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Clinical Research

Glass Ionomer Versus Self-adhesive Cement and the Clinical Performance of Zirconia Coping/ Press-on Porcelain Crowns

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Clinical Relevance

The use of either GIC or self-adhesive resin cement has the same effect on the retention and durability of all-ceramic crowns.

SUMMARY

Objective: This split-mouth clinical study investigated the effect of luting cement on the performance of veneered yttrium-stabilized tetragonal zirconia polycrystal (Y-TZP) zirconia crowns.

Methods and Materials: A total of 60 crowns prepared with Y-TZP coping and press-on porcelain were made with a split-mouth design in 30 participants. The crowns were cemented either with glass ionomer cement (GIC) (Meron, Voco) or with self-adhesive resin cement (Bifix-SE, Voco).

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The restorations were assessed immediately after treatment and after 6, 12, 24, 36, and 48 months using the modified United States Public Health Service criteria. The parameters analyzed were retention, color stability, marginal discoloration, marginal adaptation, surface roughness, anatomic form, and secondary caries. The differences between the groups were analyzed by the Fisher exact test in each period of evaluation. The survival rate was analyzed with the Kaplan–Meier and log-rank test (α=0.05).

Results: After 48 months, 20 participants attended the recall. During the period of evaluation, 1 crown cemented with glass ionomer cement and 1 crown cemented with resin cement lost retention. Color match, marginal discoloration and adaptation, surface roughness, and anatomic form did not change in any of the periods evaluated, and no secondary caries was observed. No significant differences were found between the 2 luting cements for any of the clinical parameters analyzed, nor for the survival rates during the study.

Conclusions: The type of cement did not influence the performance of the crowns after 48 months of clinical use. Both cements resulted in adequate retention rates, aesthetic and functional outcomes, and biological response.

INTRODUCTION

Porcelain fused to metal (PFM) crowns are recommended as a strong and durable restoration for anterior and posterior teeth, and they are referred to as the gold-standard treatment when veneered with feldspathic ceramic.[1,2] However, the popularity of all-ceramic crowns (ACCs) has increased in recent years due to the demand for large reconstructions of damaged teeth with high aesthetic performance materials, even in challenging situations.[3-5] One of the most commonly used materials is yttria-stabilized tetragonal zirconia polycrystal (Y-TZP), which is biocompatible and aesthetic, and which has excellent mechanical properties, including flexural strength and fracture toughness.[3,6,7] It can be used as an infrastructure, veneered with ceramic (press-on or layering application), or as a monolithic crown. Survival rates up to 96.9% for Y-TZP all-ceramic single crowns have been reported.[8]

For conventional PFM crowns, mechanical retention and resistance are obtained by preparing a minimum practical convergence angle to allow for the micromechanical interlocking of the axial walls, cement, and intaglio of the crown[2] with nonadhesive cement such as zinc phosphate. However, with full feldspathic porcelain crowns, an adhesive system was recommended to avoid bulk fracture.[4,5] With the development of stronger ceramic materials, the use of adhesive cements became less essential, and even zinc phosphate or glass ionomer cements (GIC) could be used.[2,3]

Although Y-TZP ceramics, as coping or monolithically, have improved the performance of indirect restorations, a standardized adhesive cementation protocol has not been determined for this type of restoration.[9,10] The lack of a vitreous phase makes it resistant to the hydrofluoric acid etching generally used for adhesive purposes in ceramic restorations. The use of GIC for luting complete crowns has advantages in relation to the traditional nonadhesive cements, mainly the chemical bonding between the cement layer and the dentin through calcium chelation by the polyacrylic acid.[11] However, there is no chemical bonding between the cement and zirconia coping, and thus mechanical retention is also required. Another advantage is fluoride release, which can inhibit demineralization at the interface and close to the margins, preventing secondary caries.[11] Regardless of these favorable characteristics, there is no clear evidence of how glass ionomer cements influence the performance of Y-TZP ceramic restorations.

Resin cements are often used to bond indirect restorations because of their adequate marginal adaptation, high flexural strength,[5] lower solubility, and superior esthetics compared with other luting agents. Additionally, they are reported to provide a durable bond between the ceramic and tooth structure, protecting the crowns from catastrophic fractures.[10] More recently, self-adhesive resin cements (SACs) have been developed to simplify the luting procedure. Instead of a two-step procedure with an adhesive system for bonding the resin cement to the tooth structure and a dedicated primer for bonding to the crown, a single material is used. The cement contains acidic phosphate monomers capable of chemically bonding to both the tooth structure and to zirconia.[12,13] Although some adhesion can be achieved, the bond strength values to enamel and dentin have been reported to be lower than with conventional adhesive systems.[9,14,15]

The different characteristics of the cements available for luting ACCs might affect their clinical performance, mainly with regard to retention and secondary caries. Clinical trials are thus necessary to evaluate the long-term behavior of the restorations and to establish which type of material and technique would provide the best results for luting such restorations. The aim of this

randomized clinical trial was to compare the use of GIC and SAC on the clinical performance of zirconia coping/press-on porcelain crowns. The null hypothesis tested was that the type of luting cement would not influence the performance of the ceramic crown.

METHODS AND MATERIALS

Study Design and Ethical Aspects

This study was a 48-month follow-up of a longitudinal, prospective randomized clinical trial designed as a split-mouth and double-blinded (participant and clinical examiner) study. Aiming to define the parameters of the study, a PICO question was stated: P, adult patients presenting the indication of two single-unit crowns, both in the anterior or both in the posterior area; I, cementation with glass ionomer cement; C, cementation with SAC; and O, clinical performance according to modified United States Public Health Service (USPHS) criteria. A research question was determined: Do single-unit ceramic crowns perform in a clinically similar way when cemented with GIC compared with SAC according to USPHS modified criteria? The reporting of the present study followed the Consolidated Standards of Reporting Trials guidelines.[16] All participants recruited for the study signed an informed consent letter containing the details and objective of the study, and the risks/benefits of the interventions. This study was approved by the Committee for the Protection of Human Participants of the local university and was registered at the website for clinical trials.

Calculation of Sample Size

Aiming to determine the sample size, an online software program (www.sealedenvelope.com) with sample size calculators was adopted. For the present study, the sample size was determined with a calculator for a binary outcome–equivalence trial. The clinical success rate of the all-ceramic crown reported in a previous study was adopted (98.5% at 36 months).[17] A significance level of 0.05, power of 80%, and equivalence limit of 10% were considered. Twenty-six restorations per group were required, and for the split-mouth design adopted, 52 restorations were required. Considering possible dropouts, 60 restorations were provided (30 per group). Thus, 30 participants were selected.

Participant Randomization and Allocation

An online software program was adopted to generate a randomization list (www.sealedenvelope.com). First, the treatment group (GIC–Meron and SAC–Bifix SE) block sizes and list lengths were entered into the software program. Each selected participant received an identification number, and a randomization list was created. For each participant, the 2 treatment options (first and second) appeared randomly in the list. For each option, a unique two-letter and one digit randomization code was created. For instance, for participant 1, the list could be (P1, Group GIC, XS2; P1, Group SAC, RQ4). To correlate the list with the prepared tooth, the ADA numbering system was used, and the first option in the list was applied to the tooth with the smaller ADA number. For example, if the treatment was performed on tooth 3 and 14, the first treatment option was applied on tooth 3 and the second treatment option on tooth 14. A person not involved with the clinical procedures assigned a sealed paper envelope containing the information about which tooth would receive which cement during the luting procedure, as well its randomization code to each participant. All records on the clinical charts used during the evaluation recalls contained just the randomization code. The codes were broken just after the statistical analysis.

Eligibility Criteria for Participants

The participants received a clinical examination. Inclusion criteria were as follows: at least 18 years of age with good general health, healthy gingival tissue, and an indication for two single crowns in the anterior or posterior area. The participants presented normal occlusion according to the Angle classifications, without posterior or anterior crossbite or functional crossbite. The force distribution among the teeth was equivalent, and the number of posterior teeth was the same on both sides. The occlusal force should be considered normal, without signs of bruxism and clenching. The exclusion criteria were as follows: poor oral hygiene, periodontal diseases, the use of a removable prosthesis or orthodontic appliances, and an implant-supported opposing tooth. Tooth mobility grade 1 (maximum horizontal mobility of 1 mm) was accepted (maximum grade). The prospective abutment tooth was vital or optimally endodontically treated. The antagonist and adjacent teeth were present. The condition of the opposing tooth (natural, restored with composite resin, amalgam, or ceramic), core material (dentin, glass fiber post, and composite resin or metal), and the reason for treatment were recorded at the beginning of the study. To compare the clinical performance of the luting agents, a split-mouth design was followed, and each selected participant received both treatments. Therefore, the 30 participants received 60 single crowns.

Blinding

Participants and examiners were blinded to the interventions. The operators were not blinded since the procedures involved in the cementation step could not be masked.

Tooth Preparation

The operators were fully informed about all the details of the study's protocol, as well as the rationale, objectives, and design. Additionally, the operators received training on dental manikins in an attempt to standardize the tooth preparation. All clinical procedures were monitored by the principal investigator. Before tooth preparation, the tooth shade was analyzed for each crown based on the shade of the neighboring teeth using the Vitapan Classical Shade Guide (Vita Zahnfabrik, BadSäckingen, Germany). Information about the type of tooth included in the study, the reason for performing the procedure, the kind of core, and opposing tooth are described in Table 1. The teeth were prepared according to the following parameters: preferably, placing the finishing line supragingivally or equigingivally; the margin design was a 1-mm-wide chamfer;[18] the axial reduction was 1.5 mm; the occlusal/incisal reduction was 1.5–2.0 mm; the total occlusal/incisal convergence was 6–15 degrees; and the line geometry was rounded.[19] For the axial and occlusal/incisal reductions and the definition of the chamfer margin, round-end taper diamond rotary instruments of appropriate sizes were used.

Table 1. *Distribution of Opposing Teeth, Core Material, Reasons for the Replacement, and Type of Teeth of all Groups*

Characteristics	Type	GIC	SAC
Core material	Metallic	7	6
	Glass fiber + composite	5	8
	Dentin	18	16
Opposing teeth	Enamel	25	25
	Composite	2	1
	Amalgam	1	2
	Ceramic	2	2
Reasons for replacement	Caries	7	9
	Fracture	10	9
	Esthetic	11	10
	Other	2	2
Type of teeth	Molar	12	12
	Premolar	8	8
	Incisors	10	10

Abbreviations: GIC, glass ionomer cement; SAC, self-adhesive resin cement.

Interim Restoration and Impression

After the tooth preparation steps, direct interim crowns were fabricated using an autopolymerizing bis-acrylic composite resin (Structur 2 SC; Voco) according to the manufacturer's instructions. To prepare the interim crown, a quadrant impression of each tooth before the preparation was made with irreversible hydrocolloid (Jeltrate; Dentsply Sirona). When the original crown had significant loss of structure, a wax-up was performed on a gypsum cast, from which the impression was made. After the tooth preparation, the bis-acrylic material was mixed and applied inside the impression and inserted in the mouth. After 90 seconds, the impression was removed from the mouth, and after 3 minutes the crown was removed from the impression, finished, and polished. Retraction cords (Ultrapack; Ultradent) were then placed according to the double-cord technique. For this purpose, a thin retraction cord (#000) soaked in aluminum chloride hemostatic solution (Hemostop; Dentsply Sirona) was placed into the sulcus, and a second retraction cord (#00) was placed on top of it. The outer retraction cord was removed after 5 minutes. Impressions were made using a simultaneous dual-mix technique and a polyvinyl siloxane material (Express XT; 3M Oral Care). The interocclusal registration was done with autopolymerizing polyvinyl siloxane (Registrado Clear; Voco). After that, the interim crowns were cemented with eugenol-free interim cement (Provicol; Voco). Casts were prepared with Type IV extra hard dental die stone.

Fabrication of Crowns

The casts were laser scanned with a Cercon Eye CAD module (Dentsply Sirona). The coping structure was milled out of a presintered Y-TZP block (Cercon Base; Dentsply Sirona) using a CAD/CAM System (Cercon Brain; Dentsply Sirona) and evaluated on the definitive die. The milled coping was subsequently postsintered in the Cercon Heat (Dentsply Sirona) high temperature furnace using the 6-hour sintering program at a maximum temperature of 1350°C. Following this, a wax pattern was made, and a press-on ceramic (Cercon Ceram Press; Dentsply Sirona) was pressed onto the coping. Cercon Ceram Press is composed of silica, alumina, potassium oxide, sodium oxide, and calcium oxide. The crowns were fabricated by the same laboratory technician.

Cementation of Crowns

The interim crowns were removed, and the tooth preparation was cleaned. The ceramic crowns were seated, and the occlusal and proximal contacts were evaluated. For occlusal evaluation, a thin articulation foil was placed between the opposing teeth during the maximum intercuspation position and during the protrusive and lateral movements of the mandible. Whenever necessary, the contacts on the ceramics were adjusted, and the surface was polished, resulting in an adequate interocclusal relationship. The proximal contacts were evaluated with dental floss and were also adjusted whenever necessary, resulting in physiologically acceptable proximal surface contacts. The marginal adaptation was checked with an explorer before luting. The definitive luting was performed with a GIC or an SAC (Table 2) according to the manufacturer's instructions. The intaglio surface of the crowns was airborne-particle abraded with aluminum oxide particles and cleaned in an ultrasonic water bath. The Bifix SE cement was provided in a self-mixing syringe. The cement was dispensed directly into the crown, which was seated, and any excess was removed. The buccal and lingual sides were light polymerized, followed by the chemical polymerization of the material. For Meron, 1 drop of liquid and 1 scoop of powder were dispensed on a suitable mixing pad. The powder was divided into 3 portions, and each one was mixed into the liquid with a solid plastic spatula. The cement was dispensed into the crown, which was seated on the prepared tooth and any excess cement was removed.

Clinical Assessment of Ceramic Crowns

All the crowns were evaluated by 2 independent, previously calibrated observers, who were blinded to the treatment, according to the modified USPHS criteria[20] and additional parameters. The criteria were retention, color stability, marginal discoloration, marginal adaptation, surface roughness, anatomic form, and secondary caries, as shown in Table 3. For each criterion, 1 of 3 or 1 of 4 scores were applied. In addition, occlusal contacts, gingival index, pulpal status, and chipping and wear of the opposing tooth were analyzed for each crown according to the parameters presented in Table 3. Baseline data were recorded 7 days after cementation. Follow-up appointments were made 6, 12, 24, and 48 months after insertion. The following criteria were selected to determine the need for replacement: fracture of the framework material, major chipping that is not repairable by composite resin material, caries in the abutment tooth, and tooth loss because of biological complications (eg, fracture of abutment tooth, irreversible pulpitis).

Statistical Analysis

For the statistical analysis, an intention-to-treat protocol was considered.[21] Data were analyzed using the Fisher exact test (α=0.05) for each individual parameter and the following periods of evaluation (7 days and 6, 12, 24, and 48 months). To determine the survival rate regarding restoration loss (failures), the Kaplan–Meier estimate was performed, followed by the log-rank (Mentel-Cox) test.[22] The tests were performed using Statistica for Windows (StatSoft) and GraphPad (GraphPad Software) software programs.

RESULTS

Eighteen of the 48 screened participants did not achieve the study eligibility criteria previously described. Therefore, 30 patients who needed 2 complete crowns were enrolled (Figure 1). The failure of treatment was considered as the loss or detachment of the crown for various reasons. The percentage of each score for all analyses is presented in Table 4. The Kaplan–Meier survival analysis was performed, and the survival curve is presented in Figure 2. The log-rank (Mentel-Cox) test showed nonsignificant differences between the curves (p=0.5619). Both groups presented a 95.8% survival rate after 4 years. Examples of the crowns after 4 years are presented in Figure 3.

Table 2. *Luting Agents Tested (Information Provided by Manufacturer)*

Cement	Type	Composition	Manufacturer
Meron	Glass ionomer luting cement	Powder: fluoro-aluminosilicate glass, polyacrylic acid Liquid: tartaric acid and distilled water	VOCO, GmbH, Germany
Bifix SE	Self-adhesive resin cement	Bis-GMA, UDMA, Gly-DMA, phosphate monomers, glass fillers, aerosil silica, initiators, stabilizers Filler content: 70% w/w	

Abbreviations: Bis-GMA, bisphenol A-glycidyl methacrylate; Gly-DMA; UDMA, urethane dimethacrylate.

Table 3. *USPHS Criteria Used for Clinical Assessment*	
Criteria	**Scores**
1. Retention	A) Cemented crown is retained.
	B) Cemented crown is partially retained.
	C) Cemented crown is not retained (released).
2. Color match	A) Crown remains equal to the adjacent tooth structure in color, shade, and translucency.
	B) Change on shade or translucency in tolerable values when compared to the adjacent tooth structure.
	C) Change on shade or translucency values outside the tolerable compared to the adjacent tooth structure.
3. Marginal discoloration	A) No evidence of discoloration at the margin between tooth and crown cemented.
	B) Surface discoloration at the margin between tooth and crown cemented.
	C) Discoloration penetrating deeper in the margin between tooth and crown cemented.
4. Marginal adaptation	A) No visible evidence of crevice along the margin, without penetration of the explorer.
	B) Visible evidence of cracks along the banks where the explorer can penetrate.
	C) The explorer penetrates deeply into the cracks between the crown and preparation.
5. Surface roughness	A) Visually the surface is well polished, glossy, with no detectable roughness.
	B) The roughness is visually detectable.
	C) Roughness is coarse, visible, and detectable. The surface is opaque.
6. Anatomic form	A) Crown is continuous and anatomically preserved. The anatomic form is ideal.
	B) Anatomic form differs from the homologous tooth but does not affect appearance. Other irregularities in the dentition allow this to be esthetically and functionally acceptable.
	C) Anatomic form is altered and unsatisfactory, and the esthetic result is unacceptable. Replacement of the crown is necessary.
7. Secondary caries	A) No evidence of secondary caries at the margins of the preparation.
	B) With evidence of secondary caries at the margins of the preparation.
8. Occlusal contacts	A) Adequate
	B) Excessive
	C) Absent
9. Gingival index	0) Normal gingiva
	1) Mild inflammation
	2) Moderate inflammation
	3) Severe inflammation
10. Pulpal status	A) Vital
	B) Irreversible inflammation/necrosis
	C) Endodontic treatment
11. Chipping	A) Minor chipping (the chipping is smaller or equal to 2 × 2 mm, and no coping material is visible).
	B) Major chippings (the chipping is larger than 2 × 2 mm, or the coping material is visible).
	C) Fracture of the framework material.
12. Wear of the opposing teeth	A) Absent.
	B) Wear just on enamel or with dentin exposition in one point.
	C) Wear reaching dentin until 1/3 of the crown.
	D) Wear reaching dentin > 1/3 of the crown.
Abbreviation: USPHS, United States Public Health Service.	

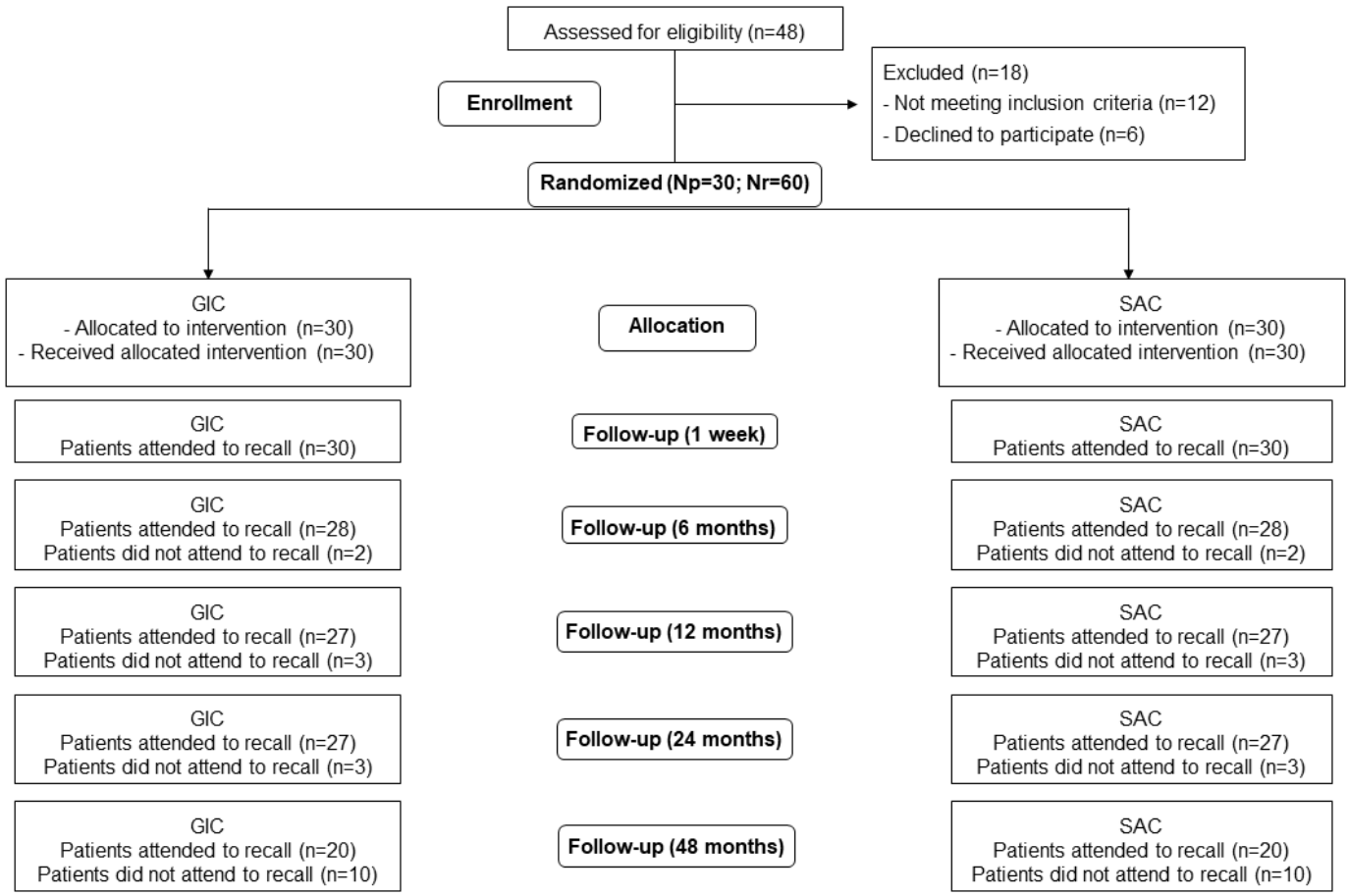

Figure 1. *Flowchart of the study (CONSORT). Abbreviations: CONSORT, Consolidated Standards of Reporting Trials; GIC, glass ionomer cement; SAC, self-adhesive resin cement.*

DISCUSSION

The clinical performance of the zirconia coping/press-on ceramic crowns cemented with either GIC or SAC presented similar clinical behavior after 48 months of evaluation. Both cements showed adequate retention rates and biological response for all the evaluated criteria, therefore the null hypothesis was accepted.

When considering the long-term clinical success of complete crown restorations, not only is the use of a strong material important but so is the retention to the remaining tooth structure produced by mechanical interlocking or adhesion of the cement to the tooth and the intaglio surface of the crown.[7] In addition, the thickness of the cementation interface, as well as the resistance of the cement to degradation in the oral environment is relevant. The presence of secondary caries around the margins is also a common cause of failure in indirect restorations,[11] and therefore the appropriate selection of cement becomes essential for clinical success. Although all-ceramic crowns, monolithic zirconia, or copings can be cemented with a variety of materials, differences in clinical outcomes of the different cements have not been fully demonstrated.[23]

A systematic review reported that some SACs have shown good clinical behavior similar to that of conventional resin cements[23] because the interaction between the cement acidic monomers and the hydroxyapatite form chemical bonds Oral Care, albeit with lower bond strength values, from a more superficial interaction with the tooth structure.[24,25] However, the self-adhesive material avoids a more complex bonding procedure, which is more susceptible to failures.[12,15] Various cement brands are available, with different formulations, which may have a great impact on their clinical behavior. The self-adhesive luting systems still need to be improved, since some in vitro studies reported that these materials presented issues regarding marginal adaptation and retention, which may be related to handling errors such as excessive drying of the cavity or residual moisture.[7,12,26]

The SAC used in the present study contained phosphate and phosphonate groups. An acidic pH provided by

Table 4. *Results of Clinical Evaluation*

Clinical evaluation		**Baseline**		**6 months**		**12 months**	
Criteria	Scores	n = 30	n = 30	n = 28	n = 28	n = 27	n = 27
		GIC	SAC	GIC	SAC	GIC	SAC
Retention	A	30 (100%)	30 (100%)	28 (100%)	28 (100%)	27 (100%)	26 (96.30%)
	B	–	–	–	–	–	–
	C	–	–	–	–	–	1 (3.70%)
Color match	A	30 (100%)	30 (100%)	28 (100%)	28 (100%)	27 (100%)	27 (100%)
	B	–	–	–	–	–	–
	C	–	–	–	–	–	–
Marginal discoloration	A	30 (100%)	30 (100%)	28 (100%)	28 (100%)	27 (100%)	27 (100%)
	B	–	–	–	–	–	–
	C	–	–	–	–	–	–
Marginal adaptation	A	30 (100%)	30 (100%)	28 (100%)	28 (100%)	27 (100%)	27 (100%)
	B	–	–	–	–	–	–
	C	–	–	–	–	–	–
Surface roughness	A	30 (100%)	30 (100%)	28 (100%)	28 (100%)	27 (100%)	27 (100%)
	B	–	–	–	–	–	–
	C	–	–	–	–	–	–
Anatomic form	A	30 (100%)	30 (100%)	28 (100%)	28 (100%)	27 (100%)	27 (100%)
	B	–	–	–	–	–	–
	C	–	–	–	–	–	–
Secondary caries	A	30 (100%)	30 (100%)	28 (100%)	28 (100%)	27 (100%)	27 (100%)
	B	–	–	–	–	–	–
Occlusal contact	A	30 (100%)	30 (100%)	28 (100%)	28 (100%)	27 (100%)	27 (100%)
	B	–	–	–	–	–	–
	C	–	–	–	–	–	–
Gingival index	0	21 (70%)	18 (60%)	23 (82.14%)	25 (89.30%)	23 (85.18%)	23 (85.18%)
	1	6 (20%)	10 (33.33%)	3 (10.71%)	2 (7.14%)	3 (11.11%)	3 (11.11%)
	2	3 (10%)	2 (6.67%)	2 (7.15%)	1 (3.56%)	1 (3.71%)	1 (3.71%)
	3	–	–	–	–	–	–
Pulpal status	A	18 (60%)	16 (53.33%)	18 (60%)	15 (53.57%)	17 (62.96%)	14 (51.85%)
	B	–	–	–	–	–	–
	C	12 (40%)	14 (46.67%)	10 (35.71%)	13 (46.43%)	10 (37.04%)	13 (48.15%)
Chipping	A	30 (100%)	30 (100%)	27 (96.43%)	28 (100%)	26 (96.30%)	26 (96.30%)
	B	–	–	1 (3.57%)	–	1 (3.70%)	1 (3.70%)
	C	–	–	–	–	–	–
	D	–	–	–	–	–	–
Wear of the opposite tooth	A	30 (100%)	30 (100%)	27 (96.43%)	28 (100%)	26 (96.30%)	26 (96.30%)
	B	–	–	1 (3.57%)	–	1 (3.70%)	1 (3.70%)
	C	–	–	–	–	–	–
	D	–	–	–	–	–	–

Abbreviations: GIC, glass ionomer cement; SAC, self-adhesive resin cement.

Table 4. Results of Clinical Evaluation (continued)

Clinical evaluation		**24 months**		**48 months**	
Criteria	Scores	n=27	n=27	n=20	n=20
		GIC	SAC	GIC	SAC
Retention	A	26 (96.30%)	26 (96.30%)	20 (100%)	20 (100%)
	B	–	–	–	–
	C	1 (3.70%)	1 (3.70%)	–	–
Color match	A	26 (100%)	26 (100%)	19 (95%)	19 (95%)
	B	–	–	1 (5%)	1 (5%)
	C	–	–	–	–
Marginal discoloration	A	26 (100%)	26 (100%)	17 (85%)	17 (85%)
	B	–	–	3 (15%)	3 (15%)
	C	–	–	–	–
Marginal adaptation	A	26 (100%)	26 (100%)	20 (100%)	20 (100%)
	B	–	–	–	–
	C	–	–	–	–
Surface roughness	A	26 (100%)	26 (100%)	20 (100%)	20 (100%)
	B	–	–	–	–
	C	–	–	–	–
Anatomic form	A	27 (100%)	26 (100%)	20 (100%)	20 (100%)
	B	–	–	–	–
	C	–	–	–	–
Secondary caries	A	26 (100%)	26 (100%)	20 (100%)	20 (100%)
	B	–	–	–	–
Occlusal contact	A	26 (100%)	26 (100%)	20 (100%)	20 (100%)
	B	–	–	–	–
	C	–	–	–	–
Gingival index	0	24 (92.30%)	25 (96.15%)	16 (80%)	16 (80%)
	1	2 (7.70%)	1 (3.85%)	2 (10%)	2 (10%)
	2	–	–	2 (10%)	2 (10%)
	3	–	–	–	–
Pulpal status	A	13 (41.85%)	14 (51.85%)	17 (85%)	16 (80%)
	B	–	–	–	–
	C	14 (51.85%)	13 (41.85%)	3 (15%)	4 (20%)
Chipping	A	26 (96.30%)	26 (96.30%)	19 (95%)	20 (100%)
	B	1 (3.70%)	1 (3.70%)	–	–
	C	–	–	1 (5%)	–
	D	–	–	–	–
Wear of the opposite tooth	A	26 (100%)	26 (100%)	20 (100%)	20 (100%)
	B	–	–	–	–
	C	–	–	–	–
	D	–	–	–	–

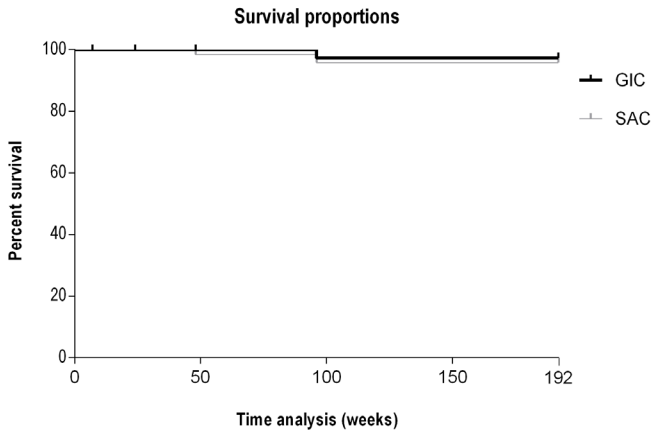

Figure 2. *Kaplan–Meier curve demonstrating survival rate of the cements for all-ceramic restorations with 95% confidence interval. Abbreviations: GIC, glass ionomer cement; SAC, self-adhesive resin cement.*

these molecules etched and simultaneously penetrated into the enamel and dentin.[24] These functional groups interact with calcium in the hydroxyapatite of enamel and dentin and can also react with the ceramic oxide surface without any pretreatment.[16,24,27] This could explain how the cement remained attached to the zirconia coping in the debonded crown in the present study (Figure 3F).

In the present study, most of the crowns (60% for GIC and 53.4% for SAC) were cemented on dentin. This substrate has been considered an adhesive challenge because of intrinsic moisture and its organic and inorganic composition. Nevertheless, SACs have shown stable adhesion to dentin because of their acidic monomers.[24,26-28]

The characteristics of higher viscosity and reduced wettability of the SACs in comparison with conventional adhesive systems explain the reduced bond strength of Bifix SE (15.28 MPa).[14,15] However, when analyzing the bonding of a cemented crown, the bonding of the cement to the tooth, and also to the intaglio surface of the ceramic coping, must be considered. The bond strength of the SACs RelyX U200 (3M Oral Care) and Bifix SE (Voco) to Y-TZP zirconia has been reported to be statistically similar.[27] However, the surface treatment of the ceramic before luting has a significant effect, and airborne-particle abrasion has been recommended.[27] The cement tested in the current clinical study (Bifix SE) showed a bond strength of 12.03 MPa to the Y-TZP zirconia after airborne-particle abrasion. The SAC seems to be an effective alternative for dentin substrate and also for zirconia.[28,29] However, these studies were in vitro, and clinical trials are scarce.

GIC is also expected to bond to the tooth structure by molecular interactions between the polyacrylic acid and the calcium of the mineralized tissues, thus providing a strong chemical bond to dentin and enamel with low solubility.[11] However, bonding to an artificial core or coping material is lacking.

The loss of retention rate observed in the present study of only 3% both for GIC and SACs was lower than the 7% previously reported in a practice-based retrospective study[30] with zinc phosphate and SAC. Only 2 of 60 crowns, 1 after one year (resin cement) and the other between 12 and 24 months (GIC) failed, evidencing the good performance of the tested materials during the study period.

Reducing the convergence angle and increasing the surface area of the tooth preparation increases

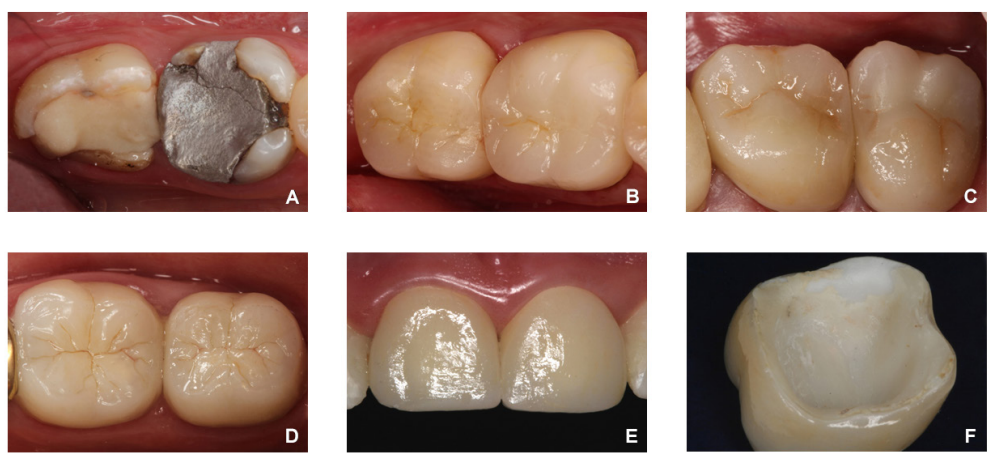

Figure 3. *Clinical pictures of two adjacent crowns. (A), (B): Clinical aspect before the treatment and after 4 years. (C)–(E): Aspects of the other patients with two adjacent crowns after 4 years. (F): Debonded crown showing that most of the self-adhesive resin cement remained bonded to the crown.*

mechanical retention for the crown.[18,19] An optimal tooth preparation, which is important in order to avoid debonding with conventional cements, is also acceptable with any other cement, including the adhesive ones.[25] In the present study, a similar clinical performance was observed for the 2 cements. The mechanical retention provided by the preparation may have been sufficient to retain the crowns despite the bonding characteristics of the cements and could explain the results. Perhaps, in challenging situations such as short crowns or excessively tapered preparations, the role of bonding would increase and have a greater influence on the results.[31]

Chipping is one of the most common clinical issues related to ceramics. This is a complex clinical situation, with little evidence about its mechanisms.[8] The crowns will still be clinically acceptable after polishing when the fracture is not severe.[32] In the present study, only minor chipping was observed, with a low incidence after 4 years (5% for only 1 crown cemented with GIC), although no relationship was found between the type of cement and crown chipping. Studies have been performed to investigate this occurrence, and several reasons have been suggested, such as surface defects of the ceramic, improper design of the zirconia framework,[33] overloading, fatigue, low fracture toughness,[34] low thermal conductivity,[32] and even parafunctional activity that was not detectable.[8] A previous study has also reported a low percentage of chipping (6.6%) in the first year.[8]

In the present study, no biological complication was encountered in the period of evaluation. Although some marginal discoloration was observed after 48 months (15% for both cements), proper marginal adaptation was observed. Secondary caries were also not detected, which could be associated with the reliable sealing provided by the luting materials and directly related to individual caries risk.[11,35] Although better caries inhibition would be expected for the GIC, nonsignificant differences were observed in relation to the resin cement. In fact, regardless of the material used, individual caries risk seems to be the major determinant for the development of secondary caries.[11] Moreover, marginal adaptation is considered one of the principal criteria for assessing the long-term success of tooth restorations.[36,37] Studies with more than 5 years of follow-up have shown the absence of secondary caries when good marginal fit and reliable sealing provided by cements are present.[8,17,30]

The present study showed that luting ceramic crowns with either GIC or SAC presented satisfactory performance. After 48 months, the survival rate was 95.8%, which is consistent with the rates of previous clinical follow-up studies.[35,38] Different results may be obtained in future recalls, because clinical factors such as aging and masticatory loads may influence the long-term behavior of the restorations.

CONCLUSIONS

Ceramic crowns cemented with GIC or SAC presented with similar behavior after 48 months of clinical use. Both cements showed adequate retention rates, aesthetic and functional outcomes, and biological response.

Regulatory Statement

This study was conducted in accordance with all the provisions of the human subjects oversight committee guidelines and policies of the Institute of Science and Technology. The approval code issued for this study is 20722713.0.0000.0077.

Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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