LONGEVITY OF CROWN MARGIN REPAIRS USING GLASS IONOMER: A RETROSPECTIVE STUDY

by

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INTRODUCTION

Traditionally, total replacement of direct or indirect defective dental restorations was an acceptable practice.[1] There are many reasons why restorations are defective. The most common causes are fracture of restorative material and secondary caries.[1-4] Clinicians have exhibited large variations in both their diagnoses of secondary caries and their decisions to restore or re-restore.[5] A 2017 retrospective study investigated the reasons for initial intervention and replacement of 824 single crowns in 476 patients treated at a university faculty practice over a two-year period. Forty-four percent of the crowns completed were replacements of existing crowns. On average, the crowns being replaced had been in service for six years or less. Secondary dental caries and failing margins accounted for 28 percent of the crown replacements.[6] However, when considering treatment for marginal defects of indirect restorations, it may be more conservative to first attempt repairing the defect rather than replacing the entire restoration. When a restoration is completely removed and replaced, sound tooth structure is lost beyond the defective area.[7]

Over the last few decades, the concept of "repair rather than replace" has emerged as an acceptable option to delay the "restoration cycle" (the serial replacement of restorations).[4, 8, 9] The restoration cycle describes the chronic degradation and eventual extraction of a tooth, beginning with the initial placement of a conservative direct restoration, followed by replacement with a larger direct restoration, and then replacement of the restoration with a crown, and then endodontic therapy followed by placement of new crown, and finally, extraction (Figure 1). The concept of repair has

been more generally applied to direct restorations. Repair of defective amalgams and resin composites in moderate caries-risk patients is as effective as restoration replacement in maintaining individual tooth function and longevity.[4] Slowing the restorative cycle at any stage can prolong the overall retention of teeth. Restoration repair can be a simpler and more conservative procedure and literature has demonstrated its effectiveness.[10]

Numerous studies have investigated the efficacy of repairing direct restorations.[4, 5, 8, 9, 11-21] These studies reported that repairing restorations increased the longevity of the defective direct restorations. Therefore, extending the longevity of a restoration seems to be the most reasonable plan to preserve tooth health, if it can be done efficiently and reliably.[22] Major US insurance companies will reimburse replacing a crown after five to 10 years, depending on the specific plan.[23, 24] Moreover, recent studies indicate a rising population of adults aged 65 years and older who have natural teeth and less tooth loss.[25, 26] However, this population may have limited dental insurance coverage since Medicare does not offer coverage for dental expenses, and obtaining additional dental insurance could be expensive, especially for people who are retired.[27] The crown margin repair (CMR) concept makes logical sense but lacks supporting data to consider it evidence-based dentistry. No studies investigating survival rates of indirect restoration margin repairs due to caries are found in the dental literature.

A CMR can be described as a procedure that is performed to remove caries or other defects at the margin of an indirect restoration where the lesion or defect is accessible. Ideally, removal of the caries lesion is accomplished at the expense of the crown rather than removing excessive sound tooth structure to access the lesion (Figure 2 through Figure 5). *In-vitro* studies have investigated margin adaptation and microleakage

of margin repairs of indirect restorations. These studies showed that glass-ionomer cements, direct gold and amalgam may be suitable materials to restore these defective margins.[28, 29]

Glass-ionomer cements have been used for a variety of restorative procedures since their development in the 1970s.[30] Annual failure rates of posterior glass-ionomer restorations have been reported to range from 0 percent to 14.3 percent.[31] The success of glass-ionomer restorations is highly dependent on an understanding of their basic properties, mechanisms of action and indications for use. Glass-ionomer cements have several favorable characteristics that make them ideal for crown margin repair procedures. They are tooth-colored, exhibit coefficient of thermal expansion similar to tooth structure, bond chemically to tooth structure, are biocompatible, and release fluoride with the ability to recharge fluoride stores.[30]

Durability of a material is another factor to consider when restoring defective or diseased teeth. Glass-ionomer cements are contraindicated in restorations that are subjected to occlusal loading; however, this is not a concern when repairing crown margins. A five-year survival rate of up to 80 percent was demonstrated when using glass-ionomer cement to restore cervical lesions at a dental hospital in the UK.[32]

The longevity of dental restorations depends on many factors, including the number of surfaces involved, the selected material, and patient-related factors such as caries risk status and parafunctional habits.[33] Restoration replacement is more time consuming and expensive, and potentially, more traumatic to the tooth than repair.

Glass-ionomer crown margin repairs have been performed in the Indiana University School of Dentistry (IUSD) Graduate Operative Dentistry clinic for many

years. However, no one has evaluated the longevity of these repairs. Furthermore, there are no studies found in the dental literature in which the longevity of glass-ionomer crown margin repairs has been investigated. Therefore, the purpose of this study was to determine the longevity of glass-ionomer crown margin repairs completed in the Graduate Operative Dentistry Clinic between 2006 and 2018.

REVIEW OF LITERATURE

CROWN SURVIVAL AND STUDY DESIGNS

Compared with direct restorations, crowns are considerably more expensive and time-consuming to place. Crowned teeth have progressed further along the restoration cycle. Hence, delaying invasive crown replacement may be more likely to slow the progress along this path toward possible tooth loss. Longevity of crowns should be considered, due to the increased cost and time of the procedure and the health of the remaining tooth structure. There are different study designs to investigate crown longevity. Benefits and drawbacks are present in each study model.

Randomized controlled studies offer numerous benefits, such as a high degree of standardization in care delivery and data collection. Procedures are often performed by experienced clinicians and within a time-controlled setting where speed of completing the procedure may not be highly prioritized and specific preparation requirements are ensured. However, randomized controlled studies are relatively more expensive compared with other study methods. The time and cost related to recruiting and retaining large numbers of subjects for the study may be difficult. In order to provide meaningful data, the restorations should be followed for many years and patients often "drop out" skewing the data. Moreover, to control for intrinsic or extrinsic variables, these studies may have exclusion/inclusion criteria that may not reflect a general population (e.g., caries risk and bruxism).[34] A recent randomized controlled trial investigated clinical outcomes of porcelain fused to metal (PFM), lithium disilicate, and bilayer ceramic crowns. Thirty-six crowns were evaluated over a three-year period. Results showed no

significant differences among the types of crowns after three years.[35] Relatively short observational periods may be attributed to the cost or other limiting factors. Another randomized controlled trial evaluated longevity up to five years for zirconia and PFM crowns. This study evaluated 90 restorations, notably more restorations than in the previous study. The common mode of failure was ceramic chipping; both PFM and zirconia crowns demonstrated a 97-percent survival rate at five years.[36] Although randomized controlled trials have numerous benefits, they often lack clinically significant observation time and a sufficiently large number of subjects.

Systematic reviews pool data from several studies, allowing for the inclusion of large numbers of restorations with the benefits of low cost to the researchers and no need for patient compliance and recalls. However, this methodology does not allow for strong standardization of materials and processes in delivering care and collecting data. A systematic review completed in 2018 evaluated 3,404 full crown restorations placed in 1,557 patients over a 15-year period. The study showed annual failure rates (AFR) of 0.8 percent to 0.9 percent for PFM crowns and 0.7 percent for lithium-disilicate crowns.[37]

With the emergence of electronic dental health records (EHR), patient data are more readily accessible to researchers than ever before. Practice-based studies are using EHR to investigate questions in the dental field. Some practice-based studies are retrospective in design and rely on the existing data in EHR. There are drawbacks and benefits associated with retrospective practice-based studies. Potential problems with the use of dental health records to investigate restoration longevity or outcomes include: 1) vague or incomplete treatment notes; 2) variable follow-up or recall intervals, occasionally leading to short observation times if patients do not return to the practice

after treatment is completed; 3) lack of standardization in documenting patient-level variables such as caries risk and bruxism, which are likely to influence outcomes. Retrospective practice-based studies often mirror day-to-day clinical practice in that they could include non-ideal restorations or subjects. Due to pre-existing data, retrospective studies are significantly less expensive and can be completed in a shorter time than prospective studies. Also, observation times can be longer because subjects can be passively observed for many years as they continue their routine dental care.[38]

A practice-based study published in 2018 investigated the longevity of 3,404 single unit crowns placed in 1,157 patients by eight dentists over 15 years. The annual failure rate (AFR) after 11 years was 2.1 percent. These large numbers are possible because of the relatively low-cost nature of retrospective EHR studies.[37] Another retrospective EHR study demonstrating its design benefits was published in 2008. A data set of over 80,000 different patients from National Health Services General Dental Services in England and Wales was analyzed. A total of 47,374 crowns were placed over an 11-year period. Their results revealed that metal crowns had a 68-percent survival after 10 years, while PFM and all-ceramic crowns were 48 percent and 62 percent, respectively.[39] This study demonstrates the strength of retrospective studies using EHR data to study outcomes on larger and more diverse populations who receive care in real world settings and over a longer time period than is possible through randomized clinical trials.

No single study design type is sufficient to make firm clinical recommendations for restoration longevity; rather, a combination of many well-designed studies utilizing the different study designs is needed.

RESTORATION REPAIR

Restoration repair has been investigated more frequently in recent years. This body of literature includes topics such as the efficacy of repaired restorations and the teaching of restoration repair.[4, 8, 11, 12, 14, 17, 19, 20, 28, 40-49] Clinical diagnosis of secondary caries is the most common reason for replacement of all types of direct and indirect restorations, comprising 50 percent to 60 percent of all restorations replaced.[50] Typically, when primary caries is diagnosed, principally only the defective area is removed with respect to tooth preparation principles (e.g., convenience, retention, and resistance forms) and non-defective areas are not prepared or removed. Every time a restoration is replaced, it leads to a subsequent increase in size of the restoration at the expense of tooth structure and to the further destruction of the tooth with eventual tooth loss.[14] Also, the tooth is subjected to increased stress as described by the Stressed Tooth Condition. Vital dental pulp is subjected to repeated damage, including operative trauma, accidents, or other pathologic changes.[51] This practice further propels the destructive tooth cycle.[7]

There has been an increasing interest among clinicians and researchers to repair, rather than replace, defective restorations. Benefits of restoration repair include conserving tooth structure, minimizing deleterious pulpal effects, increasing the longevity of existing restorations, reducing risk for tooth loss, and thereby decreasing the long-term costs of restorative treatment.[52, 53] These benefits can be seen as positive outcomes for both patients and dentists. A practice-based study analyzed the annual failure rate 59,722 class II amalgam or resin composite restorations placed in 21,988 patients. The results demonstrated that repairing a defective restoration significantly increased the survival rate of a restoration from 65.9 percent to 74.6 percent at 10 years.[8]

The severity of a caries lesion that compromises an existing restoration may determine if the restoration can be repaired or needs total replacement. Determining lesion severity, however, is often both difficult and subjective.[7] An experienced provider may decide a restoration needs a repair, while another provider may see fit to completely replace the restoration. There are currently no specific criteria to describe whether indirect restorations should be replaced or repaired. Primary and secondary caries lesions are the same with the exception that secondary lesions occur adjacent to existing restorations. The criteria for the diagnosis of active primary caries lesions (soft, leathery, orange/yellow with a wet appearance) should be applied to secondary lesions as well.[14] Thus, secondary lesions should be treated in the same fashion as primary lesions, by removal and restoration of only the defective or diseased tooth structure.[50]

If there are differences in diagnoses among experienced providers, one could imagine the difficulty in teaching dental students how to diagnose caries with regard to restoration repair. In a 2001 survey of North American dental schools, Clark and Mjör concluded that restoration repair was poorly taught. Only 39 percent of respondents reported teaching repair, enameloplasty or partial replacement.[54] However, a 2018 systematic review and meta-analysis of restoration repair surveys by Kanzow et al. concluded that a vast majority of dental schools are teaching direct restoration repair. Of the 7,228 dentists and 276 dental schools worldwide included in the analysis, 71.5 percent of dentists and 83.3 percent of schools practiced or taught restoration repair.[40] Yet their findings also stated that although restoration repair is widely taught, the proportion of truly repaired restorations is low. Only 31.3 percent of failed direct restorations were repaired.

It is important to state explicitly that recent studies have determined the longevity of repaired restorations and demonstrated the value of repaired restorations to improve the survival time of teeth with direct restorations.[4, 8, 11, 17, 20, 45] However, to the best of our knowledge, no study has investigated the survival time of repaired defective crown margins.

GLASS-IONOMER (GI) RESTORATIONS

There are many direct restorative materials available in dentistry. It is important to select the most appropriate material for the desired restorative procedure based on the unique characteristics and properties of the material. Glass-ionomer cements exhibit many favorable properties that make them acceptable to repair defective crown margins.

Glass-ionomer cements, also known as glass polyalkenoate, first came to the market in the 1970s. By combining silicate and polyacrylic systems, glass-ionomer restorative cement was formulated.[55]

Indications and Contraindications

Considerations for the use of GI restorative cements include: high-caries-risk patients, crown margin repairs, class 3 and 5 restorations, cervical erosion and abrasion lesions. Contraindications include areas of high esthetic needs, heavy occlusal loading, and difficult moisture control. A beneficial strength is similar coefficient of thermal expansion to dentin.[56] Also, there is high-fluoride release upon placement and the ability for fluoride recharge. Since fluoride is not an essential part of matrix formation, fluoride will be released without negatively affecting the physical properties or the restoration.

Fluoride uptake from fluoridated toothpastes and varnishes allows for subsequent release of fluoride ions into adjacent tooth structure and the surrounding oral environment.[55]

Handling

The tooth surface should always be well isolated, free from saliva and blood, but not desiccated. During initial placement, restorative GI cement should be manipulated and only applied while the cement has a sheen or gloss. When a gloss is present, the material is most active to chemically bond to the tooth surface. Restorative GI cements have setting times that range from 3 min to 4 min. Light-cured resin-modified GI materials can set in approximately 30 seconds when exposed to visible light. The acid-base reaction continues slowly and mechanical properties improve over time. Finishing and polishing of GI cement should be done wet, with care not to desiccate the material. Manufacturers recommend placing a resin sealer or varnish initially to prevent excessive moisture loss or gain during setting. Desiccating the material will lead to crazing and decreased mechanical properties. Resin-modified GIs tend to be less sensitive to moisture in the finishing process.[55]

SUMMARY

It is well established that repair of defective margins of direct restorations can provide a viable treatment alternative to total replacement.[8, 9, 17, 18, 21] Benefits of this minimally invasive treatment include preservation of tooth structure, tooth vitality, increased longevity of the existing restoration, decrease costs to the patient and a simplified restorative procedure.[8] Our literature search revealed two *in-vitro* studies, completed in 1986 and 1990, that investigated material selection for repairing defective

crown margins. Those studies measured marginal adaptation and microleakage, and showed that GI, direct gold and amalgam may be suitable materials to repair the margins of indirect restorations.[28, 29] However, we found no reports of the longevity or the survival of indirect restoration margin repair. Therefore, the purpose of this study is to determine the longevity of crown margin repairs. The outcomes may allow for insights into further studies and provide evidence-based treatment options for patients with defective crown margins.

MATERIALS AND METHODS

This was a retrospective study of CMR completed on patients seen in the Graduate Operative Dentistry Clinic, Indiana University School of Dentistry (IUSD), Indianapolis, Ind., USA, between January 1, 2006 and January 1, 2018. This project was reviewed and approved under exempt status by the Institutional Review Board, Indiana University School of Dentistry, Indianapolis, IN (Study #:1808963626). One cannot do a simple query in axiUm (Exan Group, Coquitlam, BC, Canada) for CMR using GI cement, because both resin composite and GI cement share the same code on Dental Procedures and Nomenclature (CDT codes).[57] Also, there is no code for a crown margin repair procedure.

In this study, the inclusion criteria included adult patients who underwent CMR on permanent teeth in the IUSD Graduate Operative Dentistry Clinic. The database was queried for CDT codes for anterior and posterior resin or GI restorations (Table I). These patients also had treatment notes that contained words or spans of text that suggested margin repair. A list of trigger words and phrases was developed after a review of 100 randomly selected records (Table II). Any restoration that included an occlusal surface was excluded. Failure variables included extraction, new crown and re-repair.

The data set included patient demographics such as patient ID, age, gender, dates of treatments, procedure codes in the form of CDT codes, tooth type, tooth surface, existing findings such as conditions, and treatment received elsewhere and treatment notes. This study data set was placed in an IU-approved secure folder, Box Health folder, a secure server that complies with federal regulations for privacy and security

https://www.hhs.gov/hipaa/for-professionals/privacy/index.html, and with the Indiana University Office of Information Security policies.

Two reviewers who are dentists manually reviewed all patient records to confirm that the clinical treatment notes contained a treatment history for CMR. The reviewers developed a guideline to determine the words and span of text that indicated the presence of CMR in the clinical notes. They reviewed a random set of 100 patient records and calculated an inter-rater reliability score of 82.3 percent using Cohens Kappa statistic (Table III) for agreement. The reviewers then individually reviewed the remaining records. Consensus was reached on any disagreements through discussion. Only records confirmed with the presence of CMR by the two reviewers were retained in the final dataset for survival analysis.

DATA ANALYSIS

Kaplan-Meier survival curves, including 95-percent confidence intervals, were used to estimate the survival time for crown margin repairs. The mean AFR of the investigated CMRs was calculated according to the formula: $(1-y)z = (1-x)$.[58] Factors that could affect crown margin repair survival were evaluated using Cox proportional hazards models. Factors examined included age, gender, and type of tooth treated. The Cox model also included a frailty term to account for correlation among multiple teeth within a patient. A 5-percent significance level was used for all tests.

RESULTS

Our query of axiUm database for CDT codes indicating resin restorations initially identified 2,324 records. Words, phrases, and spans of texts that indicated CMR were recorded from manual review of treatment notes (Figure 7). The manual review of treatment notes eliminated 2,110 restorations. After final review, 214 teeth in 115 patients were included in the analysis. The mean age of the patients was 69.4 years (Table V). The sample consisted of 48.7 percent males (n = 56) and 51.3 percent females (n = 59) (Table V).

Of the 214 CMRs, anterior teeth accounted for 21.5 percent (n = 46) (upper and lower anterior teeth were combined due to the small number of lower anterior teeth). Lower posterior teeth accounted for 37.85 percent (n = 81), while upper posterior teeth accounted for 40.65 percent (n = 87) (Table VI).

The results revealed 62.9-percent 5-year survival with a 95-percent confidence interval, using the Kaplan-Meier survival curve (Figure 6). This can be restated as an 8.86-percent annual failure rate. Only 29.4 percent (n = 63) were observed to have failed (Table VII). The average time to an observed failure was 2.7 years (Table VIII). The remaining CMRs were censored at the last follow-up visit. The average follow-up time before censoring was 3.06 years (Table IX). Lower posterior teeth had the greatest time to failure or follow-up time (3.44 years) and also the greatest censoring time (3.34 years) (Table IX). For anterior teeth that were treated as censored, the average follow-up time was 3.01 years (Table IX); and for anterior teeth that were treated as failures, the average time was 2.48 years (Table IX).

Cox Proportional Hazards Regression analysis was performed to examine if age, gender, or tooth type affected time to failure; in addition, a frailty term was included in the model to account for correlation among multiple teeth within a patient in the study. The results showed none of the factors affected time to failure (all p values > 0.05) (Table X).

TABLES AND FIGURES

TABLE I

Inclusion and exclusion criteria

Inclusion criteria:	Exclusion criteria:
• At least 18 years old • Anterior resin composite (D2330, D2331, D2332, D2335) • Posterior resin composite (D2391, D2393, D2393, D2394) • Manual review confirmed GI or RMGI use • Manual review confirmed existing crown	• Manual review did not confirm GI or RMGI use • Manual review did not confirmed existing crown

TABLE II

Initial search words, phrases or span of text that indicated crown margin repairs

Initial search words and span of text:	
• glass ionomer	• crown margin
• GI	• margin
• resin modified glass ionomer	• defective margin
• RMGI	• recurrent caries
• crown	• recurrent decay
• repair	• secondary caries

TABLE III

Cohens Kappa statistic

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Reviewer 1 * Reviewer 2	100	100.0%	0	0.0%	100	100.0%

Reviewer 1 * Reviewer 2 Crosstabulation

Count

		Reviewer 2		
		FP	TP	Total
Reviewer 1	FP	85	1	86
	TP	3	11	14
Total		88	12	100

Symmetric Measures

		Value	Asymptotic Standard Error[a]	Approximate T[b]	Approximate Significance
Measure of Agreement	Kappa	.823	.086	8.266	.000
N of Valid Cases		100			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

TABLE IV

Complete list of keywords and span of text used to identify CMR from treatment notes

margin repair	20
marginal repair	20
crown repair	14
PFM crown	14
crown margin	13
Crown	11
gold crown	9
margin repairs	8
margin of the crown	6
Bridge	6
crowns	5
margin of gold crown	5
crown margin repair	4
bridge abutment	4
crown margins	3
FCG crown	3
margin of crown	3
margin of the crown was trimmed	3
margins of All- Ceramic crowns	3
PFM	3
margi repair	2
Cr repair	2
FGC	2
full gold crown	2
margin of crowns	2
margin of exisitng crown	2
marginal repair crown margins	2
PFM crown margin	2
PFM crown	2
PFM crowns	2
Repair margin of existing crown	2
under the Ceramic crown	2
bridge margins	2
margin of abutment	2
margins repair	1
margin reapair	1
margin repair of crown	1
margin repair of existing crowns	1
margin repaired	1
marginal repair crown margins	1
margin repair of PFM crown	1
marginal repair of the crown	1
Mesio-facial margin repair	1
repair of crown margins	1
repair of margin in crown	1
repair the margin	1

repaired margin	1
RMGI crown margin repair	1
RMGI margin repair	1
around the margin of gold crown	1
base of crown	1
beneath the facial crown margin	1
broken part of the crown	1
caries MB margin of a gold crown	1
cervical margins of gold crown	1
cervical to the existing gold crown	1
crown margin defect	1
crown margin removed	1
crown on teeth	1
crown with secondary caries	1
exposed crown margin	1
facial margin of crown	1
Gold crown margin	1
gold crowns	1
margin of old gold crown	1
margin of onlay	1
margin of PFM crown	1
margin of the gold crown	1
margin of the gold crown	1
margin of the PFM crown	1
margin under crown	1
PFM crown L margin	1
PFM crown with defective margin	1
repair a gold crown margin	1
repair around crown margin	1
repair of crown	1
repair of crown on tooth	1
root surface of crown margin	1
under gold crowns	1
under the crown	1
underneath gold crown	1
Abutment	1
abutment for PFM bridge	1
abutment of 3 units bridge	1
Abutment of FPD	1
FPD	1
margin of FPD abutment	1

TABLE V

Demographics of patients included in the final dataset (N = 115 subjects)

Gender			Frequency		Percent		
male			56		48.70		
female			59		51.30		
	Mean	**Std Dev**	**Minimum**	**Lower Quartile**	**Median**	**Upper Quartile**	**Maximum**
Age in Years	69.4	11.7	32.3	62.4	71.4	77.0	98.9

TABLE VI

Data summary by tooth (total: 214 teeth)*

Tooth type	**Frequency**	**Percent**
anterior	46	21.50
lower posterior	81	37.85
upper posterior	87	40.65

*Tooth type (combined lower anterior and upper anterior together due to small number of lower anterior).

TABLE VII

Failure rate*

Failure	**Frequency**	**Percent**
No	151	70.56
Yes	63	29.44

*Failure included: extracted, new crown and re-repair.

TABLE VIII

Average time (years) to failure or follow-up time (years)*

Failure	N	Mean	Std Dev	Min	Q1	Median	Q3	Max
No	151	3.06	3.31	0.00	0.52	1.61	4.52	13.07
Yes	63	2.70	2.11	0.00	1.02	2.10	3.91	9.42

*For teeth that were treated as censored, the average follow-up time was 3.06 years; for teeth that were treated as failure, the average time to failure was 2.70 years.

TABLE IX

Average time (years) to failure or follow-up time (years) by teeth type*

Failure	Tooth type	N	Mean	Std Dev	Min	Q1	Median	Q3	Max
No	anterior	30	3.01	3.94	0.00	0.40	0.72	5.85	13.07
No	lower posterior	60	3.44	3.50	0.00	0.54	2.25	5.23	12.55
No	upper posterior	61	2.70	2.74	0.00	0.60	1.61	3.80	9.18
Yes	anterior	16	2.48	2.07	0.00	1.02	1.14	5.07	5.73
Yes	lower posterior	21	3.34	2.31	0.44	1.69	3.18	3.96	9.42
Yes	upper posterior	26	2.31	1.90	0.02	0.96	1.62	3.55	6.45

*For anterior teeth that were treated as censoring the average follow up time was 3.01 years; for anterior teeth that were treated as failure, the average time to failure was 2.48 years.

TABLE X

Cox Proportional Hazards regression*

Variable	Coefficient	Standard Error	Odds Ratio	Lower CL	Upper CL	P-value
Patient age	0.007	0.017	1.007	0.974	1.041	0.680
Gender(female)	0.209	0.375	1.232	0.591	2.572	0.580
Lower posterior	-0.767	0.470	0.465	0.185	1.168	0.100
Upper posterior	-0.349	0.445	0.706	0.295	1.689	0.430

*Cox Proportional Hazards Regression analysis was performed to exam if age, gender, tooth type affect time to failure, a frailty term was included in the model to account for correlation among multiple teeth within a patient in the study. The results showed none of the factors effected time to failure (all p-values > 0.05).

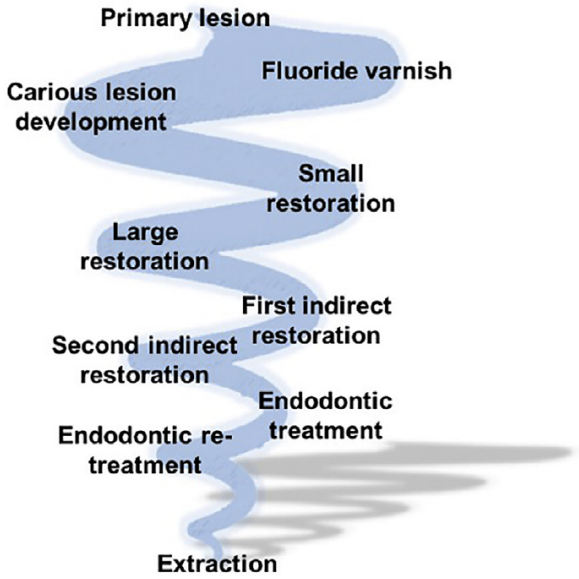

FIGURE 1. Spiral of re-interventions, also termed “death spiral of the tooth” or “restorative cycle.”

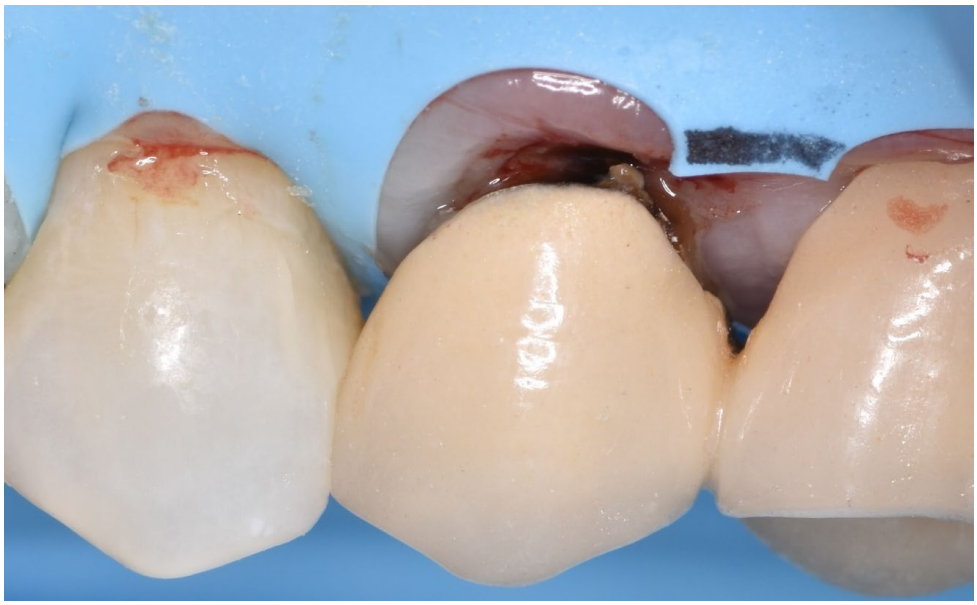

FIGURE 2. Tooth #13: Pre-operative PFM crown with secondary caries.

FIGURE 3. Isolated defective carious PFM margin.

FIGURE 4. Carious lesion removed at the expense of crown to ensure complete excavation of lesion and to minimize excess loss of sound tooth structure.

FIGURE 5. Completed crown margin repair with resin-modified glass ionomer.

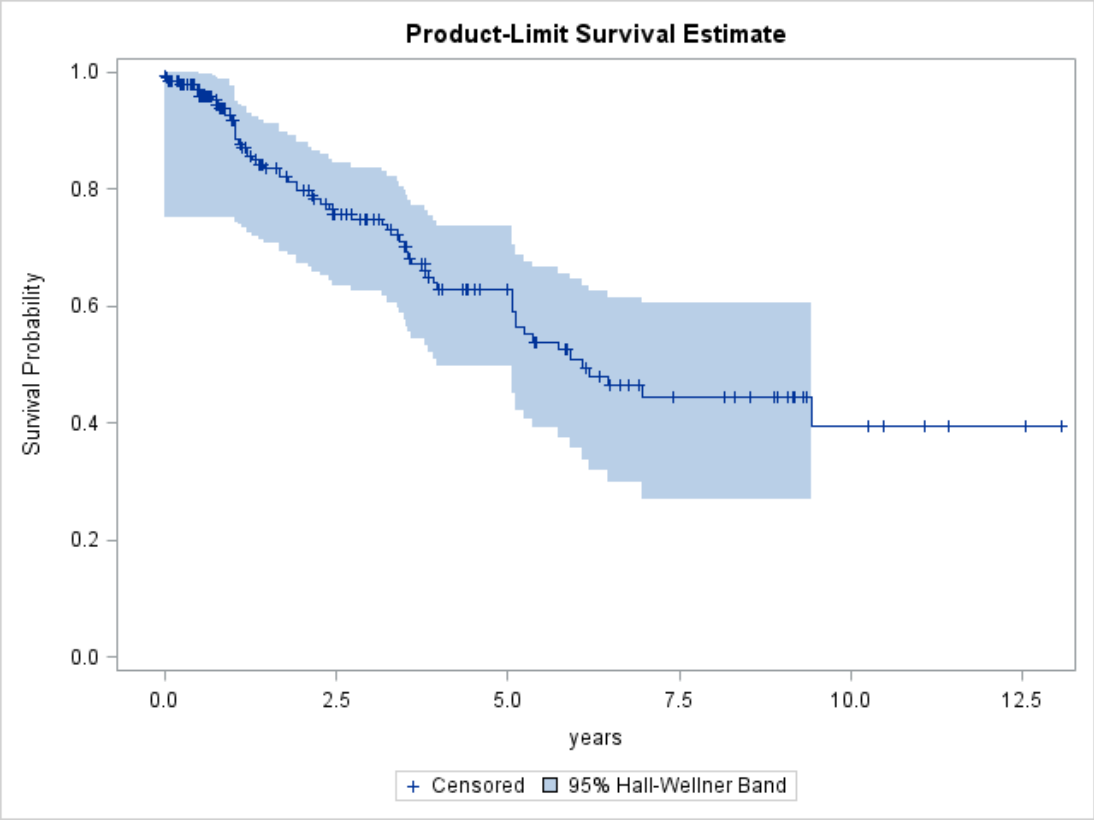

FIGURE 6. The Kaplan-Meier survival curve with confidence intervals for crown margin repairs using glass ionomer at 5 years shows a survival rate of 62.9 percent with a 95-percent confidence interval (54.2%, 71.6%).

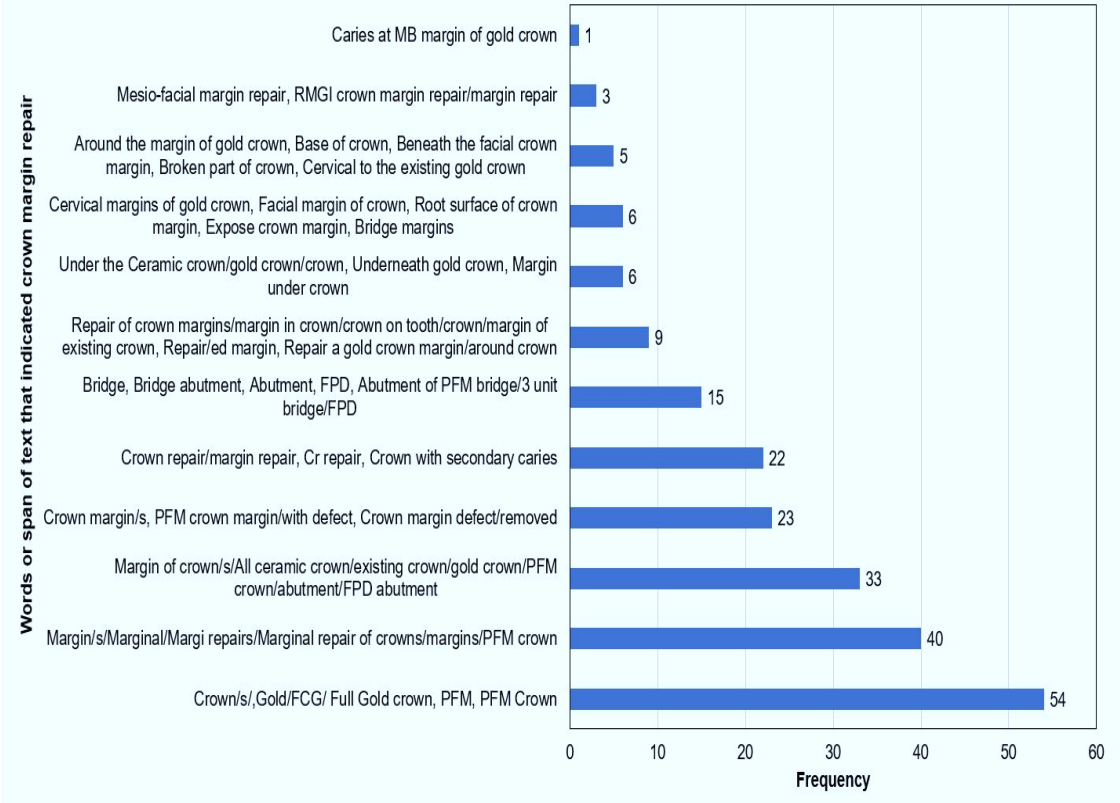

FIGURE 7. Crown margin repair keywords from manual note review.

DISCUSSION

As far as we know, this is the first study to investigate longevity of indirect restoration margin repairs. Major findings of the present study demonstrated that CMRs had a 62.9-percent survival rate of 5 years, and that there were no significant differences among the teeth on which the repairs occurred. Based on these findings, treating defective crown margins by repairing with GI cement should be considered as a potential treatment option. This may extend the survival of the crown and ultimately the tooth.

Inclusion criteria for this study stipulated that CMRs were completed with only GI cement or resin-modified GI cement material. This was done because the general philosophy in the Graduate Operative Dentistry clinic is to use GI materials for CMR. This aided in identifying CMR through axiUm queries and manual review. There may also be a need to investigate CMR with resin composite, amalgam and gold. A common philosophy of CMR technique was observed, in which the caries lesion is removed at the expense of the crown, rather than in removing excessive sound tooth structure to access the lesion. It cannot be confirmed that all included CMR were done with this technique, but rather that this is the common CMR philosophy taught in the Indiana University School of Dentistry Graduate Operative Dentistry program.

CMR technique, as described in the Introduction, can be a stepwise assessment to determine whether a defective or carious crown margin should be repaired, or if the crown should be replaced. After initiating CMR procedure, it may be determined that repairing will be impossible. This may be because complete caries removal cannot be confirmed or the remaining supporting tooth structure is highly compromised. At that

point, CMR procedure should be terminated, and crown removal with complete caries excavation should be done to assess restorability of the tooth.

This treatment option has direct implications for high caries risk and the aging population. If patients have active caries lesions, they should be considered at moderate or high risk for caries.[59] Ideally, when creating a comprehensive treatment plan for a patient, the first step is disease control.[60] It may be more prudent to repair defective margins and attempt to stabilize caries activity before completing the definitive care phase of a treatment planning sequence. Also, with an aging population that may lack dental coverage or finances for unexpected dental care expenses, CMR may be an excellent treatment option to remove the caries lesion and stabilize disease progression.

A 2018 practice-based study reported annual failure rates of 1.2 percent to 3.5 percent for single-unit crowns.[37] It may not be accurate to compare the two treatment options directly, i.e. repair of an existing crown margin versus crown replacement. Instead, risks and benefits of each option should be considered. CMR defers more extensive treatment until later, which pushes subsequent treatment further into the future. Benn and Meltzer used mathematical modeling to demonstrate that deferring initial treatment by even as little as one year significantly reduces the need for subsequent restoration replacement.[61]

Another significant outcome of this study was the manual review of the records identified words, phrases and group of words that confirmed the presence of CMRs. This manual review of 2,324 possible CMR restorations revealed three major keywords (margin repair, repair margin and crown margin) that indicated a CMR (FIGURE 7). Numerous combinations and variations of crown, margin, and/or repair were used in

conjunction with CDT codes and previous treatment notes to confirm a CMR was completed (Table IV). This list of keywords and phrases is a rich resource to identify CMR using EDR data.

Of the 2,324 restorations identified in the initial data query, only 214 CMR were confirmed. There are several reasons that may explain the low numbers. Accurate or standardized dictation of treatment notes varied in describing CMR procedures. As CDT coding evolves, it may be beneficial to have coding that identifies CMRs versus initial crown placement or replacement. In addition, GI cements should not be considered resin-based restorations, but should have their own coding index as amalgam, gold, resin composite and ceramic do. More CMR repairs may have also been identified if patients' radiographs were used adjunctively with the treatment notes to confirm the presence of an existing crown.

The reported survival rate may have been affected by variables not investigated in this study. First, failure and success were not assessed by an actual clinical examination associated with the study. Failures were described in this study as any subsequent intervention to the restored tooth, i.e. extraction, re-repair or new crown. It is possible that CMR restorations were still intact with sound restorative margins and the tooth failed due to another variable. Only 29.4 percent of the CMR restorations had an observed failure (Table IX). The average time of the observed failures was 2.7 years with only 3.1 years when a CMR was censored. Longer observation periods or recalling patients to verify survival of the CMR could lead to a potentially higher survival rate. Second, the severity and extent of the defective crown margins were not observed. The severity of the defective margin would likely be a contributing factor in the longevity of a CMR. This

would be useful in making clinical decisions to repair or replace. Identifying CDT-coded surfaces would give some insight to this question; however, the number of recorded surfaces does not indicate the axial depth of the caries defect. Recording this measurement would be done most accurately by using a prospective study design. Third, follow-up visits to observe restoration survival were not specifically planned. This led to short follow-up intervals; moreover, in some cases, the last visit was the same day as the CMR (i.e., there was no subsequent follow-up examination).

Establishing a larger data set would strengthen the data on CMR longevity. This can be achieved by broadening search criteria to include more departments within the school or utilizing other EHR databases. Keywords that were identified in the manual review of treatment notes could expedite larger studies to identify true-positives in future queries.

SUMMARY AND CONCLUSIONS

In this retrospective study of EDR data, CMRs demonstrated a 5-year survival of 62.9 percent and an annual failure rate of 8.9 percent. There were no differences in CMR survival based on tooth type or location (anterior/posterior; maxillary/mandibular), or patient age or gender. It is reasonable to assume that CMRs extend the functional life of crowns and should be considered as a valid treatment option to restore defective crown margins. Information gained in this study should be considered by dentists and patients when planning treatment for crowns with defective margins, as well as by others such as insurers, government officials, legislators and administrators of community clinics to facilitate discussions of cost effectiveness and clinical outcomes.[53]

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ABSTRACT

LONGEVITY OF CROWN MARGIN REPAIRS USING GLASS IONOMER: A RETROSPECTIVE STUDY

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Objectives: Repair of crown margins may extend the functional life of existing crowns. However, the longevity of such treatment is unknown. This study determined the survival time of crown margin repairs (CMR) with glass-ionomer (GI) and resin-modified glass-ionomer cements.

Methods: We queried axiUm (Exan Group, Coquitlam, BC, Canada) database for permanent teeth that underwent CMR in the Graduate Operative Dentistry Clinic, Indiana University School of Dentistry (IUSD), Indianapolis, Ind., USA, from January 1, 2006 through January 1, 2018. Since there is no CDT code for the CMR procedure, CDT codes for resin-composite and GI restorations (D23XX) were queried; these patients also had treatment notes that indicated CMR. The final data set included patient ID, birth date,

gender, dates of treatments, CDT codes, tooth type, tooth surface and existing findings. Two examiners developed guidelines for record review and manually reviewed the clinical notes of patient records to confirm CMR. Only records that were confirmed with the presence of CMR were retained in the final dataset for survival analysis. Survival time was calculated by Kaplan-Meier statistics and a Cox Proportional Hazards model was performed to assess the influence of selected variables ($p < 0.05$).

Results: 214 teeth (115 patients) with CMR were evaluated. Patient average age was 69.4 ± 11.7 years old. Posterior teeth accounted for 78.5 percent (n = 168) of teeth treated. CMRs using GI had a projected 5-year survival rate of 62.9 percent (K-M Analysis) and an 8.9 percent annual failure rate. Cox Proportional Hazards Regression analysis revealed that none of the factors examined (age, gender, tooth type) affected time to failure.

Conclusion: CMRs may extend the longevity of crowns with defective margins. Larger EHR studies or case control studies are needed to investigate other variables, such as the caries risk status or the severity of defects that may affect the survival rate of CMRs.

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