. Having observed a difference in fracture incidence between both groups suggests equal fracture strength for both resin-bonded crown types. As suggested by Tsitrou et al,[26] since minimally prepared composite resin and ceramic resin bonded CAD/CAM crowns demonstrate equal fracture resistance and mode of fracture to that of crowns bonded to traditionally prepared teeth, it is unlikely that the tooth preparation protocol and occlusal scheme as such determined the survival and success rates. Restoration loosening and differences in wear resistance between ceramic and composite resin veneering were the main causes for the poor success rates for the composite resin crowns.

Seventeen restorations had become loose on completion of the study. All loosened restorations were all–composite resin cemented on nonvital teeth restored with a cast post. Six of these restorations became loose several times during the 3-year follow-up period. Restoration dislodgement was thought to have been caused by the relatively large die spacing, initially set at 60 µm, whereas the luting cement itself (Linkmax) has a film thickness of about only 5 µm. Also, the design of the diamond rotary cutting instrument (rounded or flat-edged), with a relatively large diameter (≥ 1 mm), is linked to this. The GN-1 software program automatically recalculates the die coordinates to make it possible for the device to mill the designed coping. This, however, makes the die smaller, resulting in an even larger cement interface. Therefore, the setting of the die spacing was adjusted to 30 µm during the course of the study for both restoration types. What impact this might have had on the survival and success rates remains unclear. Indeed, restoration loosening still occurred when composite resin was used on cast posts. Furthermore, the adhesive luting procedure is technically demanding and the simultaneous bonding to metal (cast post) and composite resin (crown) proved to be insufficient. After an initial short polymerizing time of 3 seconds, the cement is still viscous and it is difficult to remove any excess. A prolonged polymerization time also renders its removal difficult. Moreover, the cement has a color similar to that of the tooth. This, combined with the relative inaccessibility of the approximal surfaces, renders the procedure technically sensitive. The treating clinicians reported that cement removal was particularly difficult around all–composite resin restorations.

Throughout the observation period, the veneering material chipped on six all-ceramic and three all–composite resin crowns. Most chipped restorations were polished intraorally and continued to function satisfactorily. One all-ceramic crown had to be replaced after 2.5 years of function due to a large chipping, which annoyed the patient esthetically. All except one veneer chipping were seen in the molar region. With the GN-1 CAD/CAM system, only the die is scanned and no information from the antagonistic or adjacent teeth is retained in the software. This may cause a divergent thickness of the veneering material to be applied. Thick, unsupported veneering material is reported to be susceptible to material fracture, especially in areas of high functional loading (ie, the molar area).[14] This problem can be solved by molding a custom-designed wax or resin coping aimed at evenly supporting the overlying veneering material, as long as software to relate the antagonistic teeth is lacking. This process, also called double scanning (die scanning and wax coping scanning), should be used whenever there is a large distance between the prepared and opposing or adjacent tooth.

The anatomical form and the occlusal morphology in particular scored better for the all-ceramic crowns. This result was surprising and might have been biased by the color aspect. Indeed, form and color are closely linked to each other. Even at baseline, ceramic crowns scored better than composite resin ones and the difference became larger over time. Another factor that complicated the esthetic outcome of all–composite resin restorations was the labial margin of the coping. Initially, the margin was designed according to the instructions of the manufacturer, was relatively thick, and became largely visible. To avoid this, the margin was thinned manually before veneering the composite resin. Although the veneering material was added in thin successive layers to avoid excessive polymerization shrinkage, marginal adjustment, as mentioned, might have had an impact on its fit.

It is well known that composite resins used for (in)direct restorations in the oral cavity wear at a higher rate than conventional materials[14] and enamel.[27,28] The highest values of wear are generally seen in the posterior regions. Lambrechts et al[29] calculated, using the same device as used in this study, a vertical loss of enamel on molar teeth of 122 µm after 3 years. In this study, the mean vertical wear at occlusal contact areas after 3 years was 92.5 and 174.1 µm for the all-ceramic and all–composite resin crowns, respectively. The substantial wear of the composite resin veneering material

used in this study limits its application, and points to the need for developing more wear-resistant composite resin veneering materials for complete coverage restorations.

Conclusions

The clinical performance of the GN-1 CAD/CAM-generated all-ceramic crowns was found to be similar to that of other all-ceramic CAD/CAM-generated restorations. All–composite resin crowns displayed a significantly inferior success rate compared to all-ceramic restorations after 3 years. Evidence supports the claim that elaborate preclinical material testing is necessary to develop composite resin materials for application in crown restorations that equal the esthetics and functional wear of all-ceramic crowns.

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