Received: 23 April 2022 | Revised: 9 July 2022 | Accepted: 11 July 2022

DOI: 10.1111/jerd.12947

RESEARCH ARTICLE

WILEY

Pressable lithium disilicate ceramic versus CAD/CAM resin composite restorations in patients with moderate to severe tooth wear: Clinical observations up to 13 years

Daniel Edelhoff Prof, Dr[1] | Kurt-Jürgen Erdelt Dipl.-Ing, Dr[1] | Bogna Stawarczyk Prof, Dr, MSc[1] | Anja Liebermann Prof, Dr, MSc[2]

[1]Department of Prosthetic Dentistry, University Hospital, LMU Munich, Munich, Germany

[2]Polyclinic of Prosthetic Dentistry, Faculty of Medicine and University Hospital Cologne, University of Cologne, Cologne, Germany

Correspondence
Anja Liebermann, Kerpener Str. 32, 50931 Cologne, Germany.
Email: anja.liebermann@med.uni-muenchen.de

Funding information
Ivoclar, Schaan, Liechtenstein

Abstract

Objective: To report the long-term clinical survival and failure rates of single-tooth restorations made of pressable lithium disilicate ceramics (LS_2) and CAD/CAM resin composite (RC) by two separate clinical observations.

Materials and methods: Twenty-one patients (12 female, nine male) were treated with 436 minimally invasive single-tooth restorations made of 274 pressed LS_2 ($n = 12$; posterior: monolithic IPS e.max Press; anterior: IPS e.max Ceram veneered, Ivoclar) or 162 milled from RC ($n = 9$; monolithic exp. CAD/CAM resin composite, Ivoclar). The mean age of patients was 44.1 ± 9.3 years and the mean observation time was 86.2 ± 13.5 months (7.7 ± 1.1 years), with 8.5 ± 2.7 years for LS2 and 6.7 ± 0.5 years for RC. All restorations were observed for technical/biological failures using the modified criteria of the United States Public Health Service (USPHS). Collected data were analyzed using Kaplan–Meier survival analysis and log-rank test ($\alpha < 0.025$).

Results: The 274 LS_2 restorations showed a survival of 100% and a total failure rate of 5.5%. The 162 RC restorations showed a survival of 100% and a total failure rate of 25.3%. RC restorations exhibited more material fractures ($p = 0.020$) and higher discoloration rates ($p < 0.001$).

Conclusions: Pressed LS_2 single-tooth restorations showed lower long-term failure rates than restorations made of RC.

Clinical significance: Despite the limitations of the clinical observations, single-tooth restorations of both materials can be recommended for permanent use in patients with severe tooth wear.

KEYWORDS
CAD/CAM resin composite, ceramics, failure rate, lithium disilicate, severe tooth wear, survival

1 | INTRODUCTION

Patients today retain their natural teeth into old age thanks improved medical and dental care with a growing awareness of the importance of oral hygiene.[1] However, there is a gradual physiological loss of dental hard tissue, particularly enamel, over the years, reportedly by about 15 μm in the premolar region and by 29–33 μm in the molar region.[2,3]

In addition, younger patients now often suffer from a pathological loss of dental hard tissue owing to dietary habits (acidic foods and drinks) or increased attrition, abrasion, or erosion, alone or in combination.[4–7] This accelerates the wear of the hard tissues, resulting in different manifestations of tooth wear that may, in severe cases, require a full-mouth rehabilitation.[4,5] Minimally invasive treatment approaches appear to be advantageous in this situation and is regarded as the first treatment modality by the expert field.[8–12] More emphasize should be expressed that minimally invasive treatment is regarded as the first treatment modality by the expert field.

Conventional crown preparations sacrifice approximately 45% more hard tissue than minimally invasive preparations for occlusal or full veneers.[8,9,13]

The variety of available tooth-colored materials has increased in recent years. These materials—especially silicate ceramics—can be produced either by layering, pressing, and milling (CAD/CAM technology), or a combination of these techniques. The technology selected appears to influence the material's mechanical properties.[14,15] Besides the material's influence, the fabrication process' influence, and the operator's influence the patient also has influence the long-term survival of restorative work.[16–18]

CAD/CAM can be used to fabricate not only silicate ceramics (such as lithium disilicate) but also zirconia, polymer-infiltrated ceramics, or various polymer-based materials.[19,20] They can be used for various indications, including with manual veneering for superior esthetical outcomes.[19,20]

Indirect CAD/CAM resin composite materials exhibit higher edge stability than ceramics, permitting restorations with very thin margins.[21–24] Standardized industrial fabrication of the CAD/CAM blanks under high pressure and temperature result in more homogenous and more abrasion-resistant restorations than chairside restorations using direct composite resins.[25] Ceramics are generally superior to CAD/CAM polymer-based materials in terms of flexural strength, abrasion resistance and discoloration rates, whereas CAD/CAM polymer-based materials are more antagonist-friendly.[26–31]

Lithium disilicate restorations were shown to result in a survival between 92% and 97.8% after 5 years and between 85.5% and 96.7% after 10 years.[32–34] Little data have been published on the clinical long-term performance of minimally invasive CAD/CAM resin composite single-tooth restorations, used for occlusal veneers and partial crowns over a three-year observation time,[35–42] and specifically as compared to lithium disilicate restorations for worn dentitions regardless of the fabrication method.[43,44]

The present clinical observation aimed to investigate the clinical outcomes and long-term survival and failure rates of single-tooth restorations made of pressed lithium disilicate ceramics (up to 13 years) and CAD/CAM resin composite (up to 7 years). Survival describes the retention of the restoration in situ at follow-up examination, even if a complication has occurred. The following hypotheses were analyzed:

1.Survival of evaluated restoration materials will be different for the respective follow-up period.

2.Failure rates (incidence of material fracture and discoloration) will be different for CAD/CAM resin composite and lithium disilicate ceramic restorations.

2 | MATERIALS AND METHODS

The Ethical Committee of the University Hospital in Munich had approved both prospective non-randomized clinical studies (projects 012-12 and 659-16) that were used for the present clinical observation. The requirements of the Declaration of Helsinki were observed, and written informed consent was obtained from all patients.

2.1 | Clinical population

A total of 21 patients (12 female, nine male) received restorations made of minimally invasive lithium disilicate ceramic ("lithium disilicate"; 12 patients) or experimental CAD/CAM resin composite ("CAD/CAM resin composite"; nine patients) restorations. The restorations were delivered between July 2007 and December 2014 within the framework of two different clinical studies. The recipients were regular patients of the Department of Prosthetic Dentistry at the University Hospital in Munich.

Inclusion and exclusion criteria were as follows:

a. Age between 18 and 70 years.
b. Adequate oral hygiene (BOP ≤2; PI ≤3).
c. Preparation guidelines for specific restoration materials can be followed.
d. Necessary increase in VDO due to attrition, abrasion and erosion of dental hard tissue alone or in combination (moderate to severe tooth wear) in the presence of excessive dentin exposure and patient demand for improved masticatory function and smile esthetics.
e. Absence of periodontal disease (GI ≤3; oral and vestibular PD ≤3.5 mm).
f. Absence of pregnancy and lactation.
g. Smoking status not relevant.

2.2 | Prosthetic treatment

Patients requested prosthetic treatment due to varying degrees of dental hard-tissue loss combined with losses in VDO, hypersensitivity or functional/esthetic impairments. The loss of dental hard tissue was caused predominantly due to erosion combined with functional wear (Figure 1).

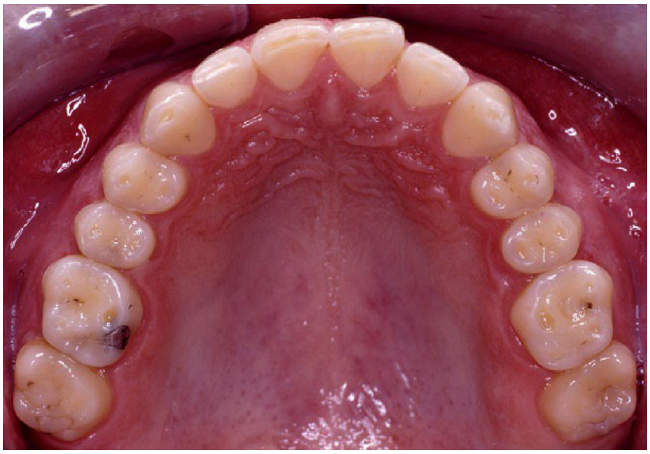

FIGURE 1 Pre-operative view of the maxilla of a 28-year-old patient with erosive and functional wear and numerous dentin exposures

FIGURE 2 Post-operative view of patient's maxilla with monolithic (posterior) and partially veneered (anterior) lithium disilicate restorations

FIGURE 3 Pre-operative view of the mandible with erosive and functional wear and numerous dentin exposure

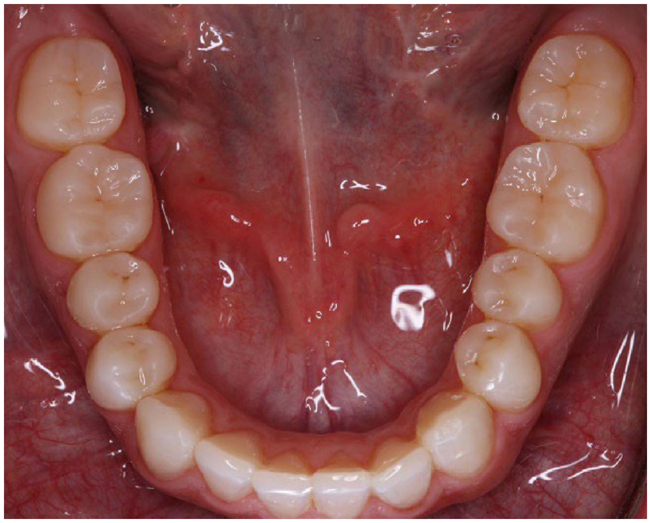

FIGURE 4 Post-operative view of patient's mandible with

FIGURE 5 Try-in of pressed lithium disilicate monolithic occlusal onlays on teeth FDI 17, 15 and 14. Preparation design

All patients had received minimally invasive tooth-colored full-mouth rehabilitations made of either

a. lithium disilicate ceramic restorations, using monolithic lithium disilicate single-tooth restorations in the load-bearing posterior regions (IPS e.max Press, Ivoclar); and lithium disilicate frameworks with manual veneering in the esthetic anterior regions (IPS e.max Press with IPS e.max Ceram, Ivoclar; Figure 2); or
b. monolithic experimental CAD/CAM resin composite restorations (Ivoclar).

Manufacturer reported about the composition of the experimental CAD/CAM composite material (Ivoclar), which consisted of 22% V_f matrix (dimethacrylate) and 78% V_f filler (barium glass fillers, 15%; ytterbium trifluoride, 9%; mixed oxides, 44%; silicon oxides, three; copolymers, 7%). The material showed mechanical properties as follows: flexural strength = 167 MPa, modulus of elasticity = 11.4 GPa, Vickers hardness = 915 MPa, and water absorption after 7 days = 28 μg/mm^3.

Most CAD/CAM resin composite restorations were additive restorations with no previous preparation. A single experienced dentist treated all the patients with lithium disilicate ceramic restorations, whereas the patients with CAD/CAM resin composite restorations were treated by three different experienced dentists. All dentists had been calibrated in advance (Figures 3,4).

The data for the lithium disilicate restorations have been published previously,[43,44] but the present clinical observation featured extended observation rates (up to 13 years) and added a comparison to CAD/CAM resin composite restorations with observation rates of up to 7 years.

Each rehabilitative treatment—regardless of the material used—started with an esthetic and functional diagnostic wax-up in centric relation, which was evaluated with the patient using a direct mock-up (esthetic evaluation). The necessary increase in vertical dimension was determined according to (a) the incisal edge positions of the central incisors, (b) the width-to-length ratio of the incisors, (c) phonetics, (d) freeway space, and (e) the facial profile. A "test drive" (3 months or more) for functional/esthetic evaluation used either a repositioning-splint or adhesively bonded polymethyl methacrylate (PMMA) anterior and posterior veneers in case of planned lithium disilicate ceramic restorations, designed according to the increase in VDO implemented in the evaluated wax-up.[43,44]

The hard-tissue removal for the lithium disilicate ceramic restorations was guided by a template (prep guide)—either a thermoplastic template/foil (Duran transparent 0.5 mm; Scheu-Dental, Iserlohn, Germany) or Silicon index fabricated from the outer contour of the diagnostic wax-up and controlled with a special periodontal probe (CP-15UNC; Hu-Friedy, Tuttlingen, Germany). The preparation guidelines—especially for the lithium disilicate ceramic restorations have been described previously.[43–47] The preparation design was dependent on the degree of destruction, preexisting fillings, and the extension of the wax-up by the dental technician.

Polyether impressions were taken (Impregum penta; 3 M, Seefeld, Germany) and plaster casts were poured. The final restorations (IPS e.max Press monolithic or partial anterior veneering by IPS e.max Ceram or CAD/CAM resin composite veneers; all Ivoclar) were fabricated by the dental laboratory according to the manufacturer's instructions as published in previous articles.[43–45,48] The composition of the lithium disilicate crowns, onlays, and veneers was as follows: silicon dioxide, 57–80%; lithium dioxide, 11–19%; potassium oxide, 0%–13%; phosphorus pentoxide: 0%–11%, zirconia, 0%–8%; zinc oxide, 0%–8%; others, 0%–10%. The CAD/CAM resin composite restorations were composed of Bis-GMA, UDMA, Bis-EMA, and TEGDMA (total monomer 18.0 wt%) and inorganic fillers of barium glass, ytterbium trifluoride, silicon dioxide and mixed oxide (82 wt%, particle size, 40 nm–7 μm) with additional additives, initiators, stabilizers and pigments (0.2 wt%).

The prepared abutment teeth were—if necessary—covered with temporary restorations (C & B; Ivoclar), and bonded (Heliobond; Ivoclar) without etching. All restorations were tried in with glycerine gel (Figure 5). If minor (<1 mm in diameter) corrections were required for the lithium disilicate restorations, the surface was repolished at chairside prior to definite adhesive placement. Major corrections (>1 mm) were followed by a glaze firing at the dental laboratory. The CAD/CAM resin composite restorations were merely repolished after any corrections.

Prior to adhesive bonding, lithium disilicate ceramic restorations were cleaned/disinfected for 5 min in an ultrasonic bath filled with alcohol (Ethanol 90%); resin composite restorations were briefly swiveled in alcohol for disinfection and then cleaned in distilled water in an ultrasonic bath for 5 min. The internal surfaces of the lithium disilicate ceramic restorations were etched with hydrofluoric acid (IPS Ceramic Etching Gel <5%; Ivoclar) for 20 s, while the internal surfaces

TABLE 1 Modified United States Public Health Service (USPHS) Ryge criteria for clinical evaluation of ceramic and CAD/CAM resin composite restorations analyzed[44,45]

USPHS	Alpha (A)	Bravo (B)	Charlie (C)
Marginal discoloration	No visual evidence of marginal discoloration	Visual evidence of marginal discoloration at the junction of the tooth structure and the restoration, but the discoloration has not penetrated along the restoration in a pulpal direction	Visual evidence of marginal discoloration at the junction of the tooth structure and the restoration that has penetrated along the restoration in a pulpal direction, renewal necessary
Secondary caries	The restoration is a continuation of existing anatomic form adjacent to the restoration	Visual evidence of dark keep discoloration adjacent to the restoration	Renewal necessary
Marginal integrity	No probe catch	Slight catch on probing, no gap	Highly over or under-contoured, renewal necessary
Surface texture	Surface texture similar to polished enamel	Surface texture gritty or similar to a surface subjects to a white stone or similar to a composite containing supramicron-sized particles	Surface pitting is sufficiently coarse to inhibit the continuous movement of an explorer across the surface, renewal necessary
Restoration fracture	Restoration is intact and fully retained, no fracture	Restoration is partially retained, polishing or repair is possible	Restoration is completely missing or huge fracture, renewal necessary

TABLE 2 Survival and failure rates (FR) for lithium disilicate and CAD/CAM resin composite restorations analyzed according to USPHS criteria (A: Alpha; B: Bravo; C: Charlie); failures evaluated separately

Patient (number)	Age (years)	Gender (male/female)	Time in situ (months/years)	Number of restorations (no. anterior/no. posterior)	Survival rate (%)	FDI position	FR (USPHS criteria)	FR (months)	Type of intervention
Lithium disilicate restorations									
1	51	Male	149/13	28 (16 posterior, 12 anterior)	100	21	Minor chipping (B)	66	Intraoral repair
						22	Minor chipping (B)	66	Intraoral repair
						23	Minor chipping (B)	11	Intraoral repair
						32	Minor chipping (B)	120	Intraoral repair
						15	Marginal crack formation (B)	120	No intervention (Observation)
						27	Retention loss (B)	149	Cleaning and adhesive reattachment
						26	Marginal discoloration (B)	60	No intervention (Observation)
						33	Marginal discoloration (B)	120	No intervention (Observation)
						36	Marginal discoloration (B)	120	No intervention (Observation)
						43	Marginal discoloration (B)	108	No intervention (Observation)
						45	Marginal discoloration (B)	108	No intervention (Observation)
						46	Marginal discoloration (B)	108	No intervention (Observation)
2	41	Male	138/12	24 (16 posterior, eight anterior)	100				
3	40	Male	98/9	28 (16 posterior, 12 anterior)	100	21	Minor chipping (B)	20	Intraoral repair
4	43	Female	90/8	28 (16 posterior, 12 anterior)	100	11	Incisal crack (B)	38	No intervention (Observation)
5	40	Male	93/8	28 (16 posterior, 12 anterior)	100				
6	50	Female	78/7	20 (14 posterior, six anterior)	100				
7	28	Male	122/11	28 (16 posterior, 12 anterior)	100				
8	58	Female	89/8	10 (10 posterior)	100				
9	44	Female	129/11	26 (14 posterior, 12 anterior)	100	42	Marginal crack formation (B)	91	No intervention (Observation)
10	54	Male	57/5	22 (10 posterior, 12 anterior)	100				
11	35	Male	49/5	16 (16 posterior)	100				
12	46	Female	48/5	16 (16 posterior)	100				
CAD/CAM resin composite restorations									
1	43	Female	73/7	15 (15 posterior)	100	27	Endodontic treatment	7	Perforation of the restoration and Endodontic treatment covered with direct adhesive composite
2	44	Female	70/6	16 (16 posterior)	100	24 44	Retention loss Restoration fracture (B)	28 36	Cleaning and adhesive reattachment Intraoral repair

TABLE 2 (Continued)

Patient (number)	Age (years)	Gender (male/female)	Time in situ (months/years)	Number of restorations (no. anterior/no. posterior)	Survival rate (%)	FDI position	FR (USPHS criteria)	FR (months)	Type of intervention
3	51	Female	83/7	27 (15 posterior, 12 anterior)	100	17	Restoration fracture (B)	53	Intraoral repair
						46	Marginal discoloration (B)	65	No intervention (Observation)
						47	Marginal discoloration (B)	56	No intervention (Observation)
4	58	Male	77/7	28 (16 posterior, 12 anterior)	100	12	Restoration fracture (B)	33	Repolishing
						42	Restoration fracture (B)	35	Repolishing
						16	Marginal discoloration (B)	45	No intervention (Observation)
						15	Marginal discoloration (B)	45	No intervention (Observation)
						11	Marginal discoloration (B)	57	Repolishing
						21	Marginal discoloration (B)	57	Repolishing
						26	Marginal discoloration (B)	45	No intervention (Observation)
						27	Marginal discoloration (B)	45	No intervention (Observation)
						36	Marginal discoloration (B)	57	No intervention (Observation)
						33	Marginal discoloration (B)	57	No intervention (Observation)
						44	Marginal discoloration (B)	45	No intervention (Observation)
						46	Marginal discoloration (B)	57	No intervention (Observation)
						47	Marginal discoloration (B)	57	No intervention (Observation)
5	45	Female	83/7	Six (six posterior)	100	36	Marginal discoloration (B)	66	No intervention (Observation)
						37	Marginal discoloration (B)	66	No intervention (Observation)
						46	Marginal discoloration (B)	29	No intervention (Observation)
						47	Marginal discoloration (B)	30	No intervention (Observation)
						47	Restoration fracture (B)	30	Intraoral repair
6	44	Female	74/7	14	100	15	Marginal discoloration (B)	56	No intervention (Observation)
						16	Marginal discoloration (B)	56	No intervention (Observation)
						17	Marginal discoloration (B)	56	No intervention (Observation)
						26	Marginal discoloration (B)	69	No intervention (Observation)
						36	Marginal discoloration (B)	69	No intervention (Observation)
						46	Discoloration restoration (B)	56	No intervention (Observation)
						46	Restoration fracture (B)	56	Intraoral repair
						47	Restoration fracture (B)	56	Intraoral repair
7	26	Female	69/6	12	100	27	Restoration fracture (B)	13	Intraoral repair
						47	Restoration fracture (B)	13	Intraoral repair
8	57	Female	75/7	16	100	47	Restoration fracture (B)	74	Intraoral repair
9	28	Male	63/6	28 (16 posterior, 12 anterior)	100	27	Secondary caries (B)	52	Selective intraoral repair

of the CAD/CAM resin composite restorations were air-abraded using a modified procedure (Rocatec soft, 1 bar pressure, approximately 10 s exposure time, 90° angle). After cleaning in an ultrasonic bath (see above), a Primer (Monobond Plus, exposure time 60s; Ivoclar) was applied to the pre-treated internal surfaces of both restoration types, followed by a thin layer of bonding material (Heliobond; Ivoclar). A low-viscosity composite resin cement (Variolink II; either light-cured or dual-cured; Ivoclar) combined with a multiple step dentin adhesive system (Syntac; Ivoclar) was used for the final placement of the restorations.

The occlusal concept realized was anterior canine guidance with "freedom in centric". Annual recalls were performed using the modified United States Public Health Service (USPHS) criteria specified in Table 1 for both clinical analyses, as described previously,[49,50] with ratings Alpha (no problem observed), Bravo (minor complications observed), or Charlie (major complications observed, remake of the restoration necessary). The recall evaluations were performed by two examiners with 10 years of clinical expertise in all-ceramics and adhesive technique.

The analysis, in addition to the classical USPHS criteria chosen, further distinguished between technical and biological failures. Technical failures in the clinical observation also included additional measured criteria: restoration fracture (major chipping), minor chipping, marginal/incisal crack formation, retention loss, or marginal/restoration discoloration. Discolorations were checked visually and documented at follow-up. Biological failures include secondary caries, with necessary endodontic treatment as an additional criterion. Occlusal wear, marginal integrity, and surface quality were detected visually and haptically with a probe during the follow-up sessions.

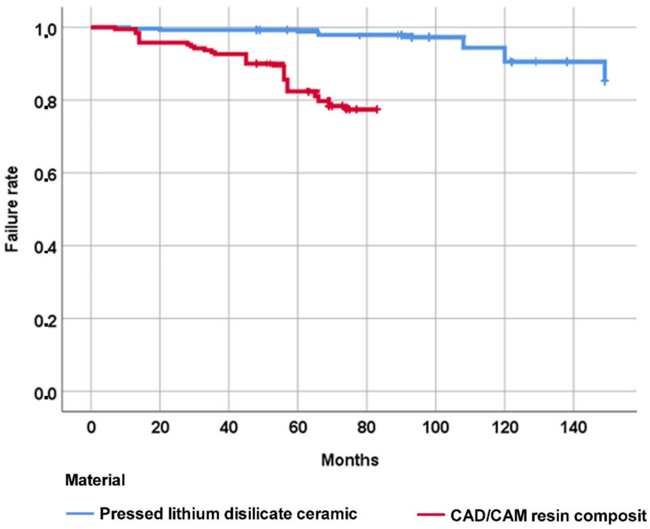

FIGURE 6 Kaplan–Meier rate of pressed lithium disilicate and CAD/CAM resin composite failures in total as comparison

FIGURE 8 Loss of retention of pressed lithium disilicate monolithic occlusal onlay after 149 months of clinical service. The composite built-up is still bonded to lithium disilicate ceramic representing an adhesive failure of the dentin adhesive on natural tooth structure

2.3 | Statistical analysis

Survival and failure rates for the lithium disilicate ceramic and CAD/CAM resin composite group were calculated using the Kaplan–Meier survival analysis and the log-rank test. Restorations were considered total failures if they had to be replaced (rated Charlie). Data

FIGURE 7 Loss of retention of posterior pressed lithium disilicate monolithic occlusal onlay (FDI 27) after 149 months of clinical service

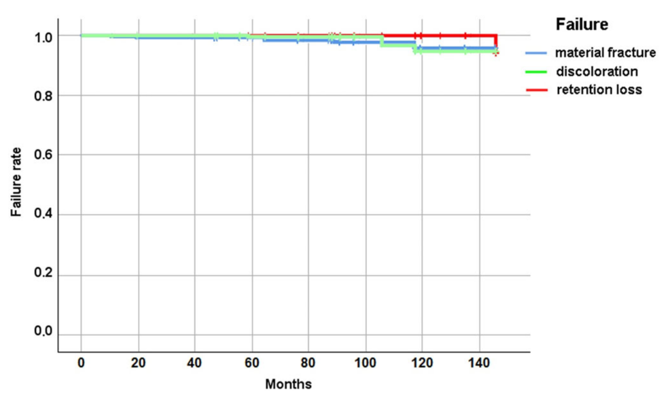

FIGURE 9 Kaplan–Meier rate for failure rates of pressed lithium disilicate restorations

FIGURE 10 Pressed lithium disilicate monolithic occlusal onlays (Figure 5) after 49 months of clinical service with visible wear

FIGURE 11 CAD/CAM resin composite restorations after adhesive bonding with high surface gloss at baseline recall

FIGURE 12 CAD/CAM resin composite restorations (Figures 11, 14) with marginal discoloration after 64 months of clinical use. The surface appeared dull with visible wear

FIGURE 13 Repairable distobuccal fracture of CAD/CAM resin composite restoration (FDI 46) after 44 months of clinical service

FIGURE 14 CAD/CAM resin composite restorations after adhesive bonding with high surface gloss at baseline recall

FIGURE 15 CAD/CAM resin composite restorations (Figure 14) with discoloration and crack of first premolar (FDI 24) and perforation on second molar (FDI 26) after 58 months of clinical service. Surface appeared dull with visible wear

were analyzed using SPSS 25 (SPSS) with a significance level of $p < 0.025$ to adjust for the variability in patient selection for the two different material groups.

3 | RESULTS

3.1 | General information

The mean age of the 21 patients was 44.1 ± 9.3 years and the mean observation period was 86.2 ± 13.5 months (7.7 ± 1.1 years). All patients were non-smokers and were seen at the clinic due to esthetic concerns, hypersensitivity, functional and masticatory problems, as well as in very rare cases pain.

All patients were treated with tooth-colored single-tooth restorations ($N = 436$), whereas 274 lithium disilicate ceramic restorations were made, of which 176 monolithic lithium disilicate restorations were placed in the load-bearing posterior regions (IPS e.max Press); 144 monolithic occlusal onlays, 32 crowns, and 98 lithium disilicate

FIGURE 16 CAD/CAM resin composite restorations (Figure 14) with discoloration and crack of first premolar (FDI 24) prior to change of prosthetic rehabilitation from CAD/CAM resin composite to monolithic lithium disilicate restorations after separating of CAD/CAM resin composite crown after 72 months of clinical service. Discoloration resulted of an adhesive failure between CAD/CAM resin composite and luting composite

FIGURE 17 CAD/CAM resin composite restorations (Figure 14) with discoloration and crack of first premolar (FDI 24) prior to change of prosthetic rehabilitation from resin CAD/CAM composite to monolithic lithium disilicate restorations after removal of CAD/CAM resin composite crown after 72 months of clinical service. Luting composite remained on abutment tooth as a sign of adhesive failure on the inner surface of the restoration

frameworks with manual veneering in the esthetic anterior regions (IPS e.max Press with IPS e.max Ceram). In addition, 162 monolithic CAD/CAM resin composite restorations were fabricated, of which 140 were in the posterior region (77 occlusal onlays, 59 partial crowns, four full crowns), and 22 in the anterior region (20 veneers and two crowns).

3.2 | Lithium disilicate restorations

Within the group of lithium disilicate ceramic restorations, five female and seven male patients with a mean age of 41.2 ± 8.2 years (female, 48.2 ± 5.8; male, 41.3 ± 8.6) were treated with a mean observation time of 95.0 ± 33.3 months (8.5 ± 2.7 years).

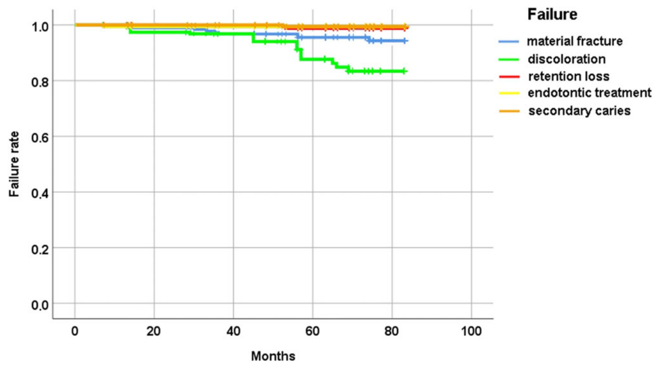

FIGURE 18 Kaplan–Meier rate for failure rates of CAD/CAM resin composite restorations

The total failure rate of lithium disilicate ceramic restorations was 5.5% with a total annual failure rate (AFR) of 0.5%. All technical failures were rated Bravo (Table 2 and Figure 6–9) with an AFR of 2.9% and discoloration with an AFR of 2.2%. For the lithium disilicate restorations, no biological complications were found. Visible occlusal wear (rated Bravo) occurred in 67.5% of the lithium disilicate restorations (Figure 10).

3.3 | CAD/CAM resin composite restorations

Within the group of CAD/CAM resin composite restorations, seven female and two male patients with a mean age of 44.0 ± 10.8 years (female, 44.3 ± 9.1; male, 43.0 ± 15.3) were treated with a mean observation time of 74.0 ± 6.3 months (6.7 ± 0.5 years). Details for the patients included are summarized in Table 2.

The total failure rate of CAD/CAM resin composite restorations was 25.3% (Figure 6) with a total AFR of 3.8%. CAD/CAM resin composite restorations exhibited more material fractures ($p = 0.020$, AFR: 6.2%) and higher discoloration rates ($p < 0.001$, AFR: 14.2%) analyzed with the log-rank test.

Thirty-nine technical failures and two biological failures occurred (one secondary caries after 52 months and one necessary endodontic treatment after 7 months), all rated Bravo (for details see Table 2). Occlusal wear (rated Bravo) was documented in 91.1% of the CAD/CAM resin composite restorations after 6 and 7 years in situ (Figures 11–18).

Neither restorative material presented any difference in survival, with no loss of restoration to follow-up.

Detailed survival and failure rates for both restoration types are listed in Table 3. Survival and failure rates as primary outcomes are listed in Table 4.

4 | DISCUSSION

Full-mouth rehabilitations of patients with moderate to severe loss of dental hard tissue with progressive VDO reduction usually represent a

TABLE 3 Descriptive results of total survival and failure rates of lithium disilicate and CAD/CAM resin composite restorations including most common failures separately

	Lithium disilicate		Composite resin	
	Total number	%	Total number	%
Total survival and failure rates				
Survival rate	274/274	100	162/162	100
Technical failure rate	15/274	5.48	34/162	24.1
Biological failure rate	0/274	0	2/162	1.20
Most common failures				
Chipping/fracture rate	8/274	2.92	10/162	6.17
Discoloration rate	6/274	2.19	23/162	14.2

TABLE 4 Results of modified USPHS criteria including number of restorations and percentages[49,50]

	Lithium disilicate			Composite resin		
	Alpha (A)	Bravo (B)	Charlie (C)	Alpha (A)	Bravo (B)	Charlie (C)
Marginal discoloration	268 (97.8%)	6 (2.19%)	0 (0%)	163 (99.4%)	22 (7.36%)	0 (0%)
Secondary caries	274 (100%)	0 (0%)	0 (0%)	189 (99.5%)	1 (0.53%)	0 (0%)
Restoration fracture	266 (97.1%)	8 (2.92%)	0 (0%)	180 (95.3%)	10 (4.74%)	0 (0%)

major challenge for the dental team. The most prevalent reasons why patients requested treatment were esthetic concerns (59%), followed by teeth sensitivities (40%), functional problems (17%), and pain (14%).[4,5,7] These reasons could be confirmed for the present study population.

Lithium disilicate ceramic is generally superior to CAD/CAM polymer-based materials in terms of flexural strength, abrasion resistance, and marginal/material discolorations.[19,20,24,25,26] These results were partially confirmed in the present clinical observation, as CAD/CAM resin composite restorations showed higher abrasion rates and significantly higher discoloration rates than lithium disilicate ceramic restorations. The annual failure rate was additionally higher for the CAD/CAM resin composite restorations.

It should be mentioned that this direct comparison between the two materials investigated is also a major limitation of the present observation, as not only the materials themselves differed but also the manufacturing methods (pressed vs. CAD/CAM). The latter can influence the mechanical and optical properties of the materials, as mentioned in the introduction for lithium disilicate ceramic.[19,21,22]

A further limitation is the inclusion gap of about 3 years of patients from the lithium disilicate ceramic population. The gap arose because the restorations were exclusively provided by a single practitioner, while the CAD/CAM resin composite observation was performed by three different practitioners within a short period. The lithium disilicate practitioner was also included in the CAD/CAM resin composite study, leading to the gap in between. It is still assumed that the clinical procedures of the lithium disilicate ceramic observation are stable, being performed only one practitioner using the same materials.

No long-term data for indirect CAD/CAM resin composite restorations in patients with worn dentitions are available.[35–39] Therefore, the present clinical observation used restorations made from a highly filled (82 wt%) CAD/CAM resin composite to evaluate long-term performance irrespective of the limitations mentioned.

Favorable long-term survival (85.5%–96.7% after 10 years and 100% for partial crowns after 7 years of clinical service) have been reported for single-tooth all-ceramic restorations[33,34,45]—and particularly for lithium disilicate ceramic restorations as investigated in the present clinical observation, with minimally invasive restoration geometries as described in the introduction.[32,34] These survivals are even surpassed by the 100% after up to 13 years of observation based on the present observational results. Fifteen minor technical failures occurred but did not require restorations to be replaced. Minor chippings (2.9%) were repaired with direct resin composite. The formation of marginal cracks is still under observation but has not changed clinically since the previous publication.[43,44] The repair rate was 1.8% for the lithium disilicate ceramic restorations examined. Even with minimally invasive geometries as used in the present clinical observation, with predominantly occlusal onlays and full veneers (lithium disilicate ceramic group), the literature shows that restorations can be stabilized by adhesive bonding, especially when applied with reduced thickness.[43,44]

The few discolorations (2.2%) of restoration margins were repolished with ceramic polishing sets. Some, however, could not be completely removed. Given their posterior location, patients did not consider this to imply an esthetic compromise and declined a remake of their restorations. Marginal discoloration occurred in one patient who was a non-smoker; the reason could not be finally determined. Most other instances of failures within the lithium disilicate group occurred in one patient with reduced compliance for the nighttime protective splint and an additional anterior trauma.

In the present clinical observation, CAD/CAM resin composite restorations exhibited the same survival as the lithium disilicate ceramic restorations, with no clinical loss of restorations—a favorable long-term outcome. Nevertheless, the failure rate for CAD/CAM resin composite restorations was significantly higher than for lithium disilicate ceramic restorations. This rate is mainly due to technical failures (24.1%) and two biological failures (1.2%). As for the technical failures, there were significantly more partial fractures (6.2%) and marginal/material discolorations (14.2%) (Figure 12). All failures with this material were amenable to repair. The favorable repair options for polymers have been described in the literature.[18]

Discoloration of the material occurred exclusively in posterior resin composite restorations, without no esthetic impairment and no replacement need. CAD/CAM resin composite restorations in this observation were significantly less resistant to abrasion than the lithium disilicate ceramic restorations and carried a higher risk for recurring VDO decrease, with occlusal wear rates of 91.1% and 67.5%, respectively. This material-specific behavior is confirmed by in-vitro as well as in-vivo data.[26,28,51] The 3-year wear data of 12 patients who were also restored using lithium disilicate ceramics and CAD/CAM resin composite as part of full-mouth rehabilitations confirm the results of the present study.[51]

An observation limitation is that the abrasion was not investigated quantitatively, but purely visually on a yes/no grid. The results obtained demonstrate the slight clinical advantages of lithium disilicate ceramic restorations over CAD/CAM resin composite ones. The clinical data cannot easily be compared with published in-vivo data, as limited data has examined CAD/CAM resin composite restorations vs. all-ceramic crowns beyond a 3-year study period.[32,33,43–45] In one study, the survival of the resin composite restorations at 3 years was already lower than in the present observation, for a survival of 87.9% with high abrasion.[35] This may be explainable by the different preparation designs in the two clinical setups. Minimally invasive restorations, such as those in the present observation, allow enamel to be preserved as an optimal substrate for adhesion rather than requiring the exposure of dentin associated with crown preparation. Both restorative materials were adhesively bonded with the same composite luting agent using a comparable method, so that differences in luting protocols should play a subordinate role. However, as in the clinical study by Vanoorbeek,[35] ceramic crowns are clearly superior to resin composite crowns and are therefore recommended for long-term use.

The hypotheses underlying the present observation, namely that there is no difference in clinical parameters or survival and failure rates between minimally invasive rehabilitation with lithium disilicate ceramic or CAD/CAM resin composite, could therefore be partially rejected, based on failure rates.

Another minor limitation of the present observation—apart from the selection of the patient cohort regarding gender and the small number of patients presenting divers lifestyle and eating habits (21)—was the influence of the treatment provider(s) (operator sensitivity) and the processing of the materials in the dental laboratory. This has been confirmed in the literature.[16,17] As the majority of prosthetic rehabilitations were performed from one operator, the influence seems to be smaller but still existent. In addition, the lack of sample size calculation is also a limitation, since the effort of total rehabilitations is very high and consequently a number was determined in advance.

The present patient cohort was highly balanced and enrolment bias should have played a rather subordinate role, with the two patients with the most failures being male. Increased chewing forces may have had an influence. In addition, there were no detailed technical investigations into possible bruxism. A further limitation was that the abrasion resistance of the two materials could only be observed between the material groups (ceramic–ceramic or composite–composite) and not with natural teeth as antagonists, as all patients had received full-mouth rehabilitations. Further clinical studies using prospective split-mouth method like restoring the upper and lower jaw or the left and right posterior region with diverse materials, or a higher number of patients should be performed.

5 | CONCLUSIONS

Within the limitations of the present clinical observations, the following conclusions may be drawn:

1. Both restoration materials presented identical survival (100%) for the respective follow-up period.
2. Failure rates were higher for CAD/CAM resin composite restorations (24.1%), including mainly technical failures, than for lithium disilicate ceramic restorations, with 5.48% technical failures. CAD/CAM resin composite restorations had a higher incidence of material fracture and higher discoloration rates.

AUHTOR CONTRIBUTIONS

Anja Liebermann, Daniel Edelhoff: Conceived and designed the observation. Anja Liebermann, Daniel Edelhoff, Kurt Erdelt, and Bogna Stawarczyk: Contributed to analysis and interpretation of data. Anja Liebermann and Daniel Edelhoff: Wrote manuscript. All authors: Read, revised, and accepted the manuscript prior to submission.

ACKNOWLEDGMENT AND DISCLOSURE

Open Access funding enabled and organized by Projekt DEAL. The authors declare that they do not have any financial interest in the companies whose materials are included in this article.

FUNDING INFORMATION

The clinical observation was supported in part by Ivoclar, Schaan, Liechtenstein. The funders had no role in conduct, analysis, interpretation or reporting of the observation.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Anja Liebermann https://orcid.org/0000-0002-1385-2195

REFERENCES

1. Kreulen CM, Van't Spijker A, Rodriguez JM, et al. Systematic review of the prevalence of tooth wear in children and adolescents. *Caries Res*. 2010;44(2):151-159.
2. Pintado MR, Anderson GC, DeLong R, Douglas WH. Variation in tooth wear in young adults over a two-year period. *J Prosthet Dent*. 1997;77(3):313-320.
3. Lambrechts P, Braem M, Vuylsteke-Wauters M, Vanherle G. Quantitative in vivo wear of human enamel. *J Dent Res*. 1989;68(12):1752-1754.
4. Lussi A, Carvalho TS. Erosive tooth wear: a multifactorial condition of growing concern and increasing knowledge. *Monogr Oral Sci*. 2014;25:1-15.
5. Loomans B, Opdam N, Attin T, et al. Severe tooth wear: European consensus statement on management guidelines. *J Adhes Dent*. 2017;19(2):111-119.
6. Shellis RP, Addy M. The interactions between attrition, abrasion and erosion in tooth wear. *Monogr Oral Sci*. 2014;25:32-45.
7. Wazani BE, Dodd MN, Milosevic A. The signs and symptoms of tooth wear in a referred group of patients. *Br Dent J*. 2012;213(6):E10.
8. Burke FM, McKenna G. Toothwear and the older patient. *Dent Update*. 2011;38(3):165-168.
9. Edelhoff D, Sorensen JA. Tooth structure removal associated with various preparation designs for posterior teeth. *Int J Periodontics Restorative Dent*. 2002;22(3):241-249.
10. Edelhoff D, Liebermann A, Beuer F, Stimmelmayr M, Güth JF. Minimally invasive treatment options in fixed prosthodontics. *Quintessence Int*. 2016;47(3):207-216.
11. Edelhoff D, Sorensen JA. Tooth structure removal associated with various preparation designs for anterior teeth. *J Prosthet Dent*. 2002;87(5):503-509.
12. Al-Fouzan AF, Tashkandi EA. Volumetric measurements of removed tooth structure associated with various preparation designs. *Int J Prosthodont*. 2013;26(6):545-548.
13. Murphy F, McDonald A, Petrie A, et al. Coronal tooth structure in root-treated teeth prepared for complete and partial coverage restorations. *J Oral Rehabil*. 2009;36(6):451-461.
14. Pjetursson BE, Lang NP. Prosthetic treatment planning on the basis of scientific evidence. *J Oral Rehabil*. 2008;35(1):72-79.
15. Raedel M, Hartmann A, Priess HW, et al. Re-interventions after restoring teeth—mining an insurance database. *J Dent*. 2017;57:14-19.
16. Frankenberger R, Reinelt C, Petschelt A, Krämer N. Operator vs. material influence on clinical outcome of bonded ceramic inlays. *Dent Mater*. 2009;25(8):960-968.
17. Goldstein GR. The longevity of direct and indirect posterior restorations is uncertain and may be affected by a number of dentist-, patient-, and material-related factors. *J Evid Based Dent Pract*. 2010;10(1):30-31.
18. Kanzow P, Wiegand A. Retrospective analysis on the repair vs. replacement of composite restorations. *Dent Mater*. 2020;36(1):108-118.
19. Kang SY, Lee HN, Kim JH, Kim WC. Evaluation of marginal discrepancy of pressable ceramic veneer fabricated using CAD/CAM system: additive and subtractive manufacturing. *J Adv Prosthodont*. 2018;10(5):347-353.
20. Gudugunta L, Mynampati P, Jeevan MB, Kumar SM, Akkaloori A, Tejavath SK. The marginal discrepancy of lithium disilicate onlays: computer-aided design versus press. *J Conserv Dent*. 2019;22(4):336-339.
21. Gerogianni P, Lien W, Bompolaki D, et al. Fracture resistance of pressed and milled lithium disilicate anterior complete coverage restorations following endodontic access preparation. *J Prosthodont*. 2019;28(2):163-170.
22. Alkadi L, Ruse ND. Fracture toughness of two lithium disilicate dental glass-ceramics. *J Prosthet Dent*. 2016;116(4):591-596.
23. Chavali R, Nejat AH, Lawson NC. Machinability of CAD-CAM materials. *J Prosthet Dent*. 2017;118(2):194-199.
24. Awada A, Nathanson D. Mechanical properties of resin-ceramic CAD/CAM restorative materials. *J Prosthet Dent*. 2015;114(4):587-593.
25. Stawarczyk B, Liebermann A, Eichberger M, Güth JF. Evaluation of mechanical and optical behavior of current esthetic dental restorative CAD/CAM composites. *J Mech Behav Biomed Mater*. 2015;55:1-11.
26. Mörmann WH, Stawarczyk B, Ender A, Sener B, Attin T, Mehl A. Wear characteristics of current aesthetic dental restorative CAD/-CAM materials: two-body wear, gloss retention, roughness and martens hardness. *J Mech Behav Biomed Mater*. 2013;20:113-125.
27. Alt V, Hannig M, Wöstmann B, Balkenhol M. Fracture strength of temporary fixed partial dentures CAD/CAM versus directly fabricated restorations. *Dent Mater*. 2011;27(4):339-347.
28. Stawarczyk B, Özcan M, Trottmann A, Schmutz F, Roos M, Hämmerle C. Two-body wear rate of CAD/CAM resin blocks and their enamel antagonists. *J Prosthet Dent*. 2013;109(5):325-332.
29. Ender A, Bienz S, Mörmann W, Mehl A, Attin T, Stawarczyk B. Marginal adaptation, fracture load and macroscopic failure mode of adhesively luted PMMA-based CAD/CAM inlays. *Dent Mater*. 2016;32(2):e22-e29.
30. Liebermann A, Vehling D, Eichberger M, Stawarczyk B. Impact of storage media and temperature on color stability of tooth-colored CAD/CAM materials for final restorations. *J Appl Biomater Funct Mater*. 2019;17(4):2280800019836832.
31. Stawarczyk B, Sener B, Trottmann A, et al. Discoloration of manually fabricated resins and industrially fabricated CAD/CAM blocks versus glass-ceramic: effect of storage media, duration, and subsequent polishing. *Dent Mater J*. 2012;31(3):377-383.
32. van den Breemer CR, Vinkenborg C, van Pelt H, Edelhoff D, Cune MS. The clinical performance of monolithic lithium disilicate posterior restorations after 5, 10, and 15 years: a retrospective case series. *Int J Prosthodont*. 2017;30(1):62-65.
33. Pieger S, Salman A, Bidra AS. Clinical outcomes of lithium disilicate single crowns and partial fixed dental prostheses: a systematic review. *J Prosthet Dent*. 2014;112(1):22-30.
34. Teichmann M, Göckler F, Weber V, Yildirim M, Wolfart S, Edelhoff D. Ten-year survival and complication rates of lithium-disilicate (empress 2) tooth-supported crowns, implant-supported crowns, and fixed dental prostheses. *J Dent*. 2017;56:65-77.
35. Vanoorbeek S, Vandamme K, Lijnen I, Naert I. Computer-aided designed/computer-assisted manufactured composite resin versus ceramic single-tooth restorations: a 3-year clinical study. *Int J Prosthodont*. 2010;23(3):223-230.
36. Zimmermann M, Koller C, Reymus M, Mehl A, Hickel R. Clinical evaluation of indirect particle-filled composite resin CAD/CAM partial crowns after 24 months. *J Prosthodont*. 2018;27(8):694-699.
37. Gresnigt MM, Kalk W, Özcan M. Randomized clinical trial of indirect resin composite & ceramic veneers: up to 3-year follow-up. *J Adhes Dent*. 2013;15(2):181-190.
38. Aslan YU, Coskun E, Ozkan Y, Dard M. Clinical evaluation of three types of CAD/CAM inlay/ Onlay materials after 1-year clinical follow up. *Eur J Prosthodont Restor Dent*. 2019;27(3):131-140.
39. Coşkun E, Aslan YU, Özkan YK. Evaluation of two different CAD-CAM inlay-onlays in a split-mouth study: 2-year clinical follow-up. *J Esthet Restor Dent*. 2020;32(2):244-250.
40. Crins LAMJ, Opdam NJM, Kreulen CM, et al. Randomized controlled trial on the performance of direct and indirect composite restorations

in patients with severe tooth wear. *Dent Mater*. 2021;37(11):1645-1654.
41. Crins LAMJ, Opdam NJM, Kreulen CM, et al. Prospective study on CAD/CAM nano-ceramic (composite) restorations in the treatment of severe tooth Wear. *J Adhes Dent*. 2022;24(1):105-116.
42. Oudkerk J, Eldafrawy M, Bekaert S, Grenade C, Vanheusden A, Mainjot A. The one-step no-prep approach for full-mouth rehabilitation of worn dentition using PICN CAD-CAM restorations: 2-yr results of a prospective clinical study. *J Dent*. 2020;92:103245.
43. Liebermann A, Erdelt K, Brix O, Edelhoff D. Clinical performance of anterior full veneer restorations made of lithium disilicate with a mean observation time of 8 years. *Int J Prosthodont*. 2020;33(1):14-21.
44. Edelhoff D, Güth JF, Erdelt K, Brix O, Liebermann A. Clinical performance of occlusal onlays made of lithium disilicate ceramic in patients with severe tooth wear up to 11 years. *Dent Mater*. 2019;35(9):1319-1330.
45. Guess PC, Selz CF, Steinhart YN, Stampf S, Strub JR. Prospective clinical split-mouth study of pressed and CAD/CAM all-ceramic partial-coverage restorations: 7-year results. *Int J Prosthodont*. 2013;26(1):21-25.
46. Edelhoff D, Prandtner O, Saeidi Pour R, Liebermann A, Stimmelmayr M, Güth JF. Anterior restorations: the performance of ceramic veneers. *Quintessence Int*. 2018;49(2):89-101.
47. Edelhoff D, Ahlers MO. Occlusal onlays as a modern treatment concept for the reconstruction of severely worn occlusal surfaces. *Quintessence Int*. 2018;49(7):521-533.
48. Teichmann M, Göckler F, Rückbeil M, Weber V, Edelhoff D, Wolfart S. Periodontal outcome and additional clinical quality criteria of lithium-disilicate restorations (empress 2) after 14 years. *Clin Oral Investig*. 2019;23(5):2153-2164.
49. Ryge G, Snyder M. Evaluating the clinical quality of restorations. *J Am Dent Assoc*. 1973;87(2):369-377.
50. Hickel R, Roulet JF, Bayne S, et al. Recommendations for conducting controlled clinical studies of dental restorative materials. *Clin Oral Investig*. 2007;11(1):5-33.
51. Burian G, Erdelt K, Schweiger J, Keul C, Edelhoff D, Güth JF. In-vivo-wear in composite and ceramic full mouth rehabilitations over 3 years. *Sci Rep*. 2021;11(1):14056.

How to cite this article: Edelhoff D, Erdelt K-J, Stawarczyk B, Liebermann A. Pressable lithium disilicate ceramic versus CAD/CAM resin composite restorations in patients with moderate to severe tooth wear: Clinical observations up to 13 years. *J Esthet Restor Dent*. 2023;35(1):116-128. doi:10.1111/jerd.12947