

# Clinical Evaluation of Chairside-Fabricated Partial Crowns Made of Zirconia-Reinforced Lithium Silicate Ceramic - 2-Year-Results

## Keywords

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## ABSTRACT

*Introduction:* In a prospective study, the clinical performance of chairside-fabricated partial-crowns made of zirconia-reinforced lithiumsilicate (ZLS)-ceramic was evaluated after 2 years. *Materials and methods:* 45 patients (28 female/17 male) underwent restoration with 61 chairside-fabricated ZLS partial-crowns on vital premolars and molars. In variation from the manufacturer's recommendations (minimum material thickness (MMT)=1.0 mm), partial-crowns with reduced material thicknesses were fabricated: group 1, MMT=0.5-0.74 mm (n=31); group 2, MMT=0.75-1.0 mm (n=30). The restorations were luted with either a self-adhesive cement (SAC) or the total-etch technique using a dual-curing composite cement (DC). The MMT and cementation technique (SAC vs. DC) were evaluated as possible covariates of the time-dependent survival (SVR) and success rate (SCR) using univariate log-rank-tests. *Results:* Forty-four patients with 59 restorations participated in the 2-year follow-up examinations. In group 1 (n=31), there were 2 losses due to ceramic fracture (SVR: 94.0% (95% confidence interval (CI): 0.85-1)). In group 2, no losses were documented (SVR: 100%). In 2 restorations cemented with SAC, recementation was necessary (overall SCR: 93% (CI: 0.87-1)). *Conclusion:* To avoid early material-related fractures, observing the recommended minimum thickness of 1.0 mm is essential. However, further validation of these results in studies with longer observational periods is required.

## INTRODUCTION

For the fabrication of tooth-colored partial crowns, dental ceramics represent the most used materials. The available clinical data indicate that up to now, material fractures are the most frequent cause of failures.<sup>1-4</sup> This observation is based on the fact that in these studies, mostly feldspathic or leucite-reinforced glass-ceramics with a mean flexural and tensile strength of less than 200 MPa were used.<sup>1-4</sup> Thus, dental ceramic materials with improved mechanical properties offer the possibility of reducing the incidence of material-related failure.<sup>5</sup>

High-strength glass ceramics, such as lithium disilicate ceramics or newly developed zirconia-reinforced lithium silicate (ZLS) ceramics with a flexural and tensile strength of 370-450 MPa, provide stability 2- to 3-times greater than that of leucite-reinforced glass-ceramics.<sup>6</sup> In vitro and clinical studies

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with mean observational periods of 7 years have demonstrated that the improved mechanical properties of lithium disilicate ceramics materials led to significantly reduced material-related failure rates of ceramic partial crowns.<sup>7</sup>

Several *in-vitro* studies focused on determining whether the improved mechanical properties of the new high-strength ceramic materials allowed a reduction in the minimum material thickness (MMT).<sup>7-10</sup> Adhesively cemented occlusal veneers fabricated from a lithium disilicate ceramic with a minimum layer thickness of 0.7-1.00 mm showed survival rates of 100% in mastication simulations.<sup>11</sup> In another mastication simulation, lithium disilicate ceramic crowns and ZLS crowns showed survival rates of 100%, even with a reduction in the MMT to 1 mm.<sup>12</sup> Based on these results, several manufacturers have reduced the recommended material thickness for high-strength glass-ceramic restorations to 1 mm.

However, it must be considered that the reasons for the failure of all-ceramic restorations are multifactorial. Apart from the material, fabrication technique, and type of cementation, patient-related factors, such as bruxism or location of the restoration, have had clinically relevant effects on the long-term durability of all-ceramic restorations.<sup>1-4,13,14</sup> A general recommendation for a reduced MMT for all-ceramic restorations made of high-strength glass-ceramics should, therefore, be based on clinical studies. Clinical data for ZLS ceramics with special regard to the effect of material thickness are not yet available.

The present prospective clinical study aimed to evaluate the risk factors of the material-induced failure of chairside-fabricated partial crowns (Cerec system SW 4.2) made of a ZLS ceramic (Vita Suprinity) with special consideration of the applied cementation technique and a reduced MMT of 0.5 to 1.0 mm. The null hypothesis of the present study was that the survival and success rates are independent of the cementation technique applied and the MMT of the restorations. Furthermore, the calculated survival and success rates should be compared to the previously reported rates for CAD/CAM-fabricated partial crowns.

## MATERIALS AND METHODS

### PATIENT RECRUITMENT

The study included 45 patients (28 female/17 male) with indications for a fully cusp-covering chairside-fabricated partial crown restoration made of a ZLS ceramic material. The inclusion criteria were vital and symptom-free premolar and molar teeth with existing antagonistic teeth with a minimum of one proximal point of contact. The following exclusion criteria were applied:

- Clinical symptoms of bruxism
- Unsuitable (deeply subgingival) preparation for optical impression taking

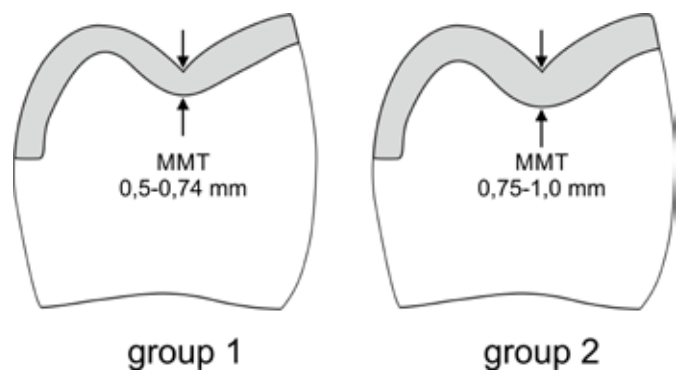
- Untreated periodontal disease
- Age less than 18 years

Each patient underwent a maximum of two restorations in this study. The study protocol was evaluated and approved by the ethics committee of the medical faculty of Georg-August-University, Goettingen, Germany (No. 27/7/13). All patients provided written consent to participate in the study.

### TREATMENT

All treatments were performed by two experienced dentists in the Department of Preventive Dentistry, Periodontology, and Cariology, University Medical Center, Goettingen, Germany, between January 1 and July 31, 2014. Prior to treatment, all patients underwent professional prophylaxis and were given instructions for domestic oral hygiene procedures. The teeth were prepared according to the published recommendations for all-ceramic restorations.<sup>15</sup> The preparation was followed by optical impression taking with an intraoral scanning device (Cerec AC Omnicam) and the construction of a monolithic partial crown restoration (Cerec software 4.2). However, due to the standard setting of the construction software being an MMT of 0.7 mm, this value was applied for the construction of the restorations. This deviation from the original treatment protocol was only realized after the clinical treatment phase had been completed, thus leading to the fabrication of restorations with an MMT falling below the recommended thickness of 1.0 mm. The ethics committee was informed about this deviation from the study protocol and approved the continuation of the study. Based on an analysis of the generated construction data, the fabricated ceramic partial crowns were divided into two groups (Figure 1).

After production in a wet-milling unit (Cerec MCXL), the restorations underwent crystallization and stain firing according to the manufacturer's recommendations. The internal surfaces of the partial crowns were treated with hydrofluoric acid (5%, Vita Ceramics Etch) for 20 sec, cleansed, and silanized (Monobond S; exposure time: 1 min).



**Figure 1:** Schematic presentation of the preparation design and group distribution related to the occlusal minimum material thickness (MMT). Group 1- MMT=0.5-0.74 mm. Group 2- MMT=0.75-1.0 mm

The adhesive cementation of the partial crown restorations was performed, either with a dual-curing composite cement (DC) and multi-bottle bonding with the total-etch technique (Syntac classic and Variolink) or with a self-adhesive cement (SAC), (RelyX Unicem), each under complete desiccation. For the random assignment of participants to the cementation groups, an online statistical computing web program ([www.randomization.com](http://www.randomization.com)) was used to generate the randomization schedule. Thirty restorations were fixed with a DC material using the total-etch technique, while 31 restorations were inserted with a SAC material.

After removing the excess cement, the cementation material of each restoration was polymerized for 120 sec. Then, occlusion was restored according to the initial situation (anterior-canine guided occlusion or unilateral dynamic guidance) (Figure 2a and b).



**Figure 2a:** Clinical example for the treatment outcome with a CAD/CAM-fabricated ZLS partial crown, prior to treatment



**Figure 2b:** Clinical example for the treatment outcome with a CAD/CAM-fabricated ZLS partial crown, clinical situation after adhesive luting and finishing (baseline)

## CLINICAL EVALUATION

The following evaluation parameters were applied: the survival rate (restoration remained in situ), the success rate (intervention-free functional period of the restoration), and the modified USPHS criteria. Follow-up examinations started at the time of cementation (baseline) and were scheduled in 6-month intervals.

The last follow-up examinations were performed between March and August 2016 by a trained dentist (A.B.). This dentist was not involved in the insertion of the restorations and was trained and calibrated by one of the authors (D.Z.) regarding the survival and success criteria.<sup>16</sup> The training was repeated until each examiner had substantial correlation, as measured by Cohen's Kappa ( $k \geq 0.6$ ). All restorations available for follow-up were clinically evaluated with a mirror, a probe, and intraoral images. The vitality of the teeth was confirmed by CO<sub>2</sub> testing. Every restoration was examined regarding fissures, fractures, loosening, caries, and marginal discolorations. Failures that occurred before the examinations due to negative events (restoration loss, recementation if necessary, ceramic fracture, biological complications) were documented in the patient files and considered in the final results.

## STATISTICAL ANALYSIS

The statistical analysis was based on information on the survival and success rates of the reconstructions. Survival was defined as the restoration being in situ at the time of the follow-up examination without signs of a total loss (i.e., the in situ criterion).<sup>16</sup> A total loss was defined as a clinically unacceptable ceramic fracture of the restoration or a biological event (caries, tooth fracture, or periodontal disease) requiring complete replacement of the restoration or removal of the affected tooth. Success was defined as the reconstruction remaining unchanged and functional in situ, without any intervention throughout the total observational period.<sup>16</sup> The survival time of a restoration was defined as the period between the day of cementation and either the last follow-up examination or, in the case of failure, the day of failure documentation in the patient file. The time-dependent survival rates of the restorations (based on the in situ criterion) and the success rates (intervention-free) of the partial crowns were calculated by Kaplan-Meier survival analysis.

The MMT (0.5-0.74 mm vs. 0.75-1.0 mm) and the cementation technique (SAC vs. DC) were evaluated as possible covariates of the time-dependent survival and success rates. All potential risk factors of interest are on categorical scales. The influence of the potential risk factors was studied via univariate log-rank tests. Cox regression was not possible due to the limited number of events.<sup>17</sup>

A p-value of less than 0.05 was accepted as statistically significant. All analyses were performed with the statistic software R (version 3.5.3); using the R-package survival (version 2.44.1.1) for the time-to-event analyses.

The changes in the clinical criteria over time between the baseline and the 2-year examination were evaluated separately for each luting procedure. For the statistical analysis of the data, the chi-square test was applied ( $\alpha=0.05$ ).

## RESULTS

### STUDY POPULATION

In the present study, 45 patients were originally restored with a total of 61 partial crowns between January and June 2014. One female patient withdrew her written consent for participation in the study at the time of the baseline examination. Forty-four patients (27 female/17 male, recall rate: 97.8%) with a total of 59 partial crowns participated in the 2-year follow-up examination. The mean age of the patients was  $50.7\pm 10.6$  years. This follow-up examination was performed between March and August 2016 (mean observational period:  $24.4\pm 3.4$  months). Thirty-one restorations were assigned to group 1, and 28 were assigned to group 2. Thirty-four of the examined restorations were placed in the maxilla, and 25 were in the mandible (23 premolar and 36 molar partial crowns) (Table 1). Thirty of the examined restorations were cemented with DC using the total-etch technique, and 29 partial crowns were inserted with a SAC material.

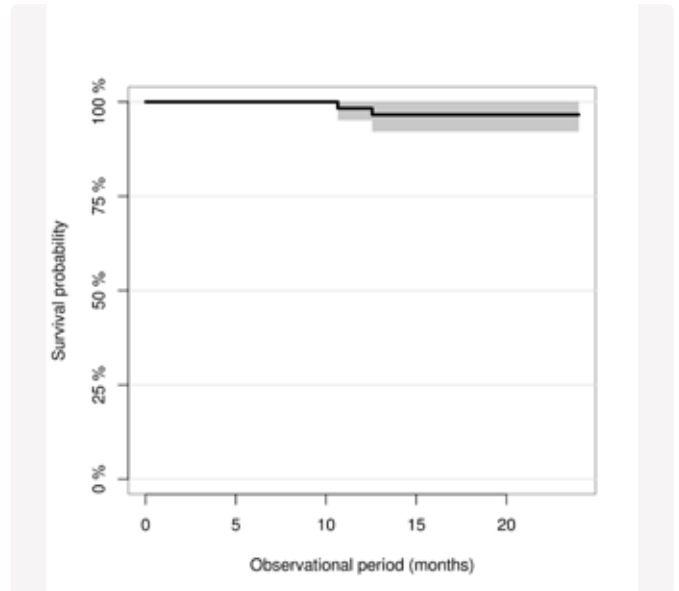
**Table 1: Distribution of partial crown restorations included in the study**

Tooth	17	16	15	14	24	25	26	27	Total Maxilla
Number	4	6	9	3	0	3	4	5	34
Tooth	47	46	45	44	34	35	36	37	Total Mandible
Number	2	6	1	1	1	5	8	1	25

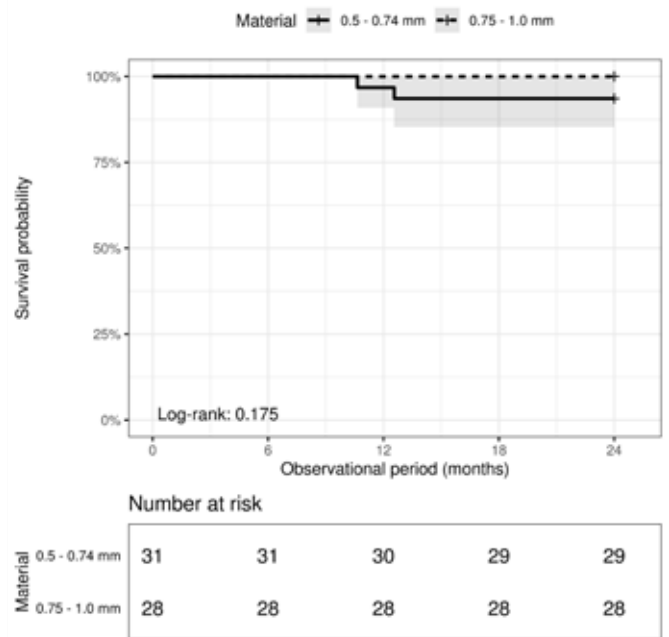
### SURVIVAL RATE

At the time of the 2-year follow-up examination, the loss of 2 partial crowns was documented. The overall survival rate after 2 years was 97% (95% confidence interval (CI): 0.92-1) (Figure 3). All losses occurred in group 1 (MMT=0.5-0.74 mm), and they were related to material fractures. The 2-year survival rate of group 1 was 94% (95% CI: 0.85-1) and 100% in group 2 (MMT=0.75-1.0 mm) (Figure 4).

The difference in the survival rate was not statistical significant (log-rank-test,  $p=0.175$ ) (Figure 4). The cementation technique (SAC vs. DC, log-rank-test  $p=0.161$ ) showed no significant influence on the survival rate of the partial crowns. Therefore, the null hypothesis cannot be rejected regarding the survival rate.



**Figure 3:** Overall survival rate of the chairside-fabricated zirconia-reinforced lithium silicate (ZLS) partial crowns after a mean observational period of 2 years.



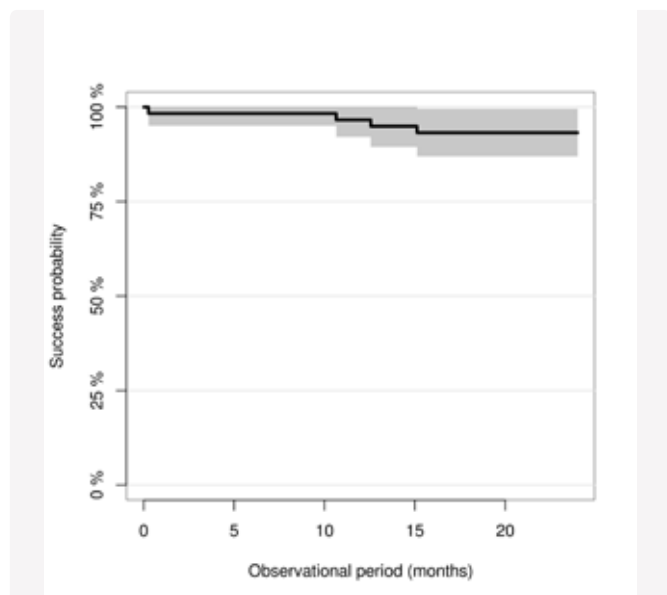
**Figure 4:** Survival time of the partial crown restorations by the occlusal minimum material thickness (MMT).

### SUCCESS RATE

Apart from 2 total losses, two restorations (2 patients) required clinical interventions to maintain function. The time-dependent overall success rate (intervention-free survival) was 93.0% (95% CI: 0.82-0.97) after 24 months (Figure 5). All clinical interventions required to keep the restorations functional were caused by the loss of the retention of partial crowns inserted with SAC. Both restorations did not show any defects and were recemented with the same material. Further interventions due to temperature sensitivity, loss of vitality, or secondary caries were not necessary. The

success rate of partial crowns in group 2 (MMT = 0.75-1.0 mm) cemented with DC was 100%.

The overall success rate (intervention-free survival) was independent of the MMT of the partial crowns (0.5-0.74 mm vs. 0.75-1 mm, log-rank-test  $p = 0.917$ ) and the cementation technique (log-rank-test  $p=0.972$ ) was documented. The null hypothesis was not rejected for the success rate.



**Figure 5:** Overall success rate of the chairside-fabricated zirconia-reinforced lithium silicate (ZLS) partial crowns over a mean observational period of 2 years.

Further interventions due to ceramic fractures, temperature sensitivity, or secondary caries were not necessary (100% Alfa ratings for the USHPS criteria “surface texture”, “postoperative sensitivity”, and “recurrent caries”).

At baseline, the marginal adaptation was rated alfa in 29 restorations (96.7%) in group DC and 27 restorations (93.1%) in group SAC. All other restorations were rated bravo. At the 2-year recall, the alfa ratings decreased to 82.1% in group DC and to 72.4% in group SAC, and the remaining restorations were rated bravo (Table 2).

At baseline, the marginal discoloration was rated alfa for all restorations in both groups. At the 2-year clinical examination, the alfa ratings decreased to 75.0% (group DC), and 69.0% (group SAC). Regarding marginal adaptation and marginal discoloration, a statistically significant difference ( $p<0.05$ ) could be found in both groups for the data assessed at baseline and after 2 years (Table 2).

Regarding the parameters “marginal adaptation” and “marginal discoloration”, no significant differences for the data assessed at the 2-year recall were detected between the restorations in group DC and group SAC.

## DISCUSSION

In the present study, chairside-fabricated partial crowns made of a ZLS ceramic material showed a survival rate of 100% at an MMT of 0.75-1.0 mm after a mean observational period of 2 years, while the survival rate of partial crowns with an MMT of  $<0.75$  mm was 94%. Clinical interventions (recementation) to

**Table 2:** Rating for selected USPHS criteria at the 2-year clinical examination.

Group	Time	Marginal adaptation <sup>2</sup>				Marginal discoloration <sup>2</sup>		
		alfa	bravo	charlie	delta	alfa	bravo	charlie
DC	Baseline (n=30)	29 (96.7%)	1 (3.3%)	0	0	30 (100%)	02	0
	2-year (n=28) <sup>1</sup>	23 (82.1%)	5 (17.9%)	0	0	21 (75.0%)	7 (25.0%)	0
SAC	Baseline (n=29)	27 (93.1%)	2 (6.9%)	0	0	29 (100%)	0	0
	2-year (n=29)	21 (72.4%)	8 (27.6%)	0	0	20 (69.0%)	9 (31.0%)	0

<sup>1</sup>Only 28 restorations remained because two partial ceramic crowns failed. <sup>2</sup>Significant difference between baseline and 2-year investigation ( $p\leq 0.05$ )

Applied modified USPHS criteria (Federlin et al. 2007/Federlin et al. 2014)

**Marginal adaptation:** alfa - Margin not discernible, probe does not catch

bravo - Probe catches on margin but no gap; dentin or liner exposed

charlie - Probe catches on margin and gap on probing, dentin or liner exposed

delta - Restoration fractured or missing

**Marginal discoloration:** alfa - No marginal discoloration

bravo - Marginal discoloration, not penetrated toward pulp

charlie - Marginal discoloration penetrated toward pulp

maintain the function of restorations were required for 2 restorations cemented with SAC.

The results of the present study should preferably be compared with those of clinical studies on all-ceramic crowns with a similar design (prospective), comparable survival and success rates, and a comparable observational period.<sup>18-20</sup>

Federlin *et al.* (2007) documented a survival rate of 93.1% after three years for chairside-fabricated partial crowns (Cerec system) made from a feldspathic ceramic material (Vita MK II) with an MMT of 1.5 mm. The material fracture was the most frequent cause of failure. The survival rate of the partial crowns made of gold in the control group was 100%.<sup>18</sup> Another prospective study reported a survival rate of 97% for chairside-fabricated partial crowns made of a leucite-reinforced glass-ceramic material (ProCAD) with an MMT of 1.5 mm. The control group consisted of conventionally fabricated partial crowns made of a lithium disilicate ceramic material (IPS e.max) which showed a survival rate of 100%.<sup>19</sup>

A prospective study with a mean observational period of 3 years on conventionally fabricated partial crowns made of a leucite-reinforced glass-ceramic material (IPS Empress) reported that a mere reduction in the MMT to 1.0-1.4 mm caused a significant increase in fracture-related loss.<sup>20</sup>

In the present study, no fracture-related losses were documented with a moderate reduction relative to the manufacturer-recommended MMT (0.75-1.0 mm), independent of the applied cementation technique. Thus, the survival rate was in the same range as that of chairside-fabricated partial crowns made of leucite-reinforced ceramic materials and conventionally fabricated partial crowns made of lithium disilicate ceramic materials with an MMT of 1.5 mm. Fracture-related losses occurred only after a massive reduction relative to the recommended MMT (0.5-0.74 mm).

In this group, the survival rate after a mean observational period of 2 years was 94% due to 2 fractures. This result was not statistically significant ( $p=0.175$ ), therefore results from prolonged observational periods are needed to verify a possible effect of the MMT on the survival of CAD/CAM-fabricated partial crowns.

Considering the yet limited observational period, the results of the present study can be interpreted as an initial clinical verification for the clinical performance of high-strength glass-ceramic materials. The postulation of previous *in vitro* studies that the occlusal MMT can be reduced to 1.0 mm without an increase in the rate of fracture-related failures is justified.<sup>11,12</sup> However, to specify a defined limit for an MMT leading to fracture-related failures, additional studies with larger populations and longer observational periods are required.

Throughout the observational period, clinical interventions for maintaining the function of restorations were only required due to the loss of retention. Endodontic complications or secondary caries were not observed.

All losses of retention occurred in restorations that were inserted with SAC, while restorations inserted with DC showed no loss of retention. This observation is in accordance with the results of other prospective studies showing increased rates of retention loss in chairside-fabricated partial crowns inserted with SAC.<sup>13,21,22</sup>

It is worth mentioning that in the present study, all restorations could be recemented after the loss of retention; in contrast, in studies on restorations fabricated from feldspathic materials, the loss of retention was mostly related to restoration fracture, so no recementation was possible.<sup>13,21,22</sup> This observation can be explained by the increased mean flexural strength of the applied ZLS ceramic materials in comparison with feldspathic ceramic materials.<sup>6</sup>

In the present study, for both luting agents a significant increase in “bravo” ratings for marginal adaptation and marginal discoloration could be observed from baseline to the 2-year examination. This is in accordance with the findings of previous studies reporting USPHS criteria changes in the same range for CAD/CAM-fabricated partial crowns from different materials.<sup>18,21,22</sup>

In the present study, none of the examined covariates (MMT, cementation technique) showed a significant influence on the determined survival and success rates. This is due to the relatively short observational period, the small study population, and the limited number of losses and events. These aspects represent the major limitations of the present study.

Another limitation is the operating error in the construction software that led to a deviation from the MMT recommended by the manufacturer. Thus, the restorations were not randomized regarding this parameter. This is a limitation for a clinical research project. On the other hand, this inadvertent deviation from the study protocol provided important evidence on the possible clinical impact of errors in the fabrication process of chairside-fabricated restorations. To the best of the authors' knowledge, this impact has not yet been documented in the literature.

Despite these limitations, the present study provides important information on the clinical evaluation of chairside-fabricated partial crowns because it offers clinical results for relatively new ZLS ceramic materials, which have only rarely been previously documented and only with significantly shorter observational periods.<sup>23</sup> However, due to the limited sample size, a clinical recommendation must be made with caution, as the present study was underpowered to detect significant effects of potential risk factors.

For a final evaluation of the risk factors examined in the present study, clinical studies with longer observational periods and larger sample sizes are essential.

## CONCLUSION

After a mean observational period of 2 years, chairside-fabricated partial crowns made of a ZLS ceramic material showed a survival rate of 100% with a moderate reduction relative to the manufacturer's recommendations regarding the occlusal MMT, independent of the cementation technique. A further reduction in the occlusal MMT (0.5-0.74 mm) led to a tendency for an increased rate of catastrophic ceramic fractures requiring a replacement of the restorations. Clinical interventions were caused by a loss of retention and occurred only for restorations cemented with SAC. Clinical evaluations with longer observational periods and larger sample sizes are essential for further examination of these potential influencing factors.

## MANUFACTURERS' DETAILS

- Cerec SW 4.2, Cerec AC Omnicam, Cerec MCXL: all by Dentsply Sirona, Bensheim, Germany
- IPS E.max, IPS Empress, Monobond S, IPS ProcCAD, Syntac Classic, Variolink: all by Ivoclar Vivadent, Schaan, Liechtenstein
- RelyX Unicem: 3M, Seefeld, Germany
- R-project for statistical computing, version 3.5.0: [www.r-project.org](http://www.r-project.org)
- Vita Ceramics Etch, Vita MK II, Vita Suprinity: all by Vita Zahnfabrik, Bad Säckingen, Germany

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