Eleven-Year Retrospective Survival Study of 275 Veneered Lithium Disilicate Single Crowns

Piero Simeone, DDS, MSc, CDT[1]
Stefano Gracis, DMD, MSD[2]

The aim of the present clinical retrospective study was to evaluate the long-term survival and clinical performance of veneered lithium disilicate single restorations in anterior and posterior areas after up to 11 years. Following a rigid protocol, 275 lithium disilicate single crowns (35 IPS Empress II and 240 e.max Press) were cemented over 11 years, in 106 patients, using an adhesive technique; of these, 106 were anterior (38.5%) and 169 posterior (61.5%) teeth. Teeth receiving endodontic therapy and composite reconstruction (50%) and teeth with preexisting metal-ceramic crowns, called prosthetic retreatments *(PR; 65%), were included as well. Of the 106 patients enrolled in the study, 25 (23.5%) were diagnosed with bruxism habits, and 7 of these patients (6.6% of all patients) received full-mouth single lithium disilicate restorations (FMR). The exclusion criteria for this retrospective clinical study were: monolithic lithium disilicate crowns, teeth with cast post and cores, implant-supported all-ceramic crowns, active periodontitis, and/or poor oral hygiene. Clinical reevaluation was performed by the clinicians who prepared and luted them during maintenance appointments between January 2012 and October 2013. Number of restoration failures and characteristics of failures were recorded. Marginal adaptation and marginal discoloration were evaluated based on the Cvar-Ryge criteria. The overall cumulative survival rate was 98.2%. The failures recorded were the result of either mechanical failure or debonding. Five crowns failed mechanically—three because of chipping and two because of core fracture—but only the two fractured were replaced. None of the failed crowns was associated with the bruxers with FMR. A total of 15 crowns debonded (5.5% of all crowns); however, 11 belonged to the same patient who had endodontically treated and reconstructed abutments. In this retrospective clinical evaluation of up to 132 months, veneered lithium disilicate single crowns had a low failure rate.*
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[1]Private Practice, Rome, Italy.
[2]Private Practice, Milan, Italy.

Correspondence to: Dr Piero Simeone, Via Antonio Bertoloni 1/E pal F, 00197 Rome, Italy.
Email: pierosimeone@hotmail.it

The demand for high-quality esthetic restorations in prosthetic dentistry has resulted in the development of all-ceramic materials for inlays, onlays, veneers, single crowns, and bridges.[1]

All-ceramic crowns have become very popular because most clinicians and patients consider metal-free restorations more attractive.[2,3] Today's esthetic concerns have increased the demand for these materials not only when prosthetically restoring a tooth for the first time, but also when replacing existing metal-ceramic restorations. In the early years, all-ceramic systems had high failure rates because of fractures, especially when used for the fabrication of posterior crowns.[4–8] In recent decades, however, the development of new high-strengh ceramic materials and adhesive luting techniques have allowed clinicians to use a metal-free approach virtually in any situation.[9]

IPS Empress II and E-max Press (both Ivoclar Vivadent) are heat-pressed glass-ceramic materials with a crystalline phase consisting of lithium disilicate and lithium orthophosphate, which increases resistance without negatively influencing the translucency; their biaxial flexural strength is 407 ± 45 MPa.[10] This material is used to fabricate both high-strength cores for porcelain support and full contour (monolithic) restorations.[11]

In vitro studies have investigated the flexural strength of all-ceramic crowns.[12,13] In vivo studies, however, have been the standard for evaluating the performance and acceptance of restorative materials and crowns. Few have described the survival of IPS Empress restorations and evaluated the variables that might affect their survival.[14–17]

Only one study has reported long-term survival data on lithium disilicate single crowns.[18] In general, clinical studies show that crowns placed in the posterior region tend to have a higher fracture rate; furthermore, molar crowns reveal higher failure rates than premolar crowns.[19] Patients with severe bruxism are generally excluded from this type of study because they are considered to be at high risk for fracture.

The purpose of this retrospective study was to evaluate the success rate and estimated survival rate of lithium disilicate restorations placed in a private dental practice over an 11-year period. The restoration-specific failure rate was investigated to characterize both patient- and restoration-specific variables, and to identify those that may help predict ceramic restoration failures. Furthermore, preliminary data for the bruxer subgroup in the present study are presented.

Method and materials

Over an 11-year period, from January 2002 to October 2013, 106 patients were treated in a private dental clinic by the same clinician; 275 veneered lithium disilicate single crowns were placed, 106 were for anterior and 169 for posterior natural teeth. All patients were included in a 3- to 6-month professional hygiene maintenance program. A minimum of 1 year of observation was the criterion to include crowns in this study. The exclusion criteria were poor oral hygiene, active periodontitis, probing depths more than 4 mm associated with bleeding on probing, and presence of cast metal post and cores. Implant-supported restorations and monolithic lithium disilicate crowns were also not included in this study. On the other hand, patients with preexisting metal-ceramic crowns needing replacement because of esthetic, biological, or functional reasons were included in the study (65%). These were called *prosthetic retreatments* (PRs) and were recorded separately to follow the behavior of disilicate crowns bonded on a substrate whose nature may be different from that of freshly cut dentin/enamel. All other crowns, without any preexisting restorations, were included for functional and esthetic reasons.

Twenty-five (23.5%) of the 106 patients enrolled presented with occlusal signs and clinical symptoms of bruxism, and after preliminary treatment for bruxism (occlusal splint, physiotherapy, and drugs), seven (6.6% of total) patients received an all-ceramic single crown full-mouth restoration (FMR). The assumption was that this group of crowns had a higher risk for crown fracture.[20–27]

Tooth preparation and impression procedures

The teeth were prepared with a 1- to 2-mm overall reduction, except for the occlusal and incisal surfaces, which were reduced by 2 mm. A circumferential chamfer preparation with rounded smooth contours was chosen for all treated areas. All internal angles were rounded to reduce stress concentration during fabrication, cementation, and function.

Whenever possibile, the crown margins in the molar region were placed equigingival or supragingival to facilitate impression making, crown luting, and reevaluation.

The margins of the anterior teeth were always placed slightly in the crevicular sulcus. In these cases, a nonimpregnated retraction cord was used (Ultrapak, Ultradent) for refining the preparation finish line. No enamel was found in the prepared abutments of the PR crowns; quite often, margins were located on radicular structure because of loss of periodontal support. The ET teeth were restored with a composite core, associated whenever necessary with an esthetic fiber post (Tech-Post, ISASAN) according to well-known guidelines.[28,29]

Either polyvinylsiloxane (Aquasil, Dentsply) or polyether (Impregum Penta, 3M ESPE) impression materials were used for all crowns. A custom tray was used whenever an impression of more than three units per arch had to be detected.

Provisional crowns were delivered for occlusal and esthetic reasons and also to maintain gingival health and tooth position; they

were luted using a provisional cement containing eugenol (Temp-Bond, Kerr).[30]

Articulator mounting and setting

Zeiser master casts were produced from the impressions, and mounted on a semiadjustable articulator (SAM III, SAM Germany and Reference SL, Gamma Dental). A facebow was routinely used to transfer the upper arch to the articulator anytime more than three units had to be fabricated. In cases of a complete arch or full-mouth rehabilitation, condylographic recordings (Condylograph CADIAX, Gamma Dental) were made for diagnosis, planning, and setting of the articulator for horizontal condylar inclination, Bennett angle, immediate and progressive side shift and anterior guidance path. In addition, lateral cephalometry was produced for the FMR patients (CADIAS, GAMMA Dental) to analyze the variations of the lower facial height (vertical dimension), occlusal plane, and anterior guidance inclination.[31]

The mandibular casts were mounted in centric relation if all teeth in an arch were to be crowned, and in maximum intercuspation in all other cases. The intended occlusal scheme for all ceramic restorations was an anterior-guided protrusive and canine-guided laterotrusive movement.

Cementation procedures

The restorations were fabricated by three dental technicians following the manufacturer's recommendations. Each crown was assessed for proximal contacts, occlusal relationships, shade matching, and marginal adaptation.

Cementation followed a precise protocol.[32] Before cementation, the restorations were etched with 5% hydrofluoric acid (HF IPS Ceramic Etching gel, Ivoclar Vivadent) for 20 seconds, washed with water for 5 minutes in an ultrasonic bath, dipped in alcohol for 3 minutes, dried, and silanized with Monobond-S (Ivoclar Vivadent) applied to the inner surface of the crowns for 60 seconds without polymerization. After provisional removal, the prepared teeth were cleaned with an ultrasonic scaler, and brushed with a scrub cream (Consepsis Scrub, Ultradent). The abutment surface was treated with a three-step adhesive procedure: 37% phosphoric acid was placed on enamel for 30 seconds and on dentin for 15 seconds (total etch); the tooth was then rinsed and dried for 2 seconds; finally, a primer-adhesive (Heliobond Syntac, Ivoclar Vivadent) was applied in combination with a dual-cured resin cement (Variolink, Ivoclar Vivadent). The operative field was isolated with cotton rolls and high-speed suction. A rubber dam was not used for cementation, because the preparation margins were generally intracrevicular.

Different luting agents have been used (Fig 3): a self-etching adhesive two-step dual-polymerizing composite cement (Multilink Automix, Ivoclar Vivadent for 29.2% of the crowns), two one-step cements (RelyX/S ADH, 3M Espe, and Speedcem, Ivoclar Vivadent for 12.7% and 22.5% of the restorations, respectively),[33,34] and a three-step cement (Variolink and Variolink Veneer for the remaining 35.6%). Before initial light polymerization, cement was removed from the interproximal areas with Superfloss (Oral-B). Cement excess was removed from the buccal and lingual surfaces using a manual scaler (Periodent USA H6/H7) after 2 seconds of light polymerization. Final polymerization was performed for additional time (20 seconds per side) with a 930-mW/cm halogen curing light (PolyiLUX II, Kavo).

The occlusion was refined whenever necessary and the adjusted ceramic surfaces were polished with diamond-impregnated silicon disks and felt wheels with polishing paste (Enamel Shiny, Micerium). After cementation and finishing, the occlusion was checked again carefully under ×4.5 magnification, and if indicated, adjusted in canine-guided occlusion.[35–40]

Clinical evaluation method

The Cvar-Ryge quality criteria[41] were used to standardize the clinical evaluation of the crowns. Restorations were clinically examined by two dentists after careful calibration.

The patients were examined every 3 to 6 months during routine hygiene appointments.

All patient recalls took place between January 2012 and October 2013.

Table 1 Clinical rating of restorations (Cvar-Ryge criteria)

Parameters	Code word	Rating of restorations
Marginal discoloration	Alfa	No discoloration of the margin.
	Bravo	Superficial discoloration, but not penetrating in a pulpal direction.
	Charlie	Discoloration penetrates along the margin of the restorative material in a pulpal direction.
Marginal adaptation	Alfa	The explorer does not catch when drawn across the restoration-tooth margin either from tooth to restoration or vice versa. If a catch exists, there is no visible crevice along the periphery of restoration. The edge appears to adapt closely to the tooth structure along the entire periphery of the restoration.
	Bravo	The explorer does catch and there is visible evidence of a crevice into which the explorer penetrates, indicating that the edge of the restoration does not adapt closely to the tooth structure. The dentin or base is not exposed, and the restoration is not mobile, fractured, or missing in part or in toto.
	Charlie	The explorer penetrates into the crevice, indicating that a space exists between the restoration and the tooth structure. The dentin or the base is exposed at the periphery, but the restoration is not mobile, fractured, or missing in part or in toto.
	Delta	The restoration is mobile, fractured, or missing in part or in toto.

*Alfa and Bravo = restoration is acceptable/succesful; Charlie and Delta = restoration is not acceptable.

Every examination was performed using an intraoral mirror, a sharp explorer, and a periodontal probe (XP23/OW probe, Hu-Friedy); radiographs were recorded every year.

Each crown was carefully evaluated with a sharp dental explorer for apparent alterations in its outward structural integrity (veneer chipping, cracks, and fractures) including marginal discoloration and marginal adaptation, in accordance with the Cvar-Ryge criteria. Evaluation parameters (Alfa, Bravo, Charlie, and Delta) were used to classify the long-term quality of crowns (Table 1). If a crown had a catastrophic failure, it was replaced.

Statistical analysis

Survival rate of the ceramic crowns was statistically evaluated using the cumulative survival rate analysis. Survival time was defined as the period starting at baseline and ending when the clinician deemed that an irreparable failure of the crown had occurred.

Data were tabulated using Excel 2008 (Microsoft). The statistical analysis included descriptive indexes (mean, standard deviation, percentages), and survival analysis was performed using BMDP statistical software 2004 (Statistical Solutions).

Results

Two hundred seventy-five crowns in 106 patients (33 men, 73 women) were reevaluated in 2013. The mean observation time was 56 ± 34 months (women, 53 ± 34 months; men, 53 ± 34 months). The mean age of patients at the time of cementation was 52 ± 15 years (women, 52 ± 14 years; men, 52 ± 17 years). One hundred six crowns (38.5%) were placed in the anterior and 169 (61.5%) in the posterior areas. The average number of crowns cemented in each patient was 2.5.

Table 2 lists the number of crowns cemented per year. Table 3 lists data regarding location, time of placement, and other features of interest. The main types of failure observed during the study were crown material failure (five crowns, 1.77% incidence) and crown decementation (15 crowns, 5.5% incidence).

The five crowns that had a material fracture had a common clinical feature: the abutments on which they were cemented were all ETs and PRs. Only one of the crowns failed in a bruxer. According to the cumulative survival analysis method, the crowns' overall survival rate over 11 years was 98.23%. The survival rate was 100% in the

Table 2 Lithium disilicate crowns positioned per year in an 11-year period

Year of placement	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total
No. of crowns delivered	8	11	27	16	31	26	23	25	22	40	46	275

Table 3 Patient and crown distribution

Total no. of patients	Total no. of crowns	No. (%)							
		Anterior crowns	Posterior crowns	Vital teeth	Nonvital teeth	Bruxers	No. of crowns in bruxers	No. of patients with FMRs	No. of crowns in FMRs
106	275	106 (38.5)	169 (61.5)	103 (38.5)	172 (62.5)	25 (23.5)	130 (47.3)	7 (6.6)	92 (33.5)

FMR = full-mouth restoration.

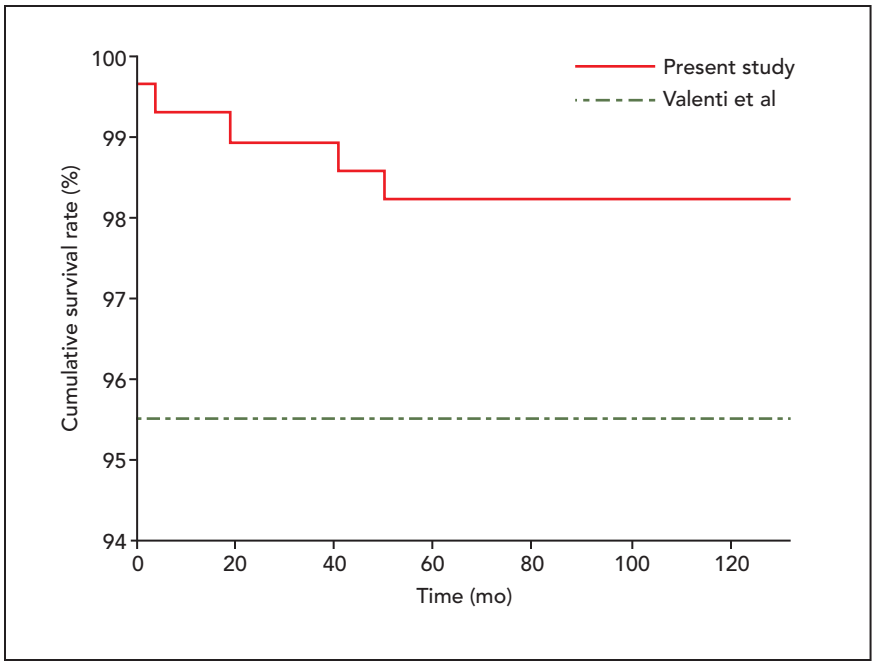

Fig 1 (left) *Comparison of survival rate of the present study and a similar one by Valenti et al.*[17]

Fig 2 (below) *Example of a core fracture in a bruxer who had prosthetic retreatment and endodontic treatment.*

106 anterior crowns and 97.1% in the 169 posterior restorations. Fig 1 illustrates the crowns' survival rates. Only the two crowns with core failures were replaced (Fig 2), and the new restorations were not included in the subsequent evaluation.

Table 4 lists all pertinent information regarding the fractured or chipped crowns. Fifteen crowns debonded (5.5%); of these, 11 were in the same patient. Fig 3 shows the cement types that were used and the relative crown distribution. For each cement type, the manufacturer's instructions were strictly followed.

All debonded crowns had a layer of cement on the inner part of the crown and none on the natural tooth (Fig 4; Tables 5, 6, and 7). This suggests failure of the bonding procedure on the tooth substrate.

One irreversibile pulpitis occurred days after crown delivery (mandibular left first molar) when the three-step total etch procedure was used. After root canal therapy, the access cavity was filled with

Table 4 Data on five crowns with material failure

Crown position, location, and type of fracture	Date of cementation	Date of failure	Time in service (mo)	Material	Cement	Prosthethic retreatment	Endodontic status	Bruxer
14 buccal (core)	11/2003	06/2005	19	Empress II	Variolink	Yes	Nonvital	Yes
34 distal (chipping)	02/2005	07/2008	41	E-max press	Variolink	Yes	Nonvital	No
37 distal (core)	09/2006	01/2007	4	E-max press	Variolink	Yes	Nonvital	No
46 lingual (chipping)	12/2010	12/2010	0	E-max press	Speed-cem	Yes	Nonvital	No
46 distolingual (chipping)	09/2005	11/2009	50	E-max press	Variolink	Yes	Nonvital	No

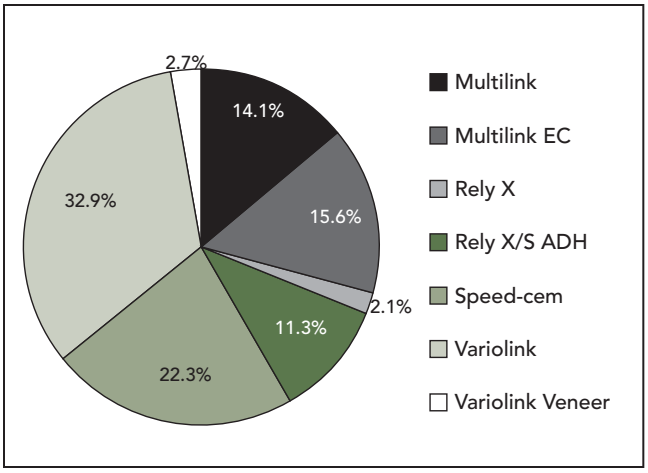

Fig 3 *Distribution of cement brands used in the study.*

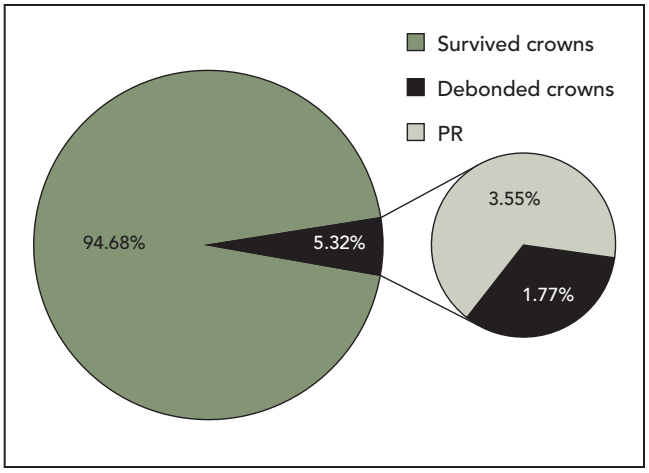

Fig 4 *Debonded crowns over the 11-year period* (left). *The diagram on the right shows the subgroup of debonded crowns, with a high prevalence of prosthetic retreatment crowns (PR).*

Table 5 Cement-related data on debonded crowns*

No. of crowns debonded	Anterior	Posterior	Prosthetic retreatment	Vital abutments	Nonvital abutments
15 (5.5)	9	6	10 (3.6): 9 vital 1 nonvital	11	4

*Numbers in parentheses are percentages.

Table 6 Cement-related data by brand*

No. of crowns debonded	Multilink	Variolink	Relyx adh	Speed-cem
15 (5.5)	1 (6.7)	11 (73.3)	2 (13.3)	1 (6.7)

*Numbers in parentheses are percentages.

Table 7 Distribution of crowns debonded in the 11-year period

Year of service	2	3	4	5	6	7	8	Total no. (%)
No. of crowns debonded	1	2	1	3	3	3	2	15 (5.5)

composite and the crown is still functioning; therefore, it was not considered a failure.

Marginal discoloration and marginal adaptation achieved the highest percentage of Alfa scores (73.3% and 79.2%, respectively) (Table 8).

Discussion

This retrospective clinical investigation evaluated the clinical performance of 275 veneered lithium disilicate crowns cemented with three different protocols in a single private practice, after up to 11 years

of function. The main complications recorded were material failure and debonding.

The crowns had a survival rate of 98.2% (Fig 1), a rate compatibile with the outcomes of several studies.[5,16,17] In the present investigation, the majority of the crowns received the highest rating (Alfa-Bravo) according to the Cvar-Ryge criteria, and only two had Charlie and three Delta ratings for marginal adaptation.

Table 8 Clinical evaluation of all single restorations after up to 11 years (Cvar-Ryge criteria)

	No. (%)	
Rating	Marginal discoloration	Marginal adaptation
Alfa	198 (73.3)	214 (79.2)
Bravo	69 (25.5)	51 (18.8)
Charlie	3 (1.1)	2 (0.74)
Delta		3 (1.1)

The high success rate achieved in this study was mainly because of the careful treatment plan, the precise transfer of data to the laboratory, and a rigid protocol used for optimizing occlusion. The occlusion of the patients who received FMR was checked on the articulator. Static and dynamic occlusal contacts were meticulously checked in the oral cavity during all clinical procedures and compared with those developed on the articulator.

The fracture rate was lower for anterior crowns than for posterior crowns.[6,7,41] Fradeani and Redemagni[5] showed that posterior crowns are associated with a higher risk of fracture than anterior crowns (84.4% vs 98.9% survival rates, respectively). This was confirmed in the present study (posterior survival rate, 97.1%; anterior survival rate, 100%). Because of the higher occlusal forces applied to molar teeth, the dentist has to be especially careful with material selection.

In contrast with Beier et al,[8] surprisingly, the present study showed a significantly low crown failure rate in the group with bruxism; as a matter of fact, about 45% of the crowns analyzed (130 crowns) were placed in bruxers and only one fractured; the survival rate for this group was, therefore, 99.3%. Moreover, seven bruxers received an FMR (91 crowns; 33%), and reported a 100% survival rate for this subgroup (Figs 5, 6a, and 6b).

The favorable outcome in the bruxers with FMR could be explained by the freedom to define new dentoskeletal parameters and the occlusal scheme in terms of occlusal plane inclination, vertical dimension of occlusion, steepness of the curve of Spee, and anterior guide determination, including a new dynamic function.[43] The canine-guided occlusal concept that was applied could be another factor that reduced occlusal forces during jaw movements as well as the risk of failure. In the bruxer group with FMR, splint therapy was used only as pretreatment in cooperation with other medical specialists before provisional and final restoration.[44] None of the bruxers with FMR was provided with a hard acrylic resin or other type of occlusal guards to protect the definitive all-ceramic restorations.[45]

In this study, the common characteristics of all fractured or chipped crowns is that they were all PR and cemented on nonvital abutments. However, a strong correlation between these clinical conditions and fracture incidence was not found.

Since the application of a proper protocol for cementation influences the survival rate of all-ceramic restorations,[46] resin bonding appears to be important.[47]

This study recorded the debonding of 15 crowns (survival rate of 94.5%). Eleven debonded crowns were in the same patient who had sclerotic dentin without enamel as a substrate; 10 of these crowns were PRs. The debonding occurred over several years, thus suggesting deterioration of the cement bond over time.

The stability of adhesively luted restorations may depend on many factors, such as the prosthetic material used, the nature of the dental substrate, patient-related factors, and the clinical protocol applied by the clinician.[48] External factors—such as the skill of the operator, isolation method, timing of etching and adhesive application, type of light source, and finishing instruments used—significantly influence the outcome.[49] Therefore, identifying the reasons for complications such as loss of retention can be a real challenge. However,

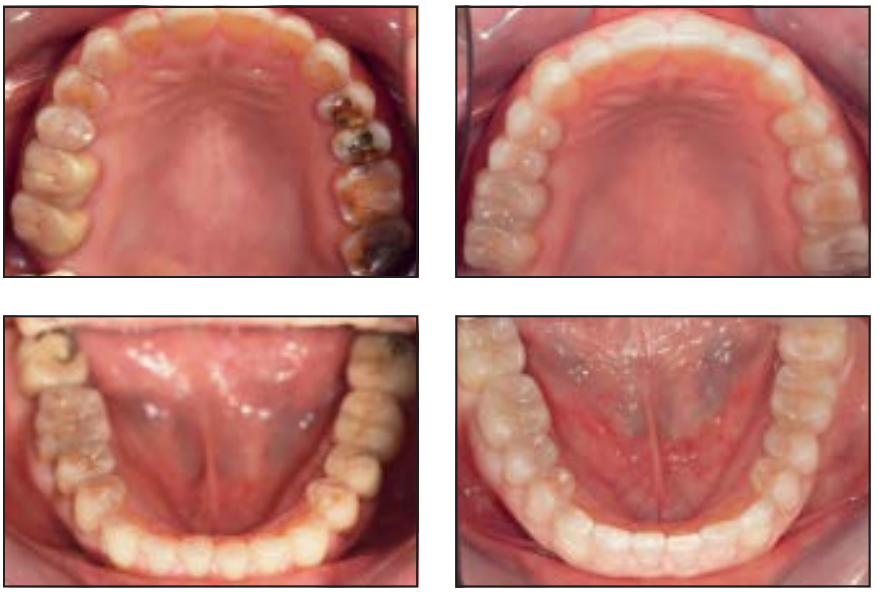

Fig 5 *Pre* (left) *and postoperative* (right) *views of a full-mouth restoration of a patient with bruxism included in this study.*

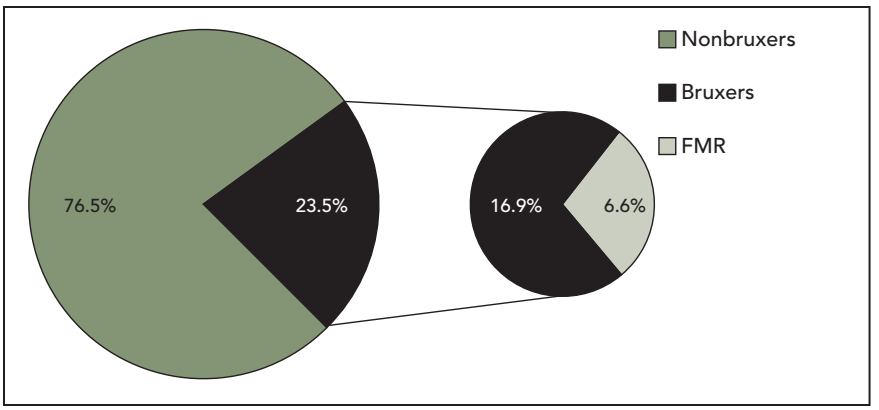

Fig 6a *Patient distribution between nonbruxers and bruxers who were rehabilitated.*

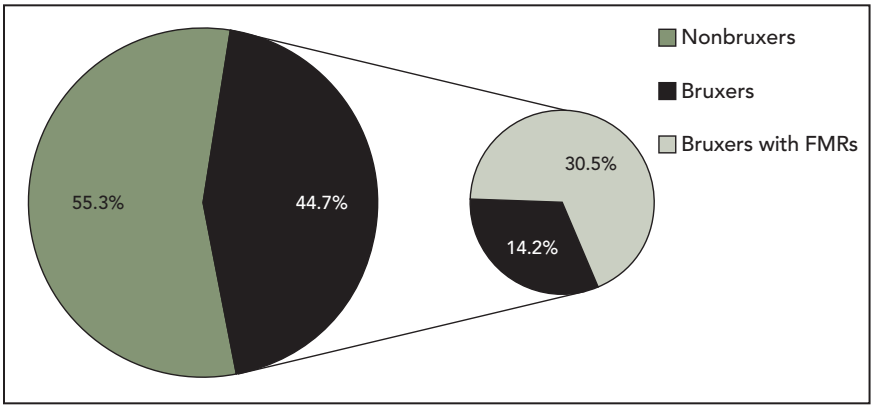

Fig 6b *Crown distribution between nonbruxers and bruxers; 30.5% of the crowns were manufactured for bruxers who had an FMR.*

in the case of PR, the literature needs to clarify whether the effectiveness of bonding procedures can be influenced by the quality of the new substrate.[50,51]

A new approach to stop the degradation of dentin-resin interfaces is the use of metalloproteinase inhibitors, such as chlorhexidine.[52,53] Although still in an early phase of in vitro and clinical research, this method seems promising.

The present retrospective study has some limitations, mainly the fact that different luting agents were used and the crowns were not manufactured by the same technician.

However, in this long-term evaluation, the clinical outcome was shown to be predictable and highly successful.

Conclusions

Within the limitations of the present study, the results show that veneered lithium disilicate single crowns cemented adhesively with composite resin cement are an effective and predictable restorative solution (survival rate 98.2%); moreover, the tendency for a high survival rate in the anterior segment (100%) compared to the posterior area (97.2%) is confirmed.

The observed crown material failures (two core fratctures and three veneer chippings) occurred in endodontically treated teeth that had previous failures, but no correlation was found.

Significantly high survival rates were observed in bruxers: there was only one failure out of 130 crowns,

and none in the FMR patient group. Even though bruxism is considered as a high risk factor for failure, the present study suggests that bruxers can be treated with ceramic-veneered lithium disilicate restorations without any kind of occlusal guards to protect the definitive all-ceramic restorations, provided that a strict clinical protocol is applied. Nevertheless, additional clinical studies should clarify other factors that may influence material selection in patients with bruxism. The other problem observed was crown debonding, but its incidence was low (15 crowns, or 5.5% of the total). Furthermore, 11 of the 15 occurred in the same patient, suggesting a problem with the bonding procedure.

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