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Success rate of all-ceramic FPDs depending on the time of restoration between 2011 and 2023

Philipp-Cornelius Pott*, Michael Eisenburger, Meike Stiesch
Department of Prosthetic Dentistry and Biomedical Materials Research, Hannover Medical School, Hannover, Germany

ORCID
Philipp-Cornelius Pott
https://orcid.org/0000-0003-1217-377X
Michael Eisenburger
https://orcid.org/0000-0003-2043-6605
Meike Stiesch
https://orcid.org/0000-0002-5953-2517

PURPOSE. Studies about success of FPDs (fixed partial dentures) mostly include restorations built by different clinicians. This results in limited comparability of the data. The aim of this study was to evaluate complications of all-ceramic FPDs built by 1 dentist between 2011 to 2023. **MATERIALS AND METHODS.** 342 all-ceramic FPDs were observed during follow-up care. 48 patients received 262 single crowns, 59 bridges and 21 veneers. Because of the different lengths of the bridges, units were defined as restored or replaced tooth. 465 units performed by the same dentist from Nov 2011 to Nov 2022 were included. Influencing factors “restoration”, “construction”, “abutment”, “localization”, “vitality” and “application period” were evaluated using Kaplan-Meier Analysis and Log-Rank Tests. **RESULTS.** 406 units (87.3 %) showed no complication. 7 correctable chippings (1.5 %) and 10 recementable decementations (2.1 %) occurred. Six decemented units got lost (1.3 %). 21 units failed due to fatal fracture (4.5 %). Crown margin complications, such as secondary caries, occurred in 15 units (3.2 %). Comparing the influencing factors resulted in higher complication rates of veneers ($P < .001$), of monolithic ceramics ($P \leq .050$) and of molar-restorations ($P = .047$). The application period had no influence on the success and survival rate. **CONCLUSION.** Overall, all-ceramic FPDs showed good clinical results. Although less complications were observed with modern restorations, these more often led to complete failure. To generate evidence-based recommendations, further studies are needed to evaluate the mid- and short-term success and survival of current all-ceramic restorations. [J Adv Prosthodont 2024;16:267-77]

KEYWORDS
All-ceramic; Complication; Success; Survival; Zirconia; Silicate

Corresponding author
Philipp-Cornelius Pott
Department of Prosthetic Dentistry and Biomedical Materials Research, Hannover Medical School, Carl-Neuberg-Str. 1, 30625 Hannover, Germany
Tel +49 511 532 4773
E-mail
Pott.Philipp-Cornelius@mh-hannover.de

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INTRODUCTION

In modern dentistry, all-ceramic restorations are frequently used as crowns, bridges or other types of restorations. In particular, the development of computer-aided processing techniques and the respective materials highly ex-

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pand the indications of all-ceramic restorations. The materials vary from glass-ceramics, which combine different fillers embedded in a glass matrix, and polycrystalline ceramics, which have no glass matrix to modern hybrid materials. These so-called resin-matrix ceramics combine the materials' benefits of both resin matrix and ceramic fillers.[1] All-ceramic restorations can be fabricated according to two design principles, either as veneered restorations consisting of veneering and framework ceramic, or as monolithic restorations made entirely of the framework ceramic. Depending on the construction method, these restorations differ in their load-bearing capacity and their complication rate.[2-4] Monolithic restorations in general show less complications and an increasing survival rate compared to veneered restorations, particularly with regard to fracture and chipping behavior.[5]

Success and survival are the fundamental terms for assessing the prognosis rates for treatment success. The success rate takes into account every complication that occurs. The survival rate only takes into account complications that have led to the loss of the restoration. Studies on success or the survival of all-ceramic restorations have in common that published data can analyze the current techniques and materials only to a limited extent due to the very rapid development in the field of materials and processing techniques. This is why studies with short and medium-term observation periods are playing an increasingly important role in the prognosis assessment of modern all-ceramic restorations. Various parameters influence success and survival rates particularly in the field of the digital workflow, e.g. the position of the area to be scanned, the accuracy of scan and matching, or the dentist's experience.[6-10] Other possible factors are the type of restoration, the restoration support by natural teeth or implants and the position of the restoration in the patient's mouth.[11] Unfortunately, there is hardly any data in the current literature comparing the success and survival of older, newer and modern all-ceramic restorations. This is particularly important, as both material development and processing techniques have progressed, especially in the last 10 years. Studies with long follow-up periods for all-ceramic restorations continue to play an important role in patient care, as this is the only way to assess expected long-term complications and restoration failures. However, because further developments in the field of all-ceramics and digital process chains are progressing ever faster, studies with shorter follow-up periods will be of greater importance for the new treatment of patients in the future, as investigated restorative materials will be replaced more quickly by more modern alternatives.

The aim of the current study was to extend the evaluation time of a previous published study,[11] which evaluated the survival rate of modern all-ceramic crowns, with special focus on the influence of the type of crown, the type of abutment, the intraoral region and on the vitality of the tooth from 2011 to 2016. Further, the success and survival rate of restorations between 2011 and 2015 were compared to newer restorations between 2016 and 2020 and modern restorations after 2020.

MATERIALS AND METHODS

For the analysis of success and survival rates, the dental status from patient's regular check-ups was taken into account as well as information from appointments for occurred complications. Modified USPHS (United States Public Health Service) criteria according to the scheme listed on the first column in Table 1 were used to classify any occurred complications (Table 1). Only restorations that were placed by the author PCP himself in the period from November 2011 to November 2022 and followed up until November 2023 were included in the analysis of success and survival rates. In this study, each restored or replaced tooth was defined as one single unit.

The restorations were produced by only two dental laboratories (Reese und Deppe GmbH, Minden, Germany and CeDent GmbH, Celle, Germany). The veneered units have a reduced anatoform framework and consist of Zenotec Zr Bridge (Wieland Dental, Pforzheim, Germany) or ZolidBion (Amann Girrbach AG, Koblach, Austria) combined with suitable veneering ceramics IPS e.max Ceram (IvoclarVivadent AG, Schaan, Liechtenstein) or Celtra Ceram (Dentsply Sirona, Bernsheim, Germany). The monolithic restorations were made of Zircon Prime (IvoclarVivadent AG) or IPS e.max CAD (IvoclarVivadent AG, Schaan,

Table 1. Observed complications sorted by USPHS-criteria

Description of the complication	USPHS-classification	incidence	percent (%)
No damage	A	406	87.3
Chipping, polishable	B	4	0.9
Chipping, repairable	C	3	0.6
Chipping, fatal	D	0	0
Delamination, polishable	B	0	0
Delamination, repairable	C	0	0
Delamination, fatal	D	0	0
Fatal fracture	D	21	4.5
Crown margin complication, polishable	B	5	1.1
Crown margin complication, repairable	C	1	0.2
Crown margin complication, fatal	D	9	1.9
Decementation, recementation possible	B	8	1.7
Decementation, recementable with new core	C	2	0.4
Decementation, fatal	D	6	1.3

Liechtenstein). In both dental laboratories, master dental technicians carried out quality control after finishing of the restorations to ensure consistently high quality.

During the entire observation period, all tooth-retained restorations were cemented following a definite cementation protocol: the abutment teeth were sanitized with chlorhexidine, degreased with alcohol and dried with oil-free compressed air. Zirconia restorations were cemented with glass ionomer cement (Ketac Cem, 3M, Neuss, Germany). Monolithic restorations made of silicate ceramic were conditioned with hydrofluoric acid, pretreated with a MDP-primer system (Futurabond U, VOCO GmbH, Cuxhaven, Germany) and cemented adhesively (Speedcem Plus, IvoclarVivadent AG, Schaan, Liechtenstein).

The statistical evaluation was performed using Kaplan-Meier analyses and log-rank tests to assess the influencing factors on success and survival rates. To analyze the success rate, the Kaplan-Meier analysis considered complications belonging to USPHS-B, -C and -D, while only fatal complications belonging to USPHS-D were used to evaluate the survival rate. Thus, the success rate based on the time until the first complication occurs and the time until a restoration failed or needed to be replaced was taken into account for the survival rate. The mechanical complications identified in this study can occur in all included units. Crown margin complications on teeth or implants cannot occur on the pontic. Further, it is not possible for a pontic to become decemented, although anchor crowns may be decemented. For this reason, pontics were not included in the overall evaluation of these two types of complications.

At Hannover Medical School, the number of monolithic restorations made of zirconia and silicate ceramics has increased since 2016, and in 2020 the Primescan system (Dentsply Sirona, Bernsheim, Germany) replaced the Omnicam system (Dentsply Sirona, Bernsheim, Germany) for intraoral scanning in the clinic. In order to consider these changes when analyzing the data, all units fitted by December 31, 2015 were summed up as older restorations; all restorations fitted by December 31, 2019 were counted as new restorations. Restorations that were fitted after January 1, 2020 were listed as modern restorations.

The ethics committee of Hannover Medical School approved the study design (8709_BO_K_2019).

RESULTS

A total of 54 patients were included in the study. 6 patients did not attend follow-up examinations, so that a total of 465 units in various FPDs (fixed partial dentures) in 24 female (age 62.1 ± 16.2 years) and 24 male (age 57.1 ± 18.2 years) patients could be exam-

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ined. The shortest period until the first complication occurred was 0.17 months. The longest period until complication took 10.5 years. The longest observation period overall was 11.8 years. The units are distributed over 263 single crowns, 117 abutment crowns, 64 pontics and 21 veneers. Figure 1 shows the distribution of the units among the patients. 143 anterior teeth (incisors or canines), 170 premolars and 152 molars were replaced or restored. 119 units consisted of monolithic zirconia, 301 units of veneered zirconia and 45 units consist of monolithic silicate ceramic. Natural teeth supported 368 units, and 97 units were implant-retained. 281 of the natural teeth were vital, 67 teeth were root canal-treated and 117 units were either implant crowns or pontics.

Over the entire observation period, 406 units remained without any complication (USPHS-A); the complications shown in Table 1 occurred at 59 units. Of these 59 complications, 23 complications were correctable or repairable intraorally (USPHS-B and -C), and in 36 cases the restoration had to be replaced (USPHS-D) (Table 1).

Referring to the mechanical complications, the success rate including all observed restorations was 91.1% over the entire observation period, and the survival rate was 94.3%. To assess the influence of the crown margin fit and the decementation, the pontics were excluded from the evaluation. The resulting success rate was 80.9%, while the survival rate was 87.9%.

The evaluation of the influencing factor “restoration type” showed 24 complications on single crowns, 17 complications on abutment crowns and 9 complications on pontics and veneers. The Kaplan-Meier analysis revealed success rates for single crowns of 86.1%, for abutment crowns of 74.1%, for pontics of 40.0% and for veneers of 41.7%. Log-rank test showed that complications occurred significantly more frequently with veneers than with the other restoration types ($P \leq .001$). The other relevant comparisons remained without statistical significance ($P \geq .126$) (Fig. 2). The survival rate of single crowns was 91.2%, of abutment crowns 80.3%, of pontics 81.4% and of veneers 82.7%. Log-rank test showed that fatal complications occurred significantly more frequently with veneers than with single crowns ($P = .024$). The other comparisons remained without statistical significance ($P \geq .075$).

The evaluation of the influencing factor “construction” showed that 15 complications occurred on monolithic zirconia units, 33 complications on veneered zirconia units and 11 complications on units made of monolithic silicate ceramic. The Kaplan-Meier analysis revealed a success rate for monolithic zirconia units of 71.9%, for veneered zirconia units of 82.7% and for monolithic silicate ceramic units of 64.0%. Log-rank test showed significantly more complications with units made of monolithic silicate ceramic than with units made of monolithic zirconia ($P < .001$) and veneered zirconia ($P = .050$). The remaining comparison remained without statistical significance ($P = .134$) (Fig. 3). The survival rate of mono-

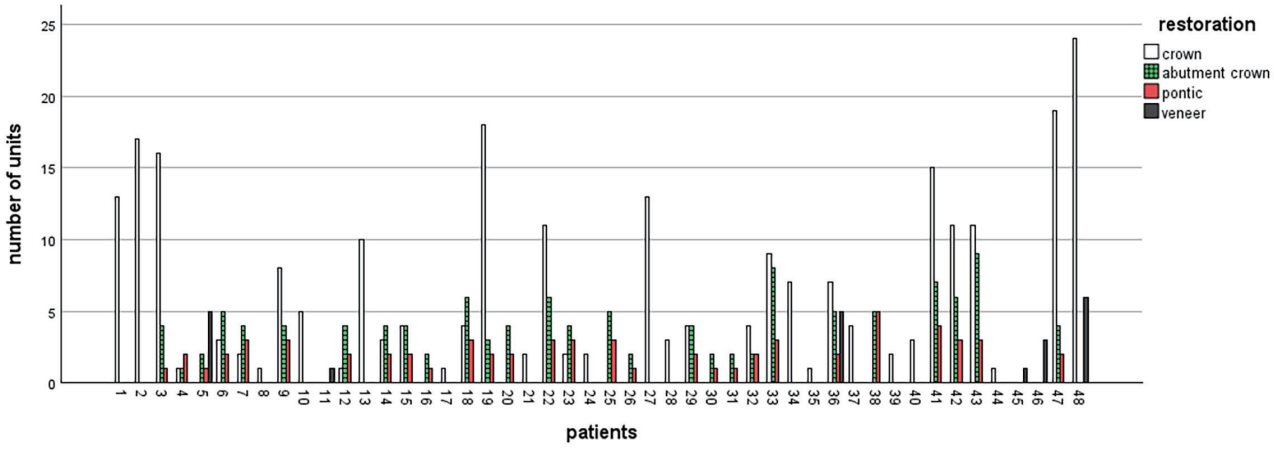

Fig. 1. Distribution of the various types of restorations among patients.

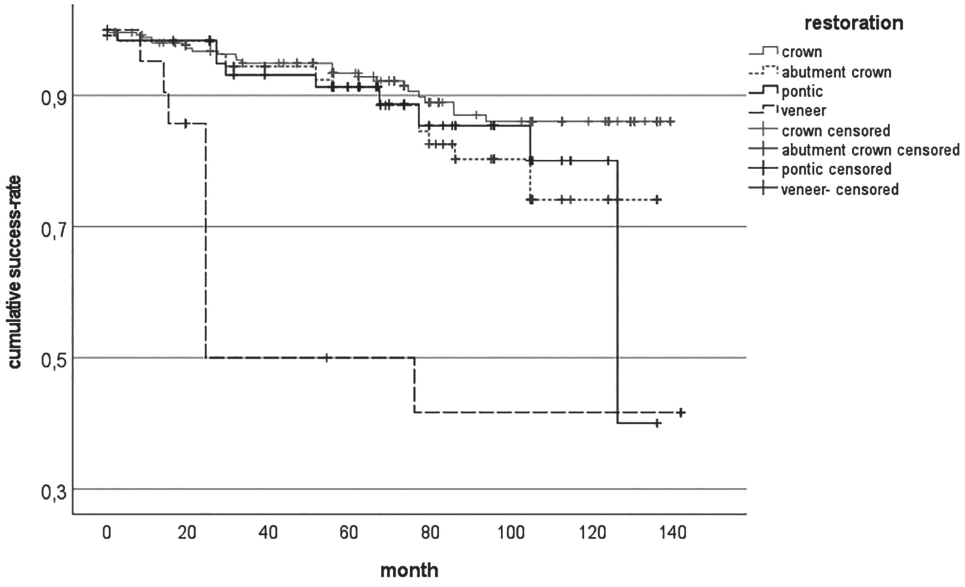

Fig. 2. Cumulative success rate of all units referring to the type of restoration.

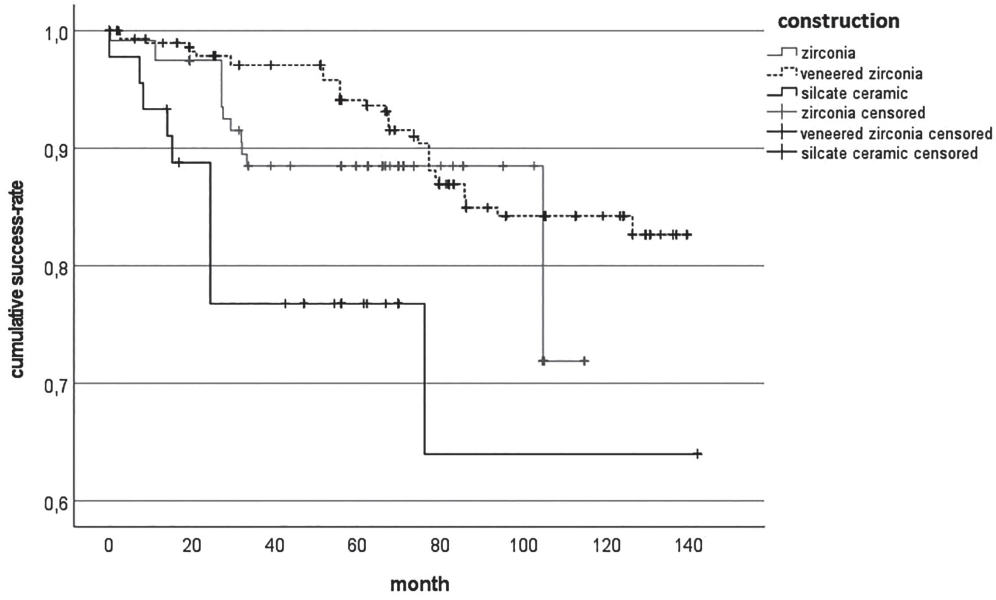

Fig. 3. Cumulative success rate of all units referring to the type of construction.

lithic zirconia units was 72.7%, of veneered zirconia units 90.2% and of monolithic silicate ceramic units 90.6%. The individual comparison showed that fatal complications occurred significantly more frequently in monolithic zirconia units than in veneered zirconia units (P = .003). The other individual comparisons remained without statistical significance ($P \geq$ .060).

The evaluation of the influencing factor “abutment” revealed 49 complications on units supported by natural teeth and 10 complications on implant-supported units. Kaplan-Meier analysis revealed a success rate for tooth-supported units of 79.1% and for implant-supported units of 81.2%. The comparison of both types of support using log-rank test showed no statistical significance (P = .409) (Fig. 4). The survival rate of tooth-supported units was 85.1% and of im-

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plant-supported units 94.0%. In comparison, there was no significant difference between the two types of restorations support with regard to the survival rate (P = .121).

The evaluation of the influencing factor "localization" showed that 16 complications occurred on anterior teeth, 17 complications on premolars and 26 complications on molars. Kaplan-Meier analysis revealed a success rate for restored anterior teeth of 84.3%, for premolars of 84.7% and for molars of 68.2%. Log-rank test showed that the success rate of the restored molars decreased significantly compared to premolars (P = .047). The other comparisons remained without statistical significance ($P \geq .168$) (Fig. 5). The survival rate of units was 93.0% on anterior teeth, 86.9% on premolars and 81.4% on molars.

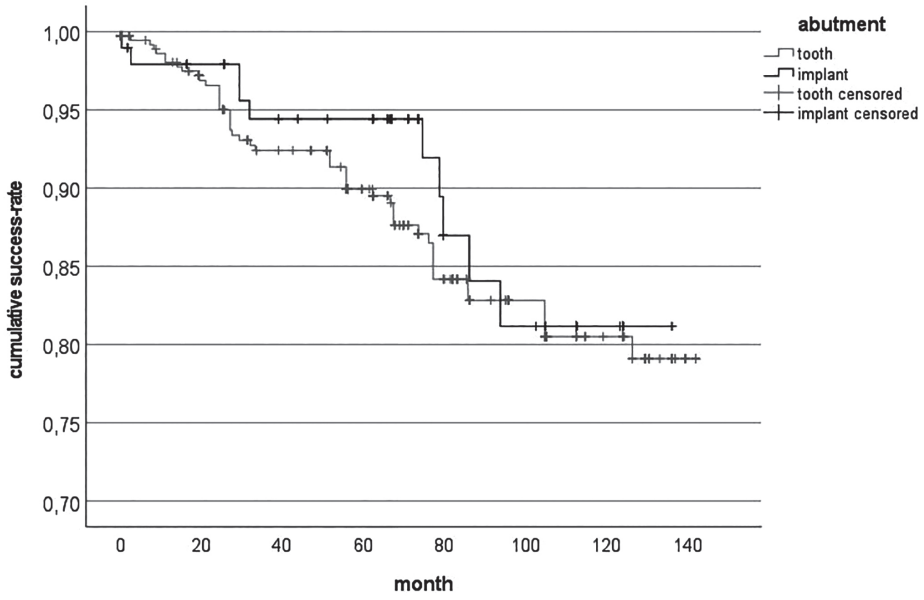

Fig. 4. Cumulative success rate of all units referring to the type of the abutment.

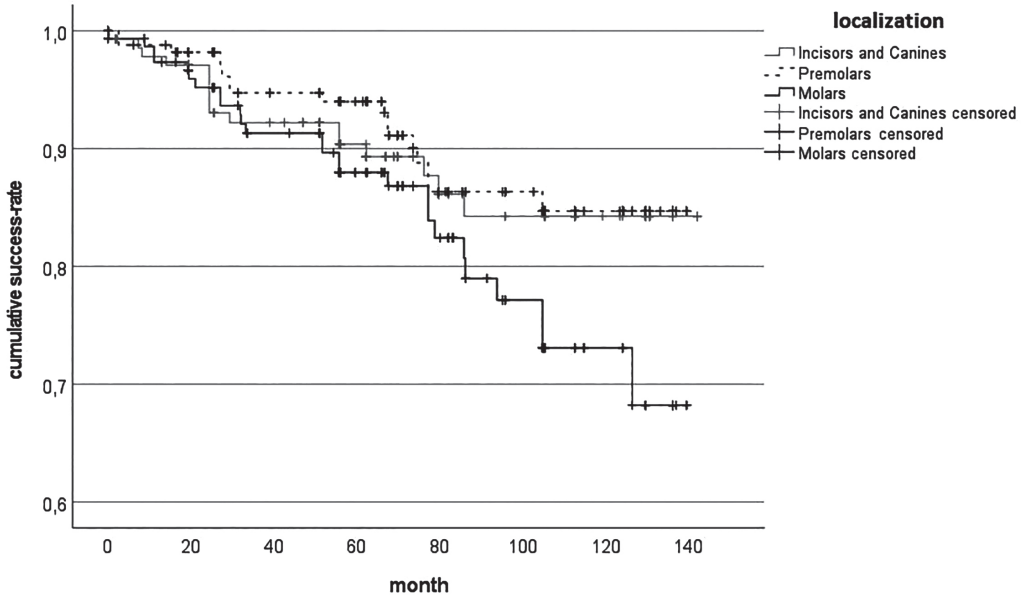

Fig. 5. Cumulative success rate of all units referring to the type of tooth.

Comparisons of these survival rates remained without statistical significance ($P \geq .116$).

The evaluation of the influencing factor "vitality" showed that 34 complications occurred on vital teeth, 12 complications on devitalized teeth and 13 complications on replaced teeth. Kaplan-Meier analysis revealed a success rate for the units on vital teeth of 81.2%, 68.1% for devitalized teeth and 82.2% for replaced teeth. In the comparison of vitality using the log-rank test, all comparisons remained without statistical significance ($P \geq .116$) (Fig. 6). The survival rate of units for vital teeth was 87.6%, 77.8% for devitalized teeth and 89.7% for replaced teeth. All relevant comparisons in this context remained without statistical significance ($P \geq .262$).

The comparison of the complications that occurred on restorations that were fitted between 2011 and 2016 (n = 278), those fitted until end of 2019 (n = 141), and those fitted after 1st of Janurary 2020 (n = 46) is shown in Figure 7. Complications occurred in older and newer restorations over the entire observation period. In total 43 complications occurred in older

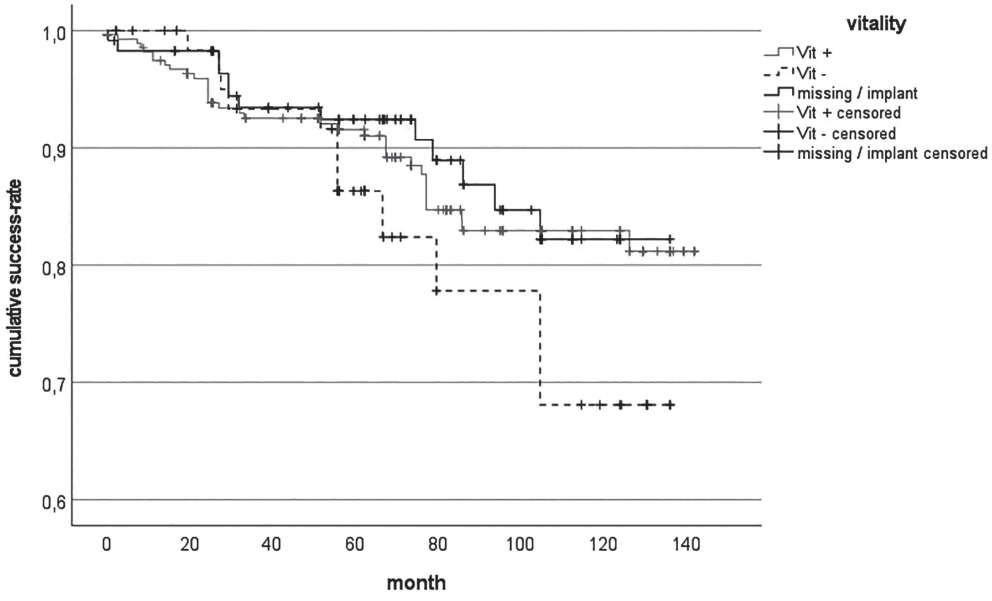

Fig. 6. Cumulative success rate of all units referring to the vitality of the teeth.

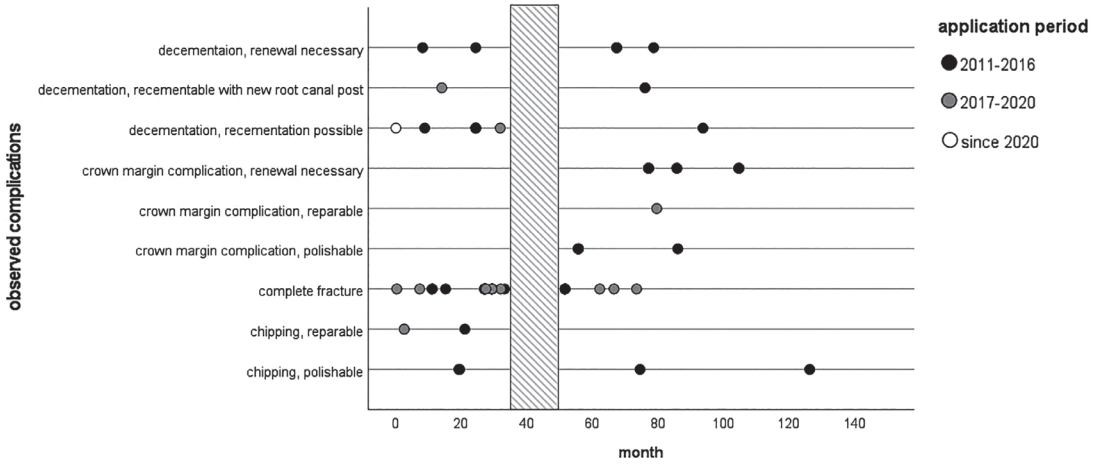

Fig. 7. Observed complications referring to the application period of the restorations. Box: Period without complications from 36th to 50th month.

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restorations (the first insertion period 2011-2016). 15 complications were observed in newer restorations fitted in the second period ending on 31st of December 2019, and only one complication occurred in the modern restorations placed since 2020. This resulted in success rates of 80.0% (2011-2016), 75.9% (2016-2019) and of 97.6% (since 2020) (Fig. 8). The survival rates in the corresponding periods in total were 90.6% (2011-2016), 93.1% (2017-2020) and 100.0% (since 2020). Kaplan-Meyer-Analysis revealed in no statistically significant differences between the restorations of the different application periods, both for success ($P = .676$) and for survival ($P \geq .951$).

DISCUSSION

In this study, a total of 465 units were examined in 48 patients over a maximum observation period of 142 months. All patients were treated and followed up by the same dentist. The restorations were fabricated in only two dental laboratories. This is a unique feature compared to many other studies on success and survival rates, which usually examine restorations from different dentists and contribute to improve quality of data collected by minimizing dentist-dependent influencing factors. In other dental disciplines, such as endodontics, data shows an influence of practitioner experience on the success of treatments.[12] Unfortunately, there is no data in the literature on the influence of treatment experience on indirect restorative measures. However, it can be assumed that the complication rate should decrease with increasing practitioner experience. For example, correct fine adjustment of the occlusion has an influence on the load capacity of the restoration and thus indirectly on the occurrence of mechanical complications.[13] These adjustments become more targeted with increasing treatment experience, which in turn can reduce the risk of complications. In this study, the increased treatment experience could partly be responsible for the continuously increased survival rate of the restorations examined in the three application periods. One of the unique features of this study is that all restorations were placed and examined by one practitioner. Of course, the practitioner's experience grew over the study period. However, there is no meaningful way to take this into account in the data analysis. The data show that there was no difference between the three different treatment periods. Since these periods relate to the increase in experience of the practitioner, it can be followed that the increasing experience of the practitioner had no influence on the

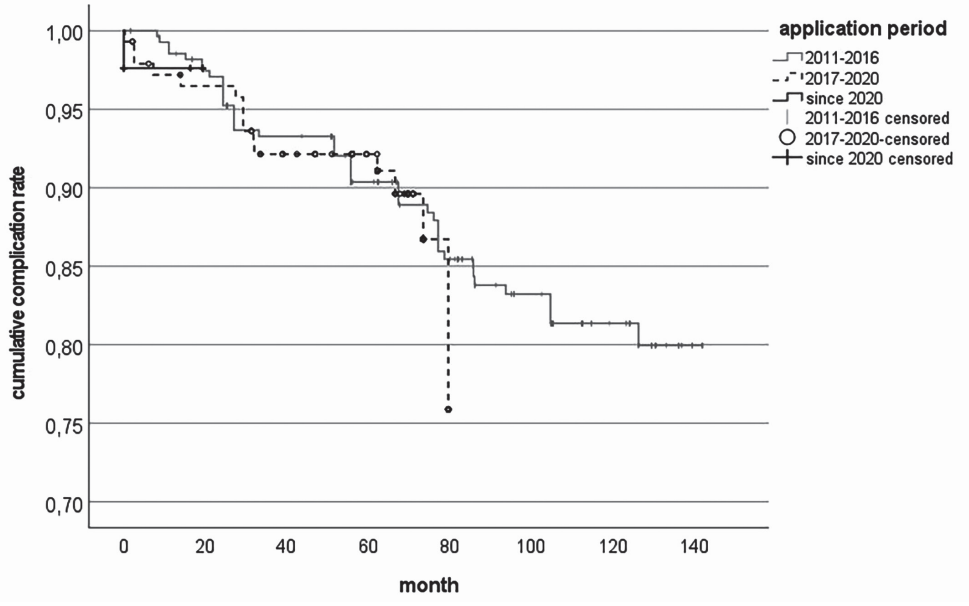

Fig. 8. Cumulative success rate of all units referring to the period of tooth restoration.

complication rates in the present study. However, this is of course only one possible parameter in addition to other restoration- and patient- factors.

Modified USPHS criteria were used to categorize the complications, analogous to a previous study.[11] The distinction between correctable, reparable and fatal complications enables to distinguish between success rate and survival rate. In this study, chipping, crown margin complications, decementations and fatal fractures of restorations were documented. Delaminations and peri-implant or periodontal complications did not occur. Fatal fractures occurred most frequently (n = 21), followed by decementations (n = 16) and marginal fit inaccuracies (n = 15). Chipping was observed in only 7 cases (Table 1). Other studies described chipping as the most frequent complication.[5,14] The different frequency distribution of complications in this study is most likely due to the increasing number of monolithic restorations since 2016, where the risk of chipping is very low due to the lack of veneering, and complete restoration fractures are more likely to occur in the event of fracture. This study examined the influence of various parameters on the success and survival rate of all-ceramic restorations. When interpreting the data, it must be generally taken into account that restoration- and patient-specific differences, for example in relation to the type of restoration, the construction method or other factors, occur to varying degrees and can naturally influence the occurrence of complications. One example of this is the varying material thickness of monolithic crowns depending on the degree of damage to the tooth to be restored. These factors are so individual that they cannot be taken into account in the statistical evaluation. This study did not investigate any further individual reasons for the occurrence of the complications observed. In particular, individual causes cannot be clearly identified over longer observation periods, since, for example, material changes due to aging can affect the mechanical strength.

With regard to the type of restoration, it was shown that complications occurred significantly more frequently with veneers (success: 41.7%, survival: 82.7%) than with single crowns (success: 86.1%, survival: 91.2%) or bridges (success: 74.1%, survival: 81.4%). Regardless of the fact that the number of veneers included here was relatively small, the results found are comparable with the data from Mazzetti *et al*. who found restoration failure in 17.1% of 1459 veneers.[15] In their review, Sailer *et al*.[14] included studies on a total of 9434 all-ceramic single crowns and found survival rates of 94.7%. Haff *et al*.[16] found success rates for all-ceramic bridges of between 73% and 91%. The results of these two studies also confirm the data of the present study. In their review published in 2017, Abou-Ayash *et al*. showed that the choice of material has no influence on the medium- and long-term success of all-ceramic single crowns and FPDs.[17] The data obtained in the present study also showed no influence of the material on the success or survival rates. However, this should generally be questioned critically, as it is also known that the occurrence of mechanical complications is directly related to the material-dependent design of the restoration.[18-20] If there is an increased risk of chipping in individual patients, e.g. because of TMJ-disorders, monolithic zirconia restorations or metal restorations should be preferred. According to Sailer *et al*.,[14] complications must be expected significantly more often in the posterior region than in the anterior region for both silicate ceramic and zirconia. In the present study, complications also occurred significantly more frequently in the molar region than in the anterior region. However, no difference was found between premolar and anterior teeth. In contrast to the success rate, the survival rate was independent of the localization. The data collected in this study show that the vitality of the abutment teeth had no significant influence on the success and survival rate of the restorations examined. These results are in contrast to the data published by Hawthan *et al*. in 2023. In their review of 26 publications, Hawthan *et al*.[21] found that the survival rate of restorations on vital teeth can be estimated better than on devitalized teeth.

Studies about success or survival of dental restorations with medium-term or long-term follow-up periods have in common that due to the rapid developments in the material and processing sector, especially with regard to the digital workflow, data on medium-term or long-term success is already outdated by the time the data is published. The present study addresses this problem by comparing the complica-

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tions in relation to the integration period of the restorations. The selected fabrication periods are due to the fact that monolithic restorations have been increasingly used in the clinic conducting the study since 2016 and that a new scanning system, the Primescan system (Dentsply Sirona, Bernsheim, Germany), has been used in the clinic since 2020. No significant difference was found in the general comparison of restorations fitted in these three application periods. In order to take into account the different observation periods, the success and survival rates of the various old restorations were evaluated after 2 and 3 years, respectively. It has been shown that the results after 2 years did not differ from the results after 3 years. However, it must be taken into account that some of the restorations in the group of modern restorations with an insertion date after 2020 could not be examined in the third year. The evaluation of the data showed a period from approximately 36 months to 50 months in which no complications occurred in total (Fig. 7). This could be related to the end of a habituation phase, as Eisenburger and Tschernitschek have also described for removable dentures.[22] In 2012, Behr *et al*.[23] concluded that risk for chipping or fractures decreases after the first year of clinical use of metal ceramic FPDs. The complications, which occurred after this period, could be caused by material fatigue during clinical use. In their in-silico study, Schmid *et al*.[24] found increasing stress peaks in close proximity to occlusal contact points with increasing occlusal interfaces after occlusal adjustments. Such stresses might also be reasonable for an increasing risk for failure. The occurrence of complications in the crown margin area, e.g. in the form of crown margin caries or plaster defects, was also observed after 56 months at the earliest. This can be explained by the fact that such biological complications take time to develop. The data of Walton support this thesis.[25] Further research is required to relate the influencing factors investigated here and the production periods to other causes for the occurrence of complications.

CONCLUSION

Taking into account the limitations of the present study, the data show that older and newer all-ceramic restorations show good clinical results. Many of the complications that occurred could be corrected or repaired. Although only one complication was observed overall with modern restorations, complete failures were observed more often with monolithic restorations. For evidence-based recommendations for the use of modern all-ceramic restorations, further studies are needed to evaluate their mid- and short-term success and survival rates.

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