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Published in:
Journal of Prosthetic Dentistry

DOI:
10.1016/j.prosdent.2017.06.009

Publication date:
2018

The 50-year follow-up of crown and veneer survival in dental practice

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Acknowledgments:

The authors thank Mick Kedge (master technician) and John McLean's ceramist. The authors also thank Dr Rashed Ala-Uddin for photographing the restorations.

JPD-17-176

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ABSTRACT

Statement of problem. Indirect restorations are an important treatment in dental practice, but long-term survival studies are lacking.

Purpose. The purpose of this retrospective study was to report on the outcome of indirect restorations, which were followed up annually for up to 50 years in a dental practice.

Material and methods. A retrospective survival study was undertaken at a mixed National Health Service (NHS)/private dental practice in London, UK. Data were collected for restorations placed between 1966 and 1996 by 1 experienced operator. It was a requirement that patients had been followed up yearly with clinical and radiographic examination until 2016. Patients were enrolled on a strict preventive policy and had excellent oral hygiene. Oral hygiene, restoration location, sensitivity, occlusion and other details (preparation design, taper, cement used) were recorded. Restoration outcome was recorded as successful and surviving, unknown, or failed. The data were described descriptively. Kaplan-Meier survival curves and hazard curves were used to assess the survival of crowns and the probability of failure over time.

Results. A total of 223 restorations were placed in 47 patients between 1966 and 1996 and reviewed annually for up to 50 years (until 2016). These restorations included 154 metal-ceramic crowns (101 posterior and 53 anterior), 25 posterior gold crowns, 22 anterior ceramic veneers, and 22 anterior ceramic crowns. Restorations were in occlusion. The mean survival for metal-ceramic crowns was estimated as 47.53 years (95% confidence interval 45.59 to 49.47 years).

Failures in metal-ceramic crowns (n=6, 3.9%) were due to periapical periodontitis. The remaining restoration types had 100% survival at 50 years.

Conclusions. This study showed that the survival of crowns and veneers is high over 50 years in clinical practice with annual follow up and good oral hygiene. The proportion of teeth with loss of vitality, confirmed clinically and with radiographs, was minimal.

CLINICAL IMPLICATIONS

Within the limitations of this study, metal-ceramic crowns, posterior gold crowns, anterior ceramic veneers, and crowns are successful treatment options in clinical practice over a period of up to 50 years. This study highlights the importance of annual follow up and oral hygiene maintenance to the survival of these restorations.

INTRODUCTION

Indirect restorations are increasingly used to improve patients' appearance and to restoring badly damaged or endodontically treated posterior teeth. With patients living longer and retaining more teeth,[1] these restorations are considered a long-term treatment option. Restoration longevity is thus important in an aging population, and patients are demanding restorations that restore teeth to both form and function.

Unfortunately, the business service authority statistics for restorations placed in dental practices in the UK ceased in 2005.[2] The average figures from 1992/1993 showed that the average number of porcelain veneers placed per year was 78 628. In addition, the average number of metal-ceramic crowns placed per year was 132 838.[3] Clinical studies and systematic reviews on crowns and veneers have been published.[4-9] However, the number of studies on

indirect restorations with a follow-up of over 20 years is lacking, despite their popularity in clinical practice and higher patient expectation with regard to their longevity. Indeed, the need for longer-term studies was recommended in 2013[9] and lack of longer-term studies (≥10 years) for conventional indirect restorations has not changed during this time.

The vitality of teeth with crowns has also been reported up to 25 years,[10-12] with the maximum loss of vitality in these studies being 19%. The ideal tooth preparations and taper have been described,[13-15] and the importance of sufficient coronal tooth structure has been investigated.[16,17] The guidelines for ideal tooth preparations, taper, and importance of sufficient coronal tooth structure were followed in this study.

The purpose of this retrospective study was to report on the outcome of indirect restorations placed by a single operator (P.M.F) in a dental practice and followed up annually for up to 50 years. Data were recorded retrospectively from patient records as part of a service evaluation of care.

MATERIAL AND METHODS

Data on patients who received indirect restorations (crown or veneer) from 1 operator were collected from 1966 until 2016 from the clinical record and radiographs. Data were included from patients who had annual clinical and radiographic examinations over this period. The same operator had been in practice for 50 years until retirement; therefore, 1 operator placed all restorations.

Each patient provided informed consent for restorations. Anterior veneers were placed to improve esthetics. Crowns were placed for extensively restored teeth (involving loss of both marginal ridges or posterior endodontically treated teeth) or to improve appearance. The

restorations were placed to conform to the existing occlusal scheme. The retention of shimstock was recorded; it was a requirement that restorations were in occlusion with natural teeth or prostheses. In addition, functional units were recorded in each patient. Each patient had at least a shortened dental arch, which has been shown to provide a functional dentition.[18] It was also a requirement that the patient's oral hygiene was excellent (less than 20% plaque scores on initial and reassessment appointments). Periodontal pocket depths at initial assessment did not exceed 3 mm. All patients were enrolled on a strict preventive policy at the practice with annual dentist appointments and six monthly visits to the practice hygienist. Home care instructions were given by the hygienist and reinforced by the dentist for all patients. This included dietary analysis for sugary and erosive beverages. Instruction on tooth brushing and interdental cleaning was provided. With new patients, the presence of plaque was demonstrated with a disclosing solution. Home care instructions continued in the follow-up appointments.

Preparations for gold or metal-ceramic crowns were complete coverage and involved a minimal convergence angle. The stored casts were measured, and the total occlusal convergence angle did not exceed 16 degrees buccolingually and 22 degrees mesiodistally in any of the preparations. A minimum circumferential axial wall height of 4 mm for posterior preparations and 3 mm for anterior preparations was maintained. Any intracoronal restorations were removed and incorporated into the design to improve resistance form. Crown lengthening procedures were not performed. The metal-ceramic crowns were designed for feldspathic porcelain only on the facial and some interproximal surfaces, with metal on the other surfaces.

The margins were chamfer finish lines. These were placed at the gingival margin for posterior teeth and in the gingival crevice (approximately 0.5 mm subgingival) for anterior

restorations. The impressions were made after adequate gingival displacement using epinephrine knitted displacement cord (Ultrapak; Ultradent Products Inc) for anterior preparations.

Porcelain laminate veneers were prepared to the incisal edge with chamfer finish margins. The margins were placed 0.5 mm subgingivally with displacement cord (Ultrapak; Ultradent Products Inc).

The same material (Permlastic; Kerr Dental) was used throughout for the definitive impression. The opposing arch impression was made in alginate (Kerr Dental). The definitive casts were trimmed, the finish lines marked by the dentist, and the casts sent to the laboratory. Interim restorations were made of autopolymerizing acrylic resin (Sevriton; Dentsply Sirona). Alternatively, a preformed acrylic resin crown (Henry Schein) was used for some anterior teeth, and preformed polycarbonate (3M ESPE) or aluminum interim restorations (Henry Schein) were used for some posterior teeth.

One commercial laboratory completed all the definitive crowns within 14 days. Gold crowns were type III cast gold alloy. Metal-ceramic crowns were precious metal alloy, with feldspathic porcelain on the facial surface. Ceramic crowns were porcelain jacket crowns, and veneers were porcelain laminate veneers. The ceramic restorations were all feldspathic porcelain. No zirconia ceramic or lithium disilicate restorations were evaluated in this study. The margin between the restoration and the tooth was assessed using a dental explorer. If a discrepancy existed, the restoration was remade following appropriate evaluation of the preparation, a new impression, and a new interim restoration.

To cement metal-ceramic crowns, either zinc phosphate cement[19,20] (Dentsply Sirona) or glass ionomer cement[21] (Ketac Cem; 3M Dental) was used. Zinc phosphate cement (Dentsply Sirona) was used for porcelain jacket crowns. For veneers, adhesive resin cement (Panavia;

Kuraray Europe GmbH) was used. The cement was mixed and applied according to the manufacturer's instructions.

A dentist and hygienist followed up the patients at least annually. High risk patients (those with caries or periodontal disease) were seen by a clinician every 6 months and by a hygienist at 3 monthly intervals. At the follow-up, the patients were asked if they had had treatment at another dentist and if they had complaints and about their history and medical history. The extraoral examination included examination of gait, external appearance, hands, and palpation of the lymph nodes beneath the chin. The intraoral examination included a complete soft tissue examination. The hard tissue examination included periodontal assessment, plaque index, records of tooth wear (and more recently the basic erosive wear examination score[22]), percussion testing of indirect restorations, and caries assessment. All restorations were also assessed for any mobility or pain, signs of root fracture (clinically and with radiographs), and any evidence of retreatment. Radiographs were made every 6 to 12 months for patients with high caries risk. Patients with low risk had radiographs every 2 years (with annual radiographs of indirect restorations placed). A full radiographic report was written. In addition, esthetic concerns were reported using patient satisfaction questionnaires and asking if the patient was happy with restorations and techniques. If, over the years, anterior crowns or veneers became lighter in color than the existing dentition, tooth whitening was suggested.

The outcome of treatment for each restoration was recorded as successful, surviving (repaired), unknown, or failed. Restorations were recorded as successful if no evidence of retreatment other than maintenance was found. Maintenance included cleaning, minor adjustments to the occlusion, and minor adjustments to the shape/smoothing that did not require repair and did not compromise esthetics as determined by the patient. The crowns were recorded

as surviving if there were minor repairs to the restoration but no changes to its integrity or the marginal integrity of the tooth or crown. If the data for a particular restoration were not present annually (from 1966 to 2016), the outcome was recorded as unknown, and the data were then excluded from the study.

Failures were defined as those which affected survival of the restoration, for example, crowns recemented more than once after initial cementation or if the marginal integrity of the crown was damaged (for example, because of caries) or if the crown itself was lost. Failures also included periapical pathology (confirmed clinically and by increasing periapical radiolucency radiographically) or pulp infection causing pain. Periapical and pulp pathology were managed by endodontic therapy or extraction. Endodontic therapy for crowns or veneers which had failed because of periapical periodontitis were managed by removing the restoration and not by making the access cavity through the existing restoration. Chips on indirect restorations were not counted as failures, unless this affected the esthetics of anterior restorations. Failures due to periodontal disease included grade III mobility with pain on mastication. Gingival recession with dentin hypersensitivity[23] was managed with desensitizing dentifrices[24-26] and altered oral hygiene practices.[27,28] It did not result in crown failure unless it compromised esthetics.

Descriptive statistics were used to summarize the sample characteristics and outcome measures. Reassessment data were present up to 50 years and included in the statistical analysis. Survival of crowns was assessed using Kaplan-Meier survival curves. Survival time was calculated from the date of cementation to the end of the survey period (2016) for outcomes classified as success and surviving, or to the date of unknown or date of failure. Hazard curves were drawn to assess the probability of failure over time.

RESULTS

A total of 223 restorations were placed between 1966 and 1996 and followed up annually for up to 50 years in 47 patients. There were 20 men and 27 women. The mean age at treatment was 49.11 years with a standard deviation of 15.65 years. Restorations included 154 (69.1%) metal-ceramic crowns (101 posterior and 53 anterior), 25 (11.2%) posterior gold crowns, 22 (9.9%) anterior ceramic veneers, and 22 (9.9%) anterior ceramic crowns. The crowns were all placed as single unit and complete coverage to conform to the existing occlusal scheme. Restorations were in occlusion with either a natural tooth or prostheses. A total of 65% (n=131) of crowns were cemented using glass ionomer cement (Ketac Cem; 3M Dental) and 35% (n=70) were cemented using zinc phosphate (Dentsply Sirona) cement. All veneers were cemented using adhesive resin cement (Panavia; Kuraray Europe GmbH). Seventeen posterior metal-ceramic crowns and 4 posterior gold crowns were used as abutments for removable partial dentures.

Forty-two patients received metal-ceramic crowns. The incidence of patients receiving different numbers of metal-ceramic crowns is shown in Figure 1. In 62% of the patients, there were 3 or fewer metal-ceramic crowns per patient. Figure 2 shows the distribution of metal-ceramic crowns and whether teeth were endodontically treated. The largest proportions of metal-ceramic crowns were provided in the first molars and maxillary incisors. Twelve metal-ceramic crowns were in endodontically treated teeth (n=8 anterior, 4 posterior) with passive fitting cast post and cores. The cast post and cores were cemented using zinc phosphate cement (Dentsply Sirona).

Ten patients had ceramic crowns and veneers placed on maxillary anterior teeth. Of these, 1 anterior crown was placed on an endodontically treated tooth with a cast post. The cast post and core was cemented using zinc phosphate cement (Dentsply Sirona).

All anterior ceramic crowns, veneers, and posterior gold crowns (n=69) survived up to 50 years. Amongst the metal-ceramic crowns (n=154), 96.1% were in service up to 50 years (successful or surviving). Failures in the metal-ceramic crowns (n=6, 3.9%) occurred in vital teeth and were due to periapical periodontitis; 2 in anterior teeth and 4 in posterior teeth. These crowns were removed to assess restorability prior to possible endodontic therapy. If less than the ideal circumferential height of coronal tooth structure (3 mm height for anterior tooth preparations and 4 mm height for posterior tooth preparations) was available, the teeth were extracted. No restorations were removed because of esthetics.

The metal-ceramic crowns were in use for 19.82 years with a standard deviation of 14.47 years based on the data. The survival function for metal-ceramic crowns is shown in Figure 3. Fifteen patients had metal-ceramic crowns for more than 45 years with no failures. From the survival analysis, the mean survival for metal-ceramic crowns was estimated as 47.53 years (95% confidence interval 45.59 to 49.47 years). The cumulative hazards function (Fig. 4) shows the failure rate increased substantially between 10 and 20 years.

Figure 5 shows indirect in situ restorations placed at the beginning of data collection in 1966 and photographed in 2017. Metal-ceramic crowns are present on maxillary right premolars, mandibular right incisors, the mandibular right canine, and the mandibular right first premolar teeth. Gold crowns are present on maxillary right molars, the mandibular right second premolar, and the mandibular right second molar teeth. The maxillary right first premolar and mandibular right second molar teeth are abutments for a removable partial denture with gingival recession and some tooth wear. Minor ceramic chipping is evident on the cervical aspect of the metal-ceramic crown on the mandibular right canine and on the facial aspect of the upper right first

premolar tooth. Esthetics, as determined by the patient, was not compromised. The margins of the restorations are intact.

DISCUSSION

Considering the many factors involved in the longevity of indirect crowns and veneers, the main purpose of this study was to report outcomes of these restorations for up to 50 years in dental practice. This study demonstrated that the survival of indirect restorations in patients with good oral hygiene who were followed up annually over this time is high. This suggests the importance of ongoing follow-up, maintenance, and oral hygiene in clinical practice. No failures of posterior gold crowns, anterior ceramic veneers, or anterior ceramic crowns were recorded. Six failures occurred in 154 metal-ceramic crowns, and the estimated survival of these crowns was 47.53 years (95% CI 45.59 to 49.47). The study was biased toward patients who were regular attenders and with excellent oral hygiene practices. Some patients with indirect restorations were lost to annual follow-up by relocation or death and their data were excluded. The precise figure is difficult to ascertain and although the study was not prospective, it does contribute to the evidence base for the longevity of indirect restorations.

The survival of metal-ceramic crowns has been reported in other studies. The longest study reported the survival of 2340 metal-ceramic crowns to be 85% up to 25 years. [5] The present study also shows high survival over a longer period for all indirect restorations, including metal-ceramic but is limited due to the sample number. The survival of both metal-ceramic and ceramic crowns is similarly high in systematic reviews.[4]

Data suggest that the survival of feldspathic porcelain crowns on posterior teeth (88%) is worse than that on anterior teeth (95%).[4] A recent systematic review[8] showed that these

differences are now smaller, but caution is still required in prescribing posterior ceramic crowns. Interestingly, lithium disilicate was observed to fail more on anterior teeth. In the present study, which did not use lithium disilicate, ceramic crowns were placed on anterior teeth, and the survival rates for these crowns were high. Low failure rates up to 10 years have also been reported for 191 porcelain laminate veneers placed in dental practice.[6] For gold restorations, 158 were reported in 25 patients, with a survival rate of 89% up to 5 years.[7]

Zinc phosphate cement was used predominately in the first decade of recording from 1966 when it was a popular choice. All crown preparations were designed in such a way to ensure good macromechanical resistance and retention form by means of a minimum total occlusal convergence angle (less than 23 degrees) and a maximum height of preparations. Furthermore, the preparations were not polished, and the internal surface of the restoration and preparation were rough; this assists retention with zinc phosphate cement.[19] The authors speculate that these factors reduced the risk of decementation. Also, zinc phosphate cement has been demonstrated to be an effective luting agent for metal crowns and can last for a period of 20 years or more, with minimal microleakage.[20] Subsequently, glass ionomer cement was more frequently used after the first decade. Studies have since shown this cement to be successful, with limited secondary caries or decementation and a low incidence of irreversible pulpitis.[21]

The metal-ceramic crown failures (n=6, 3.9%) were due to periapical periodontitis. The proportion of crowned teeth with vital pulps, which remained free from both the signs, and symptoms of pulpal deterioration over 50 years was therefore high. This outcome is similarly high to that in other studies, but over a considerably longer time scale and unlike some other studies, it was confirmed clinically and using radiographs. Other studies reported 83% pulp vitality (confirmed with radiographs) following crowns on 46 teeth at 25 years[10] and 84% vitality

(confirmed clinically and with radiographs) following crowns in 284 teeth at 10 years.[11] Furthermore, other work has shown endodontically treated crowned teeth to have similar survival rates to those of crowned teeth with a vital pulp.[10] The loss of vitality in teeth following crowns has been reported to be as much as 19% (confirmed radiographically).[12] Conservative crown preparations appear to help preserve tooth vitality.

Removing restorations before performing crown preparations enabled better examination of the tooth's restorability,[17] and the incorporation of this into the design improved the resistance form of the restoration. The importance of sufficient coronal tooth structure is emphasized. Indeed, the survival of crowns in endodontically treated teeth improves significantly with increasing coronal tooth structure.[16]

Crown lengthening procedures were unnecessary, and the occlusion was conformed. Restorations were in occlusion with teeth or prostheses. A large proportion of the metal-ceramic crowns (n=45, 29%) were on molars, and, of these, almost half were mandibular. Avoiding surgical crown lengthening in these situations reduces the risk of furcation involvement.[13] To maximize resistance form, seating grooves[29] were used reduce tensile force in the cement lute because of lateral/rotating forces to the crowns.

Metal-ceramic and porcelain jacket crowns are not conservative of tooth structure.[15] However, for metal-ceramic crowns in particular, this depends on the design of the crown and so tooth reduction was minimized on tooth surfaces where esthetics was not an issue. Minimal reduction was used with metal on occlusal, lingual, palatal, distal, and some mesial surfaces (up to the proximal contact). The authors now place lithium disilicate crowns as opposed to porcelain jacket crowns. These improve material strength and require less tooth preparation. However, the

longevity data from the lithium disilicate group are not commensurate with the feldspathic group, and they were therefore excluded from this study.

CONCLUSIONS

Based on the findings of this retrospective study, the following conclusions were drawn:

1. The estimated survival of metal-ceramic crown restorations (47.53 years (95% CI 45.59 to 49.47) and survival of anterior ceramic veneers, crowns, and gold crowns (100% survival) was high over 50 years.
2. The percentage of teeth losing vitality after restoration, confirmed clinically and using annual radiographs, was minimal (6 failures in 154 metal-ceramic crowns).

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FIGURES

Figure 1. Incidence of patients receiving different numbers of metal-ceramic crowns

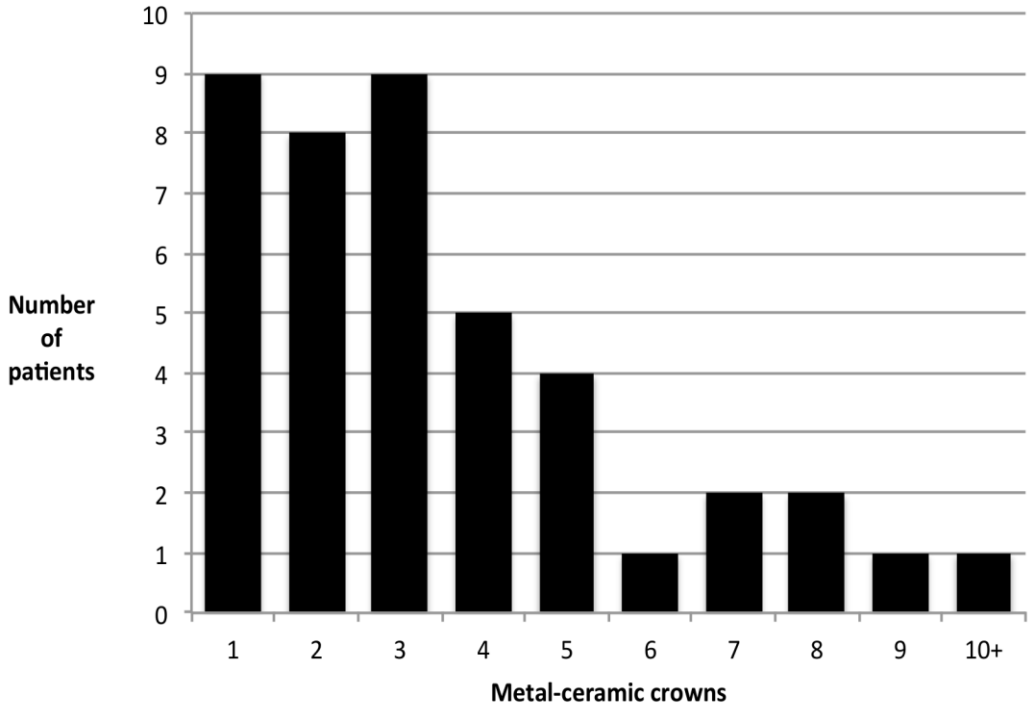

Figure 2. Distribution of metal-ceramic crowns

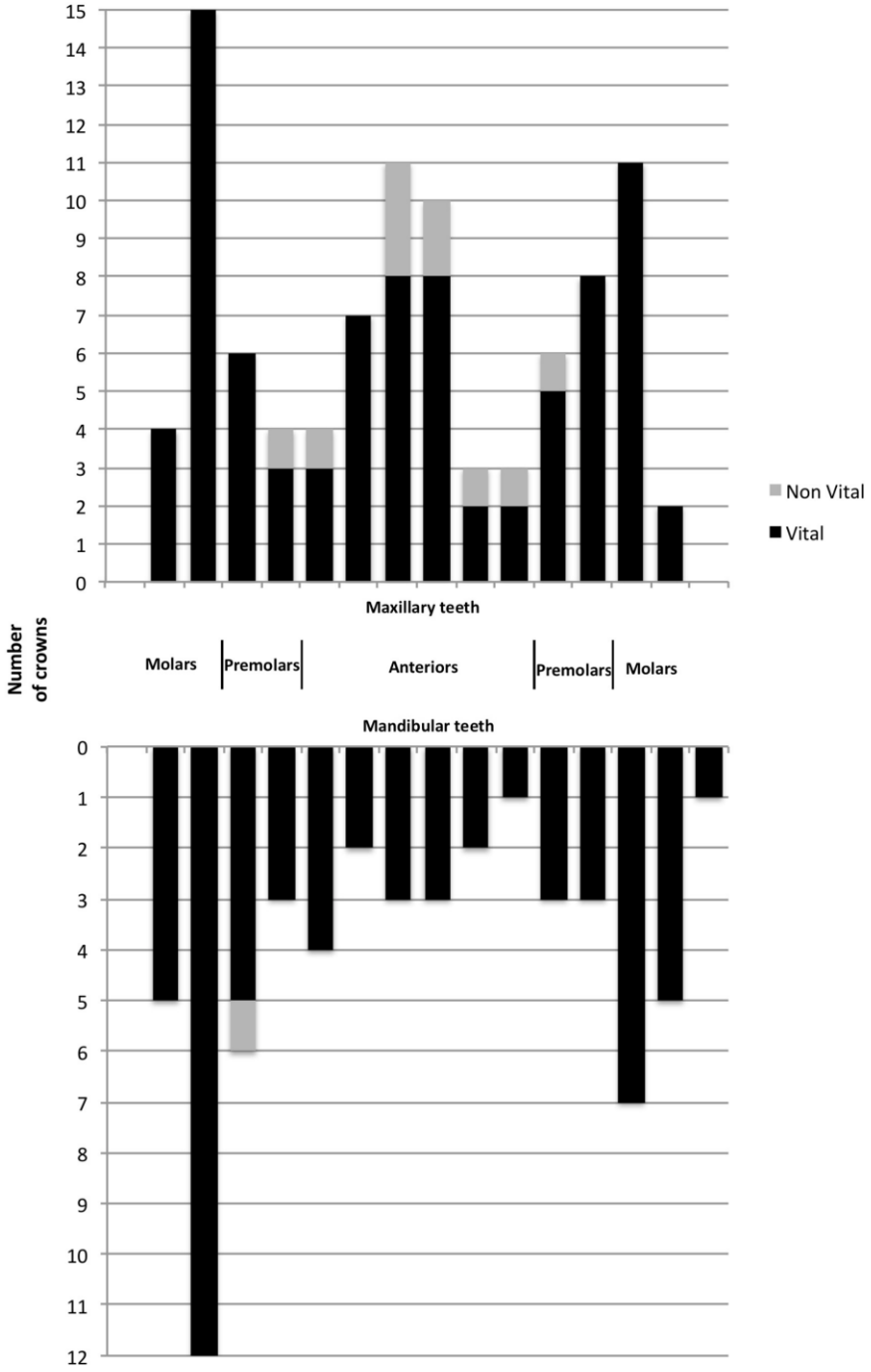

Figure 3. Kaplan Meier survival function graph for metal-ceramic crowns.

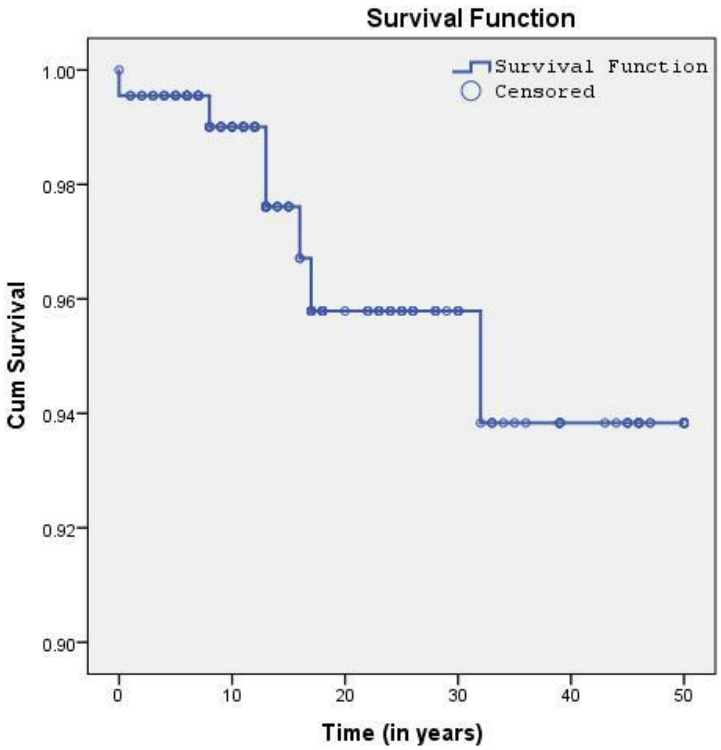

Figure 4. Hazard function for metal-ceramic crowns.

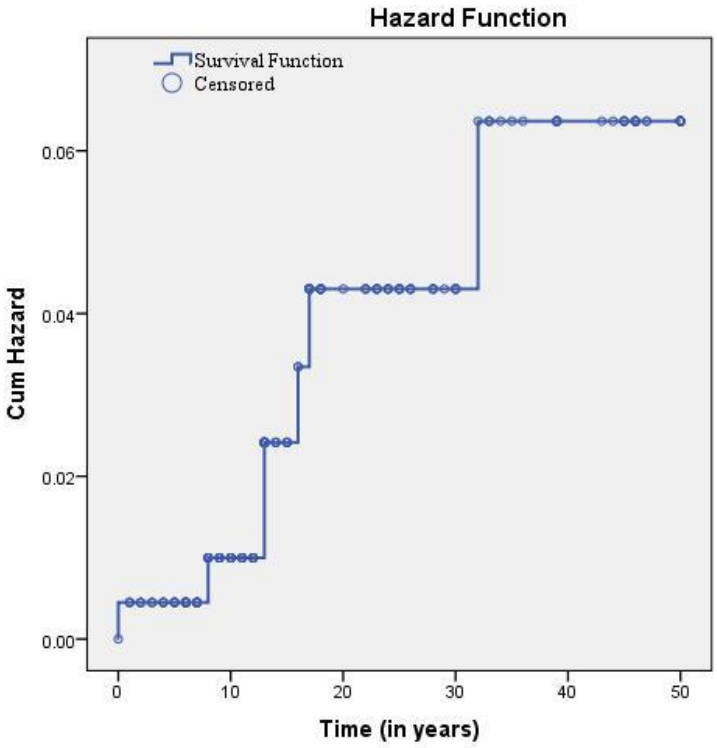

Figure 5. Restorations at fifty years

Figure 1

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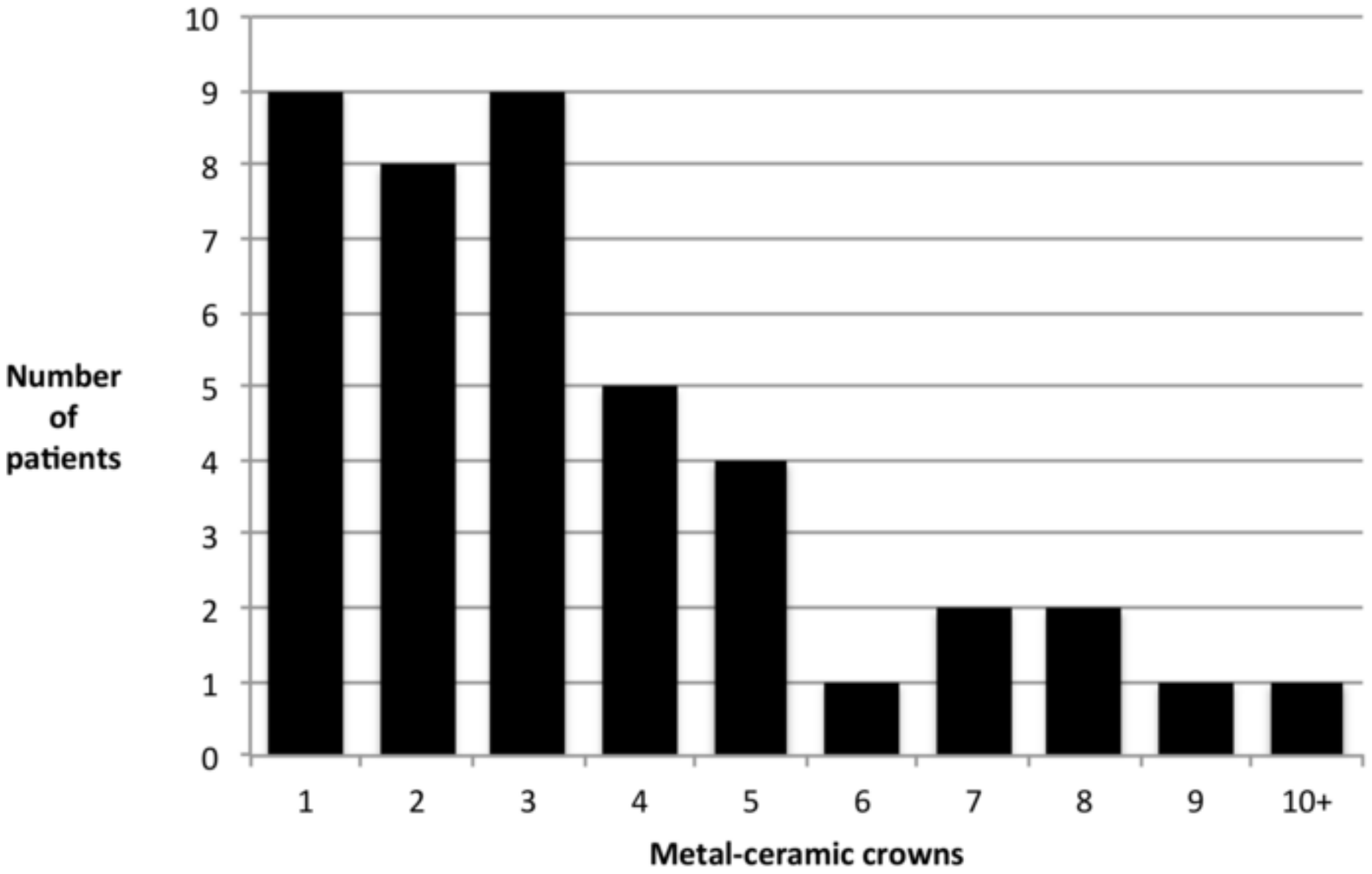

Figure 2

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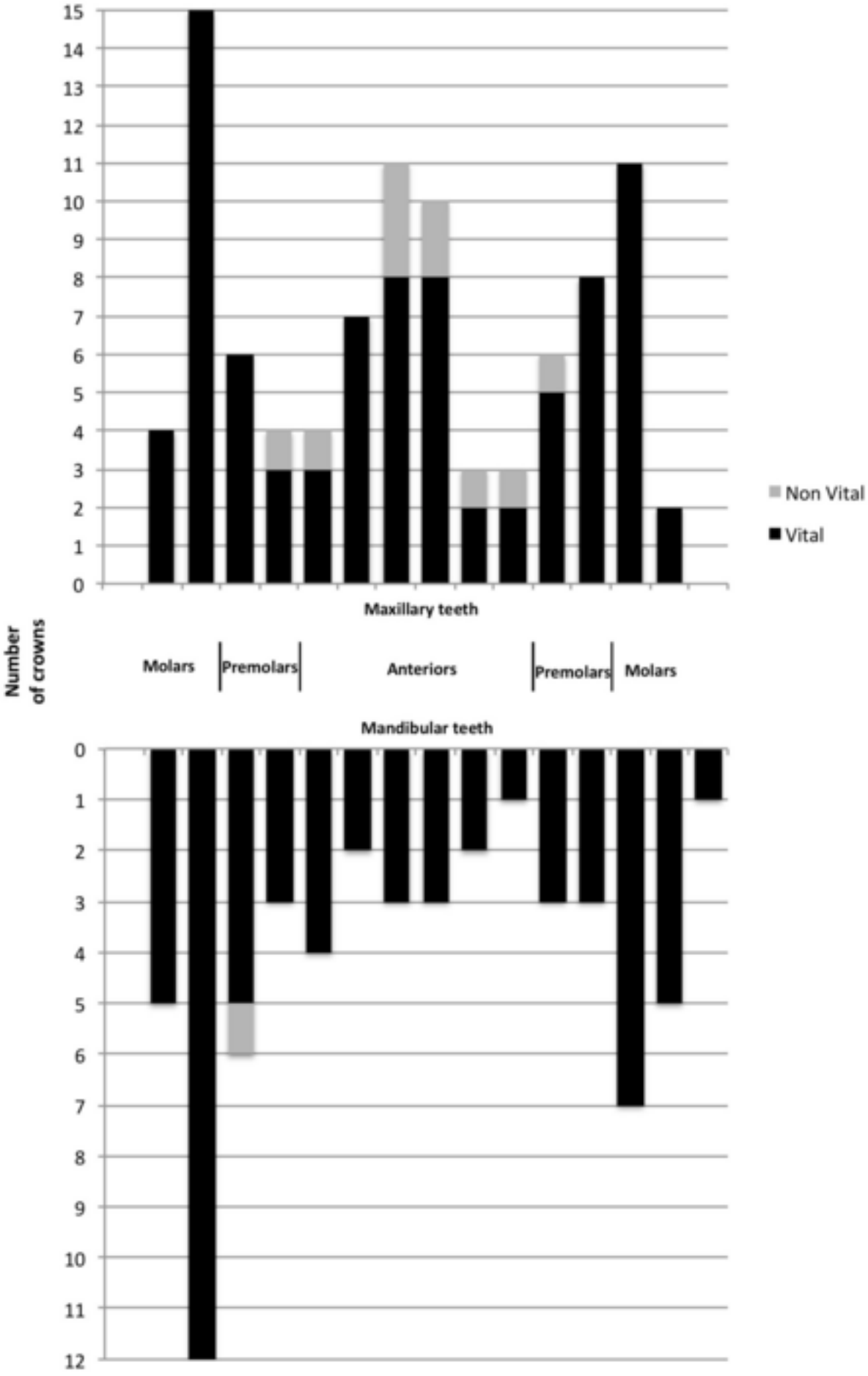

Figure 3 Kaplan Meier Survival function graph for metal-ceramic

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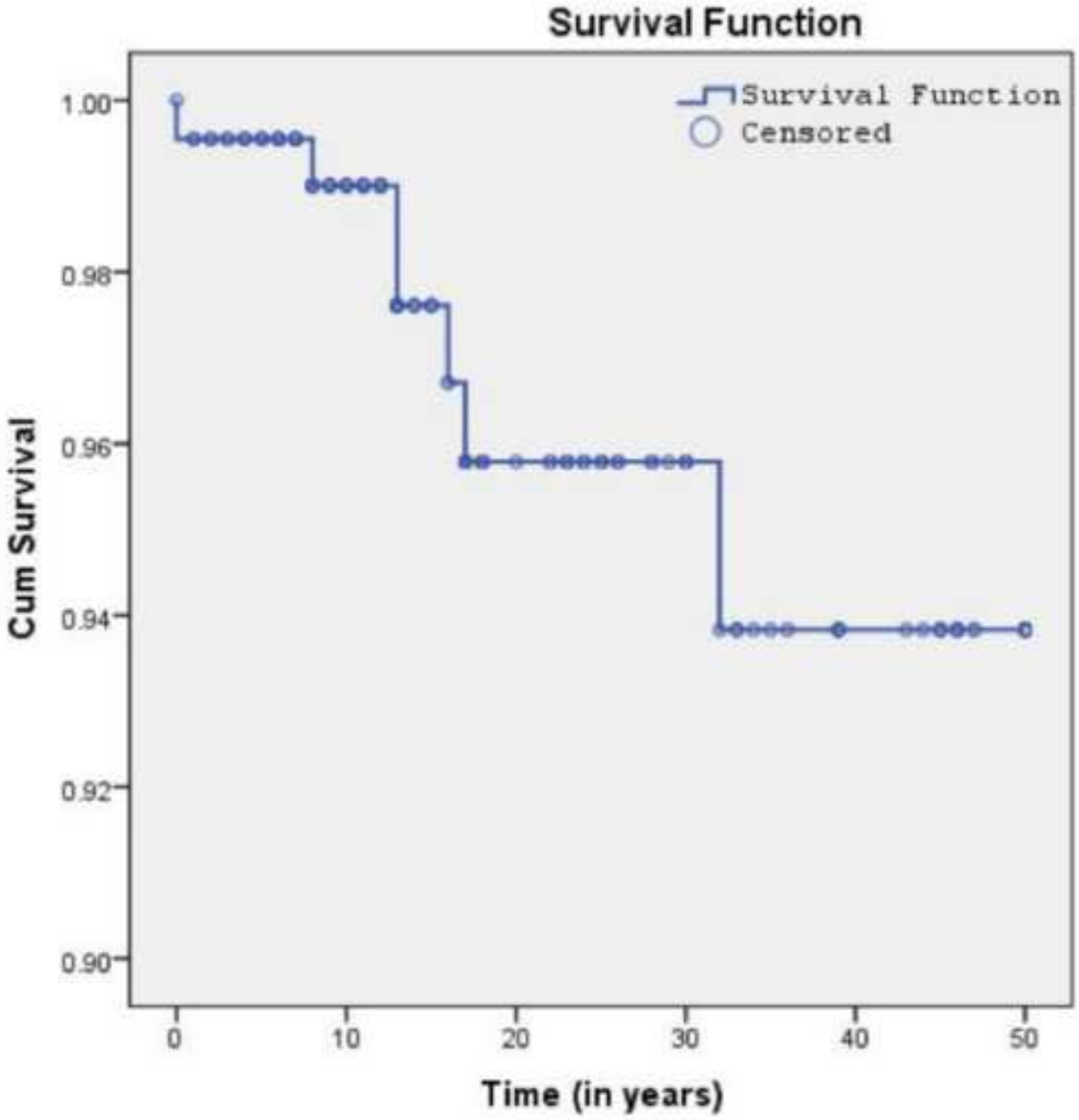

Figure 4 Hazard function for metal-ceramic crowns

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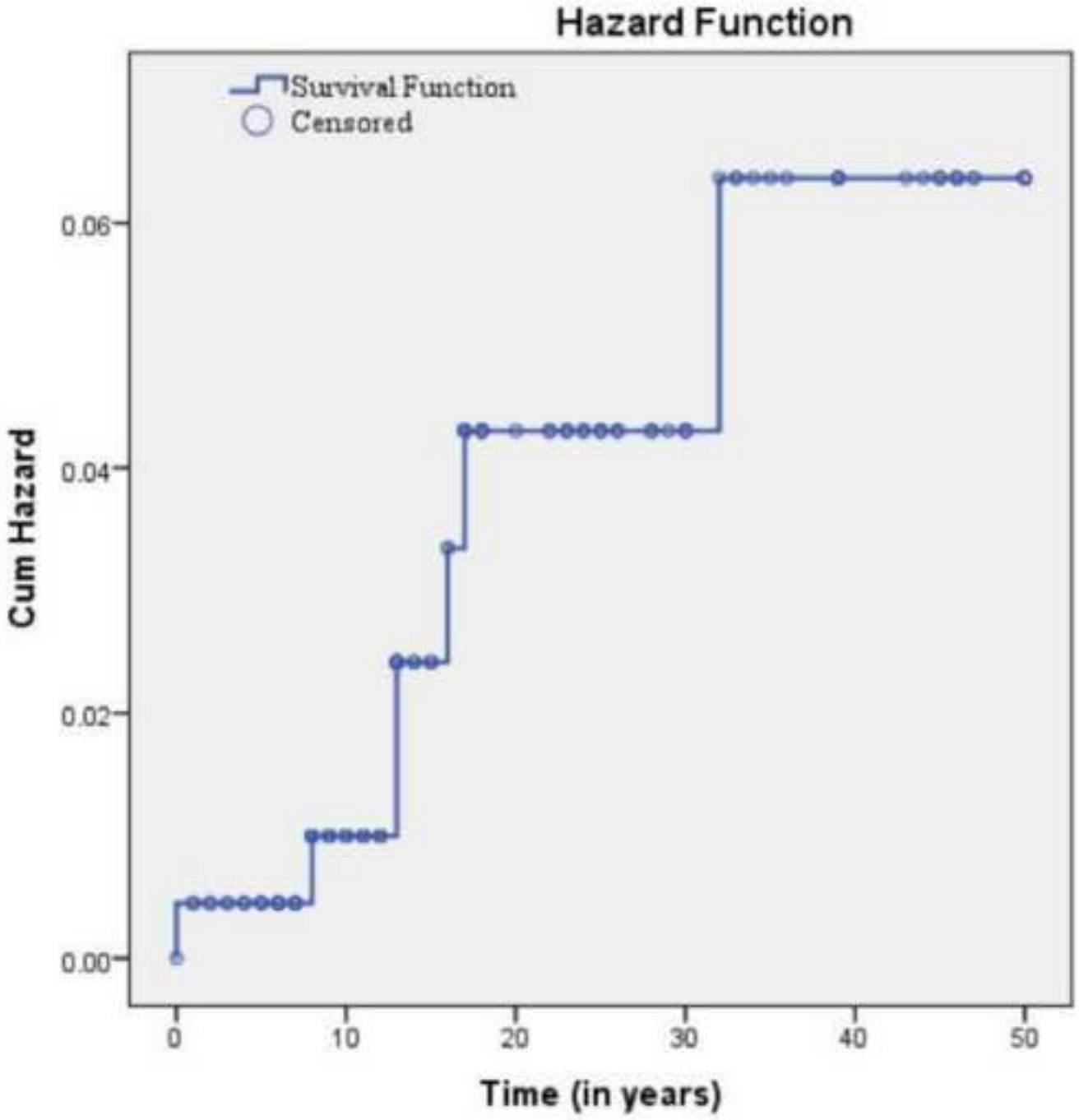

Figure 5 Restorations at fifty years
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