Original Article

Technical Complication and Failure Rates of Posterior Implant-supported Monolithic Lithium Disilicate Single Crowns: A 6-Year Prospective Cohort Study

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Running title: Prognosis of posterior implant-supported monolithic lithium disilicate single crowns over a follow-up period exceeding 6 years

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Abstract

Aims: *To assess the technical complication and survival rates of posterior implant-supported single crowns (SCs) fabricated with monolithic lithium disilicate (LDS) over an extended period.*

Materials and methods: *A prospective evaluation was conducted on 60 patients with a total of 82 implants undergoing single posterior dental implant restoration. The procedure involved the use of CAD/CAM produced customized titanium abutments and monolithic LDS crowns, with at least 6 years of follow-up. The survival rate and technical complication rate of the implant-supported SCs were analyzed using Kaplan–Meier analysis and Log-Rank tests.*

Results: *The mean observation period was 6.3 ± 0.3 years. The survival rate was 92.5%, along with 2 cases of implant failures and 4 crown fractures. The complication rate was 17.5%, resulting in an overall success rate of 75%. Notably, parafunctional habits were the only variable significantly correlated with both survival and complication rates.*

Conclusions: *Within the limitations of this clinical study, monolithic LDS appeared to be a reliable treatment option for posterior implant-supported SCs based on 6 years of clinical observation. Despite favorable outcomes, a relatively high complication rate, primarily associated with abutment screw loosening (ASL), was noted. Opting for a precise implant-abutment connection from a reputable manufacturer may contribute to improvement. Parafunctional habits were the only variable significantly correlated with clinical outcomes, suggesting the potential benefit of fabricating an occlusal appliance for implant protection.*

Key words: Dental implant, single crowns, monolithic lithium disilicate, complications

Introduction

Dental implant-supported restorations have been widely used for several decades and showcase the significant progress made due to advancements in dental technology and improvements in materials. A recent systematic review and meta-analysis estimated a 10-year survival rate of 96.4% for implants.[1] Due to their high long-term success rate and their predictability, stability, and natural functionality, dental implants are recognized as the standard of care for replacing missing teeth.[1,2]

In addition to the stability of implants, the long-term survival of implant-supported prosthetics is also a crucial concern for dentists. A systematic review by Jung et al. found an estimated five-year survival rate of 96.3% and a 10-year survival rate of 89.4% for implant-supported single crowns (SCs). Technical complications included screw-loosening (8.8% of cases), loss of retention (4.1%), and fracture of veneering material (3.5%) after five years, indicating high survival rates but also frequent complications involving implant reconstructions.[3]

The choice of implant crown material significantly influences the outcomes of implant-supported SCs. Metal–ceramic restorations, a longstanding choice, have demonstrated long-term stability.[4–6] With the advent of computer-aided design and computer-aided manufacturing (CAD-CAM) technology, all-ceramic restorations have gained popularity.[7] Systematic reviews by Pjetursson et al. in 2018 and 2021 highlighted the clinical performance of metal–ceramic, monolithic lithium disilicate (LDS), and monolithic zirconia implant-supported SCs. Metal–ceramic implant-supported SCs had the highest survival estimate (a five-year rate of 98.3%) with the longest mean follow-up period (5.7 years). Monolithic LDS implant-supported SCs had the lowest complication rate (1.7% per year). However, both monolithic LDS and monolithic zirconia implant-supported SCs lacked sufficient observation time.[5,8] Thus, this study evaluated an all-ceramic material, monolithic LDS, used as the crown material for implant-supported SCs for its long-term clinical performance.

In recent years, monolithic LDS has emerged as a promising material for natural tooth-supported SCs. A recent study reported an 80.1% survival rate and a 64.2% success rate after a 15-year follow-up.[9] The combination of strength, aesthetics, and biocompatibility has contributed to its popularity. However, a long-term evaluation of monolithic LDS as an implant restoration material is still lacking. A systematic review and meta-analysis by Rabel K et al. found that monolithic LDS crowns had a five-year survival rate of 91.0%.[10] Another systematic review and meta-analysis by Pjetursson et al. reported a three-year survival rate of 97.0% for monolithic reinforced glass–ceramic implant-supported SCs, with an annual failure rate of 1.05%.[8] In Schubert et al.'s study evaluating 40 implants with one monolithic LDS crown fracture, the overall survival rate was 97.5% over a mean follow-up time of 5.9 ± 1.4 years.[11] Despite the general use of monolithic LDS crowns over an extended period, few studies have addressed the long-term clinical outcomes of implant restorations, particularly in the posterior region.

This investigation aimed to undertake a thorough evaluation of the clinical performance and durability of posterior implant-supported SCs fabricated with monolithic LDS over an extended period. We undertook a longitudinal analysis, with the goal of providing evidence-based guidance to dental practitioners and prosthodontists on selecting the ideal material for posterior implant restorations.

Materials and methods

This study was approved by the Ethics Committee and Institutional Review Board of Chang Gung Memorial Hospital, Taiwan (201700057B0). The study employed a prospective in vivo approach to investigate the long-term performance of monolithic LDS in posterior dental reconstructions, with a follow-up period exceeding six years.

The inclusion criterion for selecting study participants was that they had undergone at least one single-implant restoration in the posterior region between December 2016 and January 2018 at the Prosthodontics Department of Linkou Chang Gung Memorial Hospital. The exclusion criteria were patients who were unable to undergo implant surgery due to general medical conditions or surgical sites with any pathological condition that might compromise treatment outcome and implants with improper angulation that could not be fabricated with a screw-retained implant crown.

A total of 60 patients, comprising 29 males and 31 females with 82 implants, were included in this study. All patients provided written informed consent after they received detailed information about the study objectives. The clinical treatment process involved a minimum three-month waiting period after tooth extraction, followed by delayed implant placements in posterior dental areas by seven periodontists at the Department of Periodontology, Linkou Medical Center, Chang Gung Memorial Hospital, Taoyuan, Taiwan. The implant systems used included Biomet 3i dental implants (Tapered or Parallel-Walled Certain Internal Connection Implants; Biomet 3i, Palm Beach Gardens, FL, USA), Straumann tissue-level (Standard or Standard Plus Implants; Straumann, Basel, Switzerland) and Straumann bone-level (Bone Level implants or Bone-Level Tapered Implants; Straumann, Basel, Switzerland) systems, and XiVE implants (XiVE S Plus implant; DENTSPLY Implants Manufacturing GmbH, Mannheim, Germany). After 3–6 months of healing, these implants were restored by a single prosthodontist (K.H.) at the Department of Prosthodontics in the same hospital. A customized titanium abutment (FIT CAD-CAM custom abutment; FIT MILLING CENTER CO, LTD, Changhua city, Taiwan), fabricated using CAD-CAM procedures, was employed. Subsequently, the final prosthesis, consisting of a monolithic LDS crown, was fabricated using IPS e.max Press (Ivoclar Vivadent AG, Schaan, Liechtenstein) with an occlusal opening to access the abutment screw, and cemented with resin cement (Rely X Unicem or Rely X U200; 3M ESPE, St. Paul, MN, USA). Finally, the assembly was delivered to the patient and tightened with torque according to the manufacturers' instructions. The screw-access hole was filled with polytetrafluoroethylene tape and then with composite resin (Filtek Z350; 3M ESPE, St. Paul, MN, USA) to a depth of at least 1 mm.

The patient records were systematically reviewed. Eight variables were considered: sex, medical history, smoking history, betel nut use, parafunctional habits, date of implant crown delivery, the position of the implant, and the type of implant. A routine follow-up examination was performed at six months, followed by a comprehensive long-term follow-up exceeding six years.

Throughout the prosthodontic examination, technical complications and failures of the implant-supported SCs were assessed by the same examiner (K.H.). Complications included fracture and/or chipping of ceramic that could be managed without impacting occlusal function, causing food impaction, or compromising patient comfort; loosening of an abutment screw; fracture of an abutment screw; and fracture of an abutment. A failure was defined as an event leading to destructive crown fracture necessitating the renewal of the entire implant-supported reconstruction; or explantation/loss of the implant and, consequently, the loss of the implant-supported reconstruction. Survival was defined as reconstructions without failures, while success was defined as reconstructions without both failures and complications.

Descriptive statistics were used for implant analysis and the Kaplan–Meier method was used to analyze the survival rate and technical complication rate. Correlations between survival rate, complication rate, and variables were determined using log-rank tests. The statistical analyses were performed using SPSS software (IBM SPSS Statistics for Mac, Version 29.0; IBM Corp., Armonk, NY, USA). The level of significance was set at $p < 0.05$.

Results

Of the 60 patients (82 implants), one patient (with two implants) was lost to follow-up and could not be contacted by telephone. The 80 examined crowns had an average functioning time of 6.3 ± 0.3 years (range: 6–7.1 years). An overview of the patient variables, implant characteristics, and the influence of these variables on the incidence of failure and complications is summarized in Table 1. Of the 80 implant-supported SCs, 6 implants (7.5%) failed (Fig. 1): 2 reconstructions were lost due to the failure of the supporting implant; and 4 implant crowns suffered destructive fractures, necessitating renewal during the 6-year examination (Table 2). The failure rates for the maxilla (7.9%) and mandible (7.1%) were similar. In the case of complications, 14 reconstructions (17.5%) had at least one issue (Fig. 2). The most frequently observed complication was abutment screw loosening (ASL) (12 cases), followed by one case of ceramic chipping and one case of abutment screw fracture. No abutment complications were observed (Table 3).

As a result, the survival rate of the implant-supported SCs after six years was 92.5% and the complication rate after six years was 17.5%. The success rate after accounting for both failures and complications was 75%. Parafunctional habits were the only variable demonstrating a significant correlation with both the survival rate (log-rank test: $p = 0.035$) and the complication rate (log-rank test: $p = 0.008$).

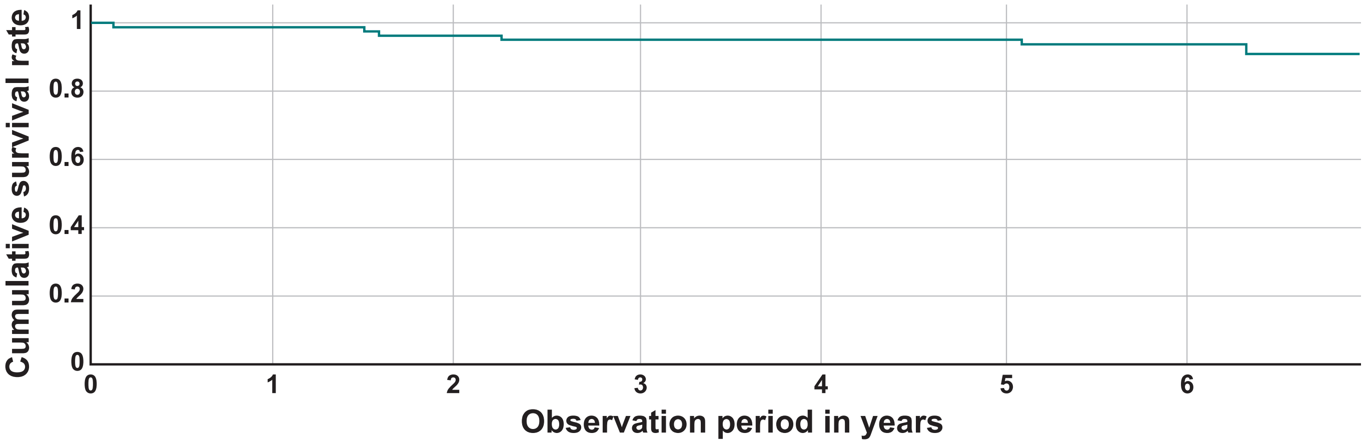

Figure 1. Restoration-based Kaplan–Meier survival function for the failure of implant-supported SCs

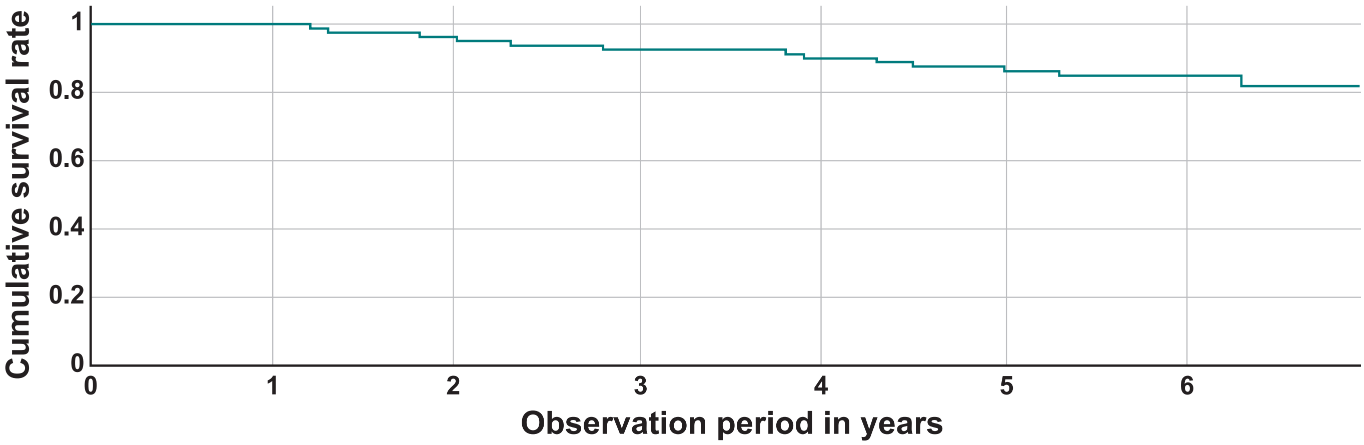

Figure 2. Restoration-based Kaplan–Meier survival function for the complication of implant-supported SCs

Table 1. Influence of patient and prosthesis variables on the incidence of failure and complication in 80 implant-supported SCs.

Variable	Category	SCs (N)	Failures of Implant-Supported SCs: Number of Events	*P*	Complications of Implant-Supported SCs: Number of Events	*P*
Gender	Male	39	4		10	
	Female	41	2	.29	4	.054
Medical history	No	79	6		13	
	Yes	1	0	.799	1	.07
Smoking & betel nut user	N0	80	6		14	
	Yes	0	0	1	0	1
Parafunctional habits	No	71	3		8	
	Yes	9	3	.035*	6	.008*
Jaw	Maxilla	38	3		7	
	Mandible	42	3	.949	7	.968
Tooth position	Premolar	26	1		3	
	Molar	54	5	.371	11	.258
Type of implant	Biomet 3i	21	1		4	
	Straumann tissue level	22	2		4	
	Straumann bone level	5	0		0	
	XiVE	32	3	.882	6	.752

*Significant p-values

Table 2. Overview of failures in the 80 implant-supported SCs during the 6-year examination

Restoration number	Gender	Tooth position	Function time(year)	Reason for failure
9	F	36	6.3	Implant failed
61	M	27	1.5	Implant failed
1	F	37	2.2	Crown fractured
42	M	34	1.5	Crown fractured
52	M	17	0.2	Crown fractured
65	M	17	5.1	Crown fractured

Table 3. Overview of complication in the 80 implant-supported SCs during the 6-year examination

Type of Complications	Number of Event	Complication Rate (%)
Ceramic chipping	1	1.25%
Abutment screw loosening	12	15%
Fracture of an abutment screw	1	1.25%
Fracture of an abutment	0	0%

Discussion

The overall six-year survival rate of the reconstructions in this prospective study was 92.5%, and the complication rate was 17.5%. This survival rate is similar to those from the two aforementioned systematic reviews.[8,10] However, both reviews reported lower complication rates compared to our result, particularly in the case of screw loosening. Schubert et al. recently reported a survival rate of 97.5% with no technical complications during an observation time of 5.9 ± 1.4 years, demonstrating a better outcome compared to our result.[11] This disparity may be attributable to the use of customized titanium abutments in our study. Schubert et al. employed titanium-base CAD-CAM abutments,[11] which reportedly show a better internal fit at the implant–abutment connection compared to custom abutments fabricated through a fully digitalized CAD-CAM process.[12] Misfit between implant and abutment can result in the loosening of screws, reduced preload, and in some cases, significant stress around the implant.[13] Hsu et al. also reported a higher rate of ASL with the same type of abutment.[14] Hsu et al. and other studies noted an increased misfit when compatible CAD-CAM abutments are associated with implants from other manufacturers, suggesting the importance of selecting manufacturers that consistently offer high quality to establish a more stable connection.[15]

Implant position plays a significant role in the prognosis of implant-supported prostheses. A recent systematic review by Rabel et al. reported a higher incidence of chipping in posterior all-ceramic implant-supported SCs.[10] In contrast, another systemic review by Pjetursson et al. found that posterior SCs with monolithic-reinforced glass–ceramics had a significantly lower rate of failure due to ceramic fracture compared to anterior SCs. The variability may also arise from different approaches to statistical analysis.[8] Further investigation is required to determine the difference between anterior and posterior implant-supported SCs fabricated with monolithic LDS.

Parafunctional habits were the only variable significantly correlated with both the survival rate and the complication rate in our study, consistent with previous studies.[2,16,17] In Kinsel et al.'s study, patients with a bruxism habit had approximately seven times higher odds of porcelain fracture and five times higher odds of major fracture compared to those without a bruxism habit.[16] Consequently, the fabrication of an occlusal appliance is recommended for patients with bruxism.

The comparison between monolithic LDS and other materials provides insights into selecting materials for implant-supported SCs. Hsu et al. evaluated posterior implant-supported SCs fabricated with metal–ceramic with a minimum six-year follow-up period and reported a higher success rate (100%) and a complication rate (16%) similar to those in this study.[14] The systematic review by Alqutaibi et al. reported similar outcomes related to prosthesis failure, mechanical and biological complication rates, and patient satisfaction for ceramic and metal–ceramic crowns. They concluded that the choice of material for a single implant crown depends on the dentist's and patient's preferences.[4]

Monolithic zirconia has gradually become the preferred material for implant reconstructions. New variations with tooth-like color and increased translucency offer aesthetic and stiffness benefits. De Angelis et al. reported similar clinical outcomes for monolithic LDS and monolithic zirconia over a three-year follow-up.[18] In a review by Pjetursson et al., monolithic LDS had a higher rate of core fracture. In contrast, monolithic zirconia showed a higher rate of abutment fracture and loss of retention, possibly due to different mechanical properties such as higher stiffness, transferring occluding force to less strong components of the implant–crown assembly.[8] Another study also suggested that the high flexural strength of monolithic zirconia used as a hybrid abutment crown may lead to deflection and deformation at the implant–abutment interface.[19] However, due to limited data, drawing any conclusions on the long-term clinical success of monolithic zirconia remains challenging.[8] Further research is necessary to evaluate its extended clinical performance.

A limitation of this study is the absence of data on biological complications, another crucial factor influencing the success of implant reconstruction. In addition, the same doctor fabricated the reconstruction and performed follow-up observations, which may limit the validity of the study, potentially leading to bias or limitations to the results. Confounding variables included the lack of uniformity in dental implant brands and the diameter and length of implants used as control factors, as well as the status of antagonist teeth. Despite these limitations, the information presented in this study suggests that monolithic LDS holds promise as a material for posterior implant-supported SCs.

Conclusions

Within the limitations of this clinical study, the following conclusions can be drawn. Six years of clinical observations in this study demonstrated that monolithic LDS is a promising material for posterior implant-supported SCs. This study found a relatively high complication rate, primarily attributed to ASL. Opting for a reputable manufacturer offering a precise implant–abutment connection may contribute to improved outcomes. In this study, the only variable significantly correlated with the clinical outcome was parafunctional habits. This issue can be addressed by fabricating an occlusal appliance for implant protection.

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