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Clinical Research

Minimal Invasive Treatment for Defective Restorations: Five-Year Results Using Sealants

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Clinical Relevance

Improvement of the marginal seal of restoration defects is a conservative approach that may improve their quality over time. Minimally invasive treatments of defective restorations showed similar outcome to replaced restorations after five years.

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SUMMARY

Replacement of dental restorations has been the traditional treatment for restorations that are defective. In this five-year randomized clinical trial, restorations with localized marginal defects were treated with sealants.

Thirty-two patients (mean age, 26.8 years) with 126 Class I and Class II restorations with defective margins (amalgam n=69 and resin-based composite n=57) were recruited. Treatment was seal with pit and fissure sealant on localized marginal defects (group A: n=43) and was compared with total restoration replacement (group B: n=40) and untreated restorations (group C: n=43) as negative and positive controls. Restorations were assessed by two examiners using the modified US Public Health Service criteria, observing five clinical parameters: marginal adaptation, roughness, marginal stain, teeth sensitivity, and secondary caries at baseline and at five years after treatment.

At the five-year recall examination, 23 patients with 90 restorations (71.4% recall rate) were examined. A significant improvement was observed in the marginal adaptation of the restorations in group A compared with group B. None of the treated group showed trends to downgrade in any parameter. Tooth sensitivity and secondary caries showed a low frequency in all groups. No significant difference in marginal adaptation of the restorations was found between amalgam and resin-based composite restorations (p=0.191). This study demonstrated that marginal sealing of restorations is a minimally invasive treatment that may be used instead of the replacement of restorations with localized marginal defects.

INTRODUCTION

Dental restorations may demonstrate degradation in the intraoral environment over time, and the principal reasons for deterioration are marginal deficiencies, fracture, and wear, possibly leading to secondary caries and/or tooth sensitivity.[1–3] Traditionally, those failures have led to complete replacement of the restorations, including in the presence of minor imperfections. Restoration replacement represents a major concern in dental practice, reaching up to 60% of general dentistry interventions.[4]

In recent times, with more insight into cariology, tooth longevity, dental biology, and dental materials science, a minimally invasive philosophy has prevailed, and the advantages of repairing rather than replacing restorations have been progressively emphasized.[5–11]

Complete restoration replacement has the disadvantages of being time-consuming, leading to unnecessary removal of healthy tooth tissue, including in areas away from the localized defects. Unnecessary removal of sound tooth tissue may result in enlarged preparation and restoration size, which could alter the proposed treatment plan and possibly result in irreversible injuries to pulp tissues.[7,8,12–15]

During recent years, new strategies such as repair and refinishing or sealing of localized defects have shown an overall improvement in the clinical properties of defective restorations, thereby increasing their longevity through minimal intervention.[9,15–17] Whenever possible, repair of restorations can be more cost-effective and acceptable to patients than restoration replacement. Because it preserves tooth structure, it has the potential to allow patients to retain most of their teeth during their lifetime.[18] In addition, the clinical results of these combined studies have changed education in operative dentistry as repair of restorations is routinely taught in most dental schools.[10,19–21]

The aim of this randomized clinical trial was to assess sealed defects at the margins of Class I and Class II amalgam and resin-based composite (RBC) restorations and to follow-up the results after five years. The hypothesis to be tested was that after five years, sealing the defects at the margins would show similar performance as restorations that were replaced.

METHODS AND MATERIALS

Thirty-two patients (19 female and 13 male; mean age, 26.8 years) with 126 Class I (n=94) and Class II (n=32) amalgam (n=69) and RBC (n=57) restorations with defective margins participated in the study. The experimental treatment group was the application of a pit and fissure sealant on localized defects in the margins of restorations (group A: n=43). The comparison groups were total restoration replacement (group B: n=40) and untreated restorations (group C: n=43), serving as negative and positive controls. Restorations were assessed using the modified US Public Health Service criteria (Table 1) observing five parameters: marginal adaptation, roughness, marginal stain, tooth sensitivity, and secondary caries by two examiners (E.F., J.M.).

Inclusion Criteria

The inclusion criteria were: 1) patients with amalgam (Am) and RBC restorations with marginal deficiencies that were judged to be suitable for sealing, 2) older than 18 years of age, 3) having more than 20 teeth in their mouth, and 4) being able to sign the consent form. In addition, the restorations had to be in functional occlusion with an opposing natural tooth and have at least one proximal contact area with an adjacent tooth.

Exclusion Criteria

The exclusion criteria were: 1) contraindications for regular dental treatment based on their medical history, 2) special esthetic requirements that could not be solved by this alternative treatment, 3) xerostomia or taking medication that significantly decreased salivary flow, 4) high caries risk, or 5) psychiatric or physical diseases that interfered with oral hygiene.

Table 1: *US Public Health Service/Ryge Clinical Criteria*[20]

Clinical Characteristic	Alpha	Bravo	Charlie
Marginal adaptation	Explorer does not catch when drawn across the restoration-tooth interface	Explorer falls into crevice or has one-way catch when drawn across the restoration-tooth interface	Dentin or base is exposed
Surface roughness	The surface of restoration has no surface defects	The surface of restoration has minimal surface defects	The surface of restoration has severe surface defects
Secondary caries	There is no clinical diagnosis of caries	N/A	Clinical diagnosis of caries
Marginal stain	There is no discoloration between the restorations and tooth	There is discoloration on less than half of the circumferential margin	There is discoloration on more than half of the circumferential margin
Teeth sensitivity	No sensitivity when an air syringe is activated for two seconds at a distance of half an inch from the restoration with the facial surface of the proximal tooth covered with gauze	Sensitivity is present when an air syringe is activated for two seconds at a distance of half an inch from the restoration with the facial surface of the proximal tooth covered with gauze and ceases when the stimulus is removed	Sensitivity is present when an air syringe is activated for two seconds at a distance of half an inch from the restoration with the facial surface of the proximal tooth covered with gauze and sensitivity does not cease when the stimulus is removed

Sample Size Determination and Randomization

Sample size was determined *a priori* using G*Power 2,[22] with an error probability of $\alpha=0.05$, effect size 0.3, and power ("β-1 error probability) of 0.80. The restorations with marginal defects (Bravo) were randomly assigned (performed by PASS software version 2004, Keysville, UT, USA) to one of three groups of treatment: A, sealing of margins (n=43); B, replacement (n=40); and C, untreated (n=43).

The Institutional Research Board and Ethical Board of the Dental School at the University of Chile approved the study (project PRI-ODO-0207). Only faculty members were allowed to provide the restorative treatment, and all patients signed inform consent forms and completed a registration form.

Caries Risk Assessment

A graphical computed program (Cariogram) was used to assess individual patients' caries risk; the program weighted the interaction between the following 10 caries-related factors: caries experience, related general disease, diet contents, diet frequency, plaque amount by Silness Löe Index, semiquantitative detection of mutans streptococci and lactobacilli in saliva by caries risk test (CRT) bacteria (Ivoclar, Vivadent AG, Schaan, Lichtenstein), fluoride program, amount of saliva stimulated secretion by CRT buffer (Vivadent), saliva buffer capacity, and clinical judgment. Patients were classified as high, intermediate, and low caries risk. In addition, the results also indicated where targeted actions to improve the situation would have the best effect.[23]

Restoration Assessment

The quality of the restorations was evaluated using the modified US Public Health System/Ryge criteria (Table 1).[24] Two examiners (J.M. and E.F.) assessed the restorations independently and by visual (mouth mirror number 5, Hu Friedy Mfg Co Inc, Chicago, IL, USA) and tactile examination using an explorer (N° 23 Hu Friedy) and indirectly by radiographic (Sirona Heliodent Vario, Charlotte, NC, USA) examination (Bite Wing, DF57, Kodak Dental System Healthcare, Rochester, NY, USA). All the restorations were examined at baseline and each year up to five years. The five parameters used in the examination were marginal adaptation, roughness, secondary caries, marginal stain, and tooth sensitivity (Table 1). If any difference was recorded between the two examiners and an agreement could not be reached, a third clinician (G.M.) was called to assist with the decision process. If the three clinicians did not reach an agreement, the lower score was recorded. All three clinicians participated in calibration exercises at the beginning and before the last examination took place, and the interexaminer reliability results were

Kappa=0.74 at the baseline and Kappa=0.87 at the fifth year.

A change from Bravo to Alpha was considered an improvement, and a change from Alpha to Bravo was considered deterioration.

Treatment Groups

A. Sealing of margins: Defective areas were acid etched with 35% phosphoric acid for 15 seconds. A resin-based sealant (Clinpro Sealant, 3M ESPE) was applied over the defective area. The sealant was polymerized with a photocuring unit (Curing Light 2500, 3M ESPE) for 40 seconds. Rubber dam isolation was used for this procedure. All treatments were provided by the same clinician (G.M.).
B. Replacement group: The defective restoration was totally removed and replaced with either a new amalgam (Tytin, Kerr Corporation, Orange, CA, USA) or RBC restoration (Filtek Supreme, 3M ESPE). Rubber dam isolation was used for this procedure. All treatments were provided by the same clinician (J.E.).
C. Untreated group: The defective restorations did not receive any treatment.

Patients were recalled each year for five years for clinical evaluation by the same examiners, using the same criteria as used at baseline.

Failed restorations were removed from the study and treated according to their diagnosed needs.

Digital photographs and bitewing radiographs were taken for all the restorations before and after treatment and every year prior to the examination.

Statistical Analysis

Wilcoxon test was used to compare the preoperative and postoperative conditions at the fifth year, and the Kruskal-Wallis test and Mann-Whitney post hoc tests were used for comparisons among groups at the error probability of α=0.05 (SPSS version 15.0, SPSS Inc, Chicago, IL, USA).

RESULTS

Twenty-three patients (14 female, 9 male) with 90 amalgam (n=53, 43-Class I and 10-Class II), and resin based composite (n=37, 34-Class I and 3-Class II) restorations distributed in three groups (group A: n=37; group B: n=23; group C: n=30) were evaluated every year and up to five years. The study had an overall attrition rate of 28.6% (5.7% per year), with nine patients with 36 restorations who were unable to be contacted.

When comparing the baseline assessment of restorations with the results after five years (Figure 1), group A showed a statistically significant improvement in marginal adaptation (p=0.0001). No significant difference was found for tooth sensitivity and secondary caries. In contrast, a significant downgrade was observed for surface roughness and marginal staining (p=0.0001 and p=0.005, respectively).

The results for Group B (Figure 2) after 5 years showed a significant improvement (p=0.022) for marginal adaptation, with secondary caries being less prevalent (p=0.008). No significant differences could be seen for marginal stain, roughness, and sensitivity.

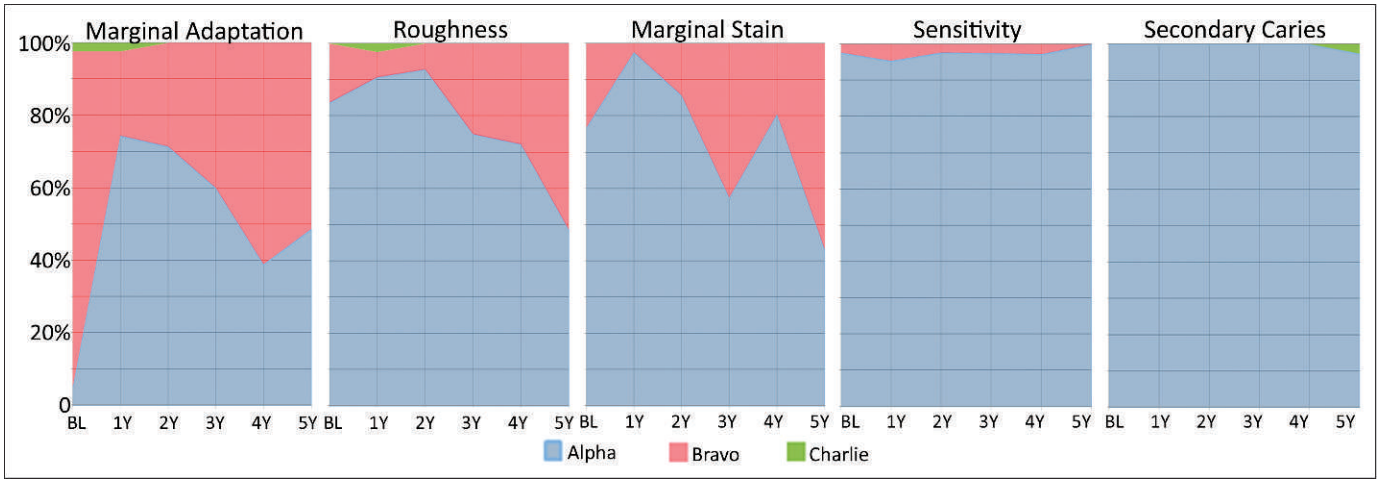

Figure 1. *Yearly summary results from group A according to the US Public Health Service/Ryge scores for each clinical parameter. BL = baseline; 1Y-5Y observation periods.*

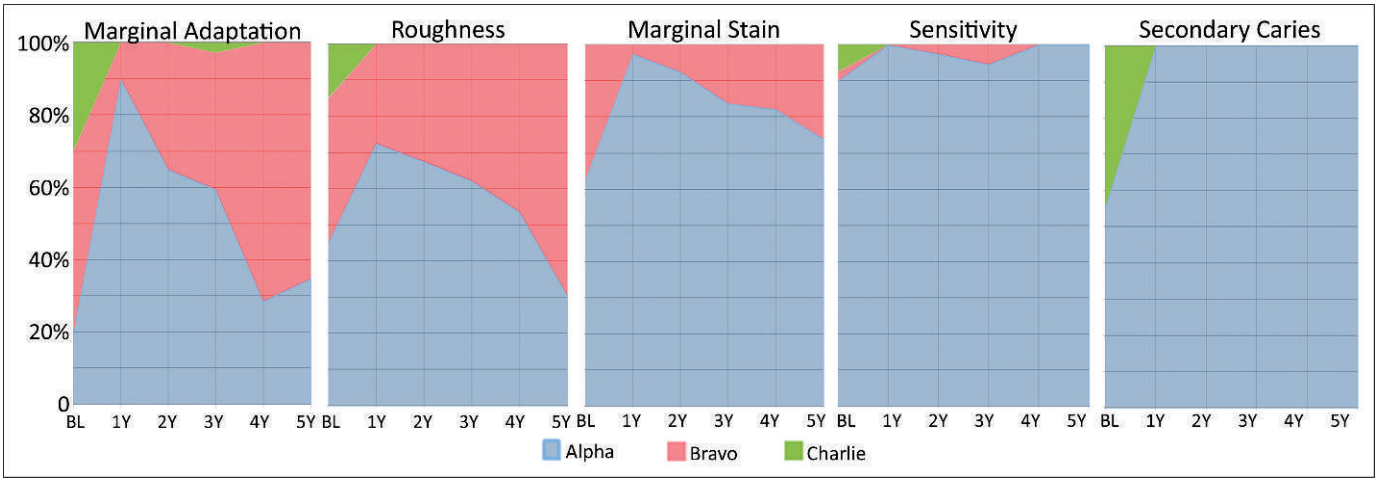

Figure 2. *Yearly summary results from group B according to the US Public Health Service/Ryge scores for each clinical parameter. BL = baseline; 1Y-5Y observation periods.*

Group C (Figure 3) presented a significant downgrade in marginal adaptation (p=0.02), roughness (p=0.001), and marginal stain (p=0.001), with no differences between the two restoration materials (p=0.130). No changes were observed for sensitivity and secondary caries after the fifth-year examination (p=1.00 for both).

No significant differences were observed between groups A and B (p=0.658) for all the clinical parameters observed (Figure 4). However, both groups showed significantly improved results for marginal adaptation when compared with group C (p=0.0001).

The comparison between groups in marginal staining showed a downgrade in group A and the same in group C (p=0.189). Group B compared with group A and C showed an upgrade in the period (p=0.001). No significant differences were observed between the three groups (p=0.073), but all groups showed downgrades. In the secondary caries parameter, the only group that showed changes was group B, with an upgrade statistically better than group A and C (p=0.000 and p=0.001; Figure 4).

No significant difference was found between amalgam and RBC restorations for any of the groups.

DISCUSSION

The management of composite or amalgam restoration with localized defects is a common challenge in clinical practice. Some restorations may certainly require replacement, while others may be given

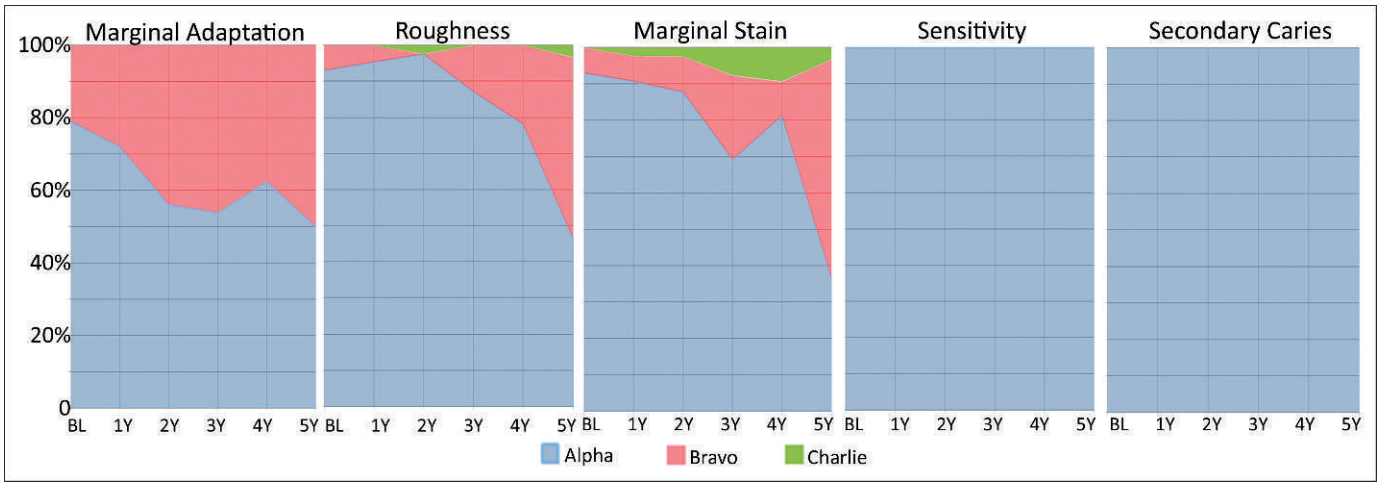

Figure 3. *Yearly summary results from group C according to the US Public Health Service/Ryge scores for each clinical parameter. BL = baseline; 1Y-5Y observation periods.*

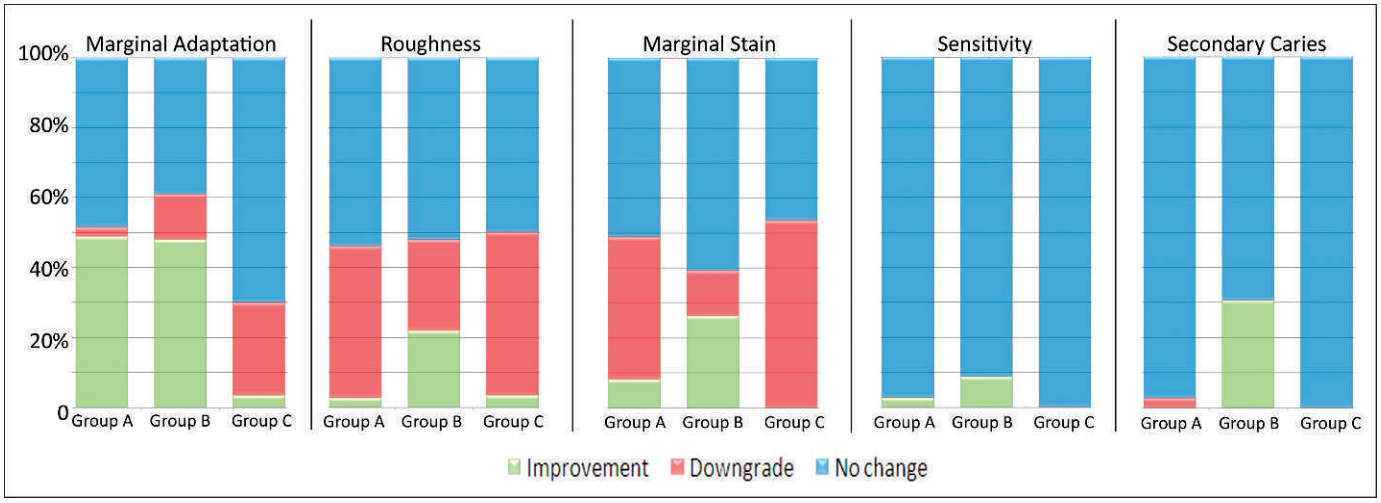

Figure 4. *Summary of the changes in US Public Health Service/Ryge scores between baseline and fifth-year evaluation (results expressed in percentages).*

extended longevity through the use of alternative procedures.[25,26]

A conservative approach to the management of defective restorations, if appropriate, has the potential to be less costly in terms of time and cost, less traumatic for patients, less likely to result in iatrogenic damage, possibly obviate the need for the use of local anesthesia and, more importantly, preserve tooth structure.[17,27] Furthermore, extended longevity of existing restorations may enhance patients' general health and satisfaction. Significant differences exist among dentists when deciding whether or not a restoration should be replaced.[28–33]

Although minimally invasive dentistry has been introduced in the dental curriculum, it has taken place only in recent years. Therefore, several dentists have not been trained on proper diagnosis and application of the minimally invasive procedures. McAndrew and others[34] concluded that it is possible to reduce examination time and provide convergence to a defined standard through a basic training program that can significantly influence the restoration replacement rate among general dental practitioners. In the dental school in Santiago, Chile, defined criteria are used by clinical students, and alternative methods to replacements are taught, including the repair of localized defects in restorations.

It is recognized that the chipping of margins of the restorations is an early sign of deterioration in clinical service, which tend to be restricted to a small part of the restoration, usually a short segment of the cavosurface margin.[35] Sealing with pit and fissure sealants, a minimally invasive procedure, will reduce the indication for replacement of the restoration.

The longevity of dental restorations mainly depends on the continuity of the interface between the restorative material and adjacent tooth tissue.[36] Some marginal defects may be sealed to increase the life of restorations.

The results of the present study showed that sealing defective margins had similar results to restoration replacement for marginal adaptation after five years. The benefit of this procedure is that it is prompt, minimally invasive to patients, and less involved than replacement for clinicians. In addition, if a sealant fails, it does not necessarily mean the presence of secondary caries, and therefore, the procedure could be repeated multiple times. In this study, only 5% of sealed restorations showed alpha value at baseline, increasing to 74% during the first year, followed by continuous margin deterioration during the next years, reaching 49% alpha value at the fifth year. The experimental and the control groups showed the same trend of downgrade of marginal adaptation over time. Amalgam and RBC restorations in marginal adaptation showed comparable annual failure rates, as shown by Manhart and others[1] in their prospective clinical studies. However, three other published studies reported better longevity of amalgam restorations compared with composite restorations.[37–39]

Despite the evident loss of restorative material at the margins of the existing restorations, observed by macroscopic clinical and photography detection, sealant was able to maintain the marginal integrity of both amalgam and RBC restorations, even though

no chemical bond occurred between amalgam and pit and fissure sealant.

At baseline, the experimental group presented an alpha score of 77% for the marginal stain parameter. After one year, it increased to 98%, but the next years showed deterioration, achieving 43% at the fifth year. Similarly, the control groups showed the same direction of downgrade, possibly because of the cavity design defects or traumatic occlusal forces that may have been inherited restoration factors were not modified.

Roughness was a parameter that presented improvement only for the replacement group during the first year (from 45% to 73% alpha value). After that, it showed constant deterioration, similar to the other groups. Logically, the sealant treatment was limited to the areas marginal to the restoration, not including other parts of the restoration. Thus, to improve roughness and the margins of the restoration, it is recommended that, in addition to sealing the margins, the surface of the restorations be polished to reduce development of surface roughness, which could potentially increase the adherence of plaque and biofilm to teeth and restorations.[26,40]

Tooth sensitivity showed a slight but not significant improvement in restorations that were sealed when compared with those that were not in the first year. Sensitivity gradually disappeared (100% alpha), and at the fourth and the fifth years, teeth showed no sensitivity. However, no significant differences could be observed among groups, and the limited sensitivity that was present was probably related to other preexisting conditions such as dentin exposure areas or reversible pulpitis.

Restorations with marginal defects without visible evidence of soft dental tissues on the wall or base of the restoration should be monitored, repaired, or sealed instead of replaced.[36] Alternative treatments are specially indicated for the highly dental-motivated patient who presents a good standard of oral health and seeks care regularly,[35] as it is important to consistently check that the sealants are present and functional. In addition, as in any planned procedure, it is important that the patient is completely informed of the advantages and possible disadvantages of the treatment.[35]

The low attrition rates in the current study (5.5% per year) are probably related to the fact that patients have regularly attended the Dental School.

An uncontrolled event of this study was related with the restorations of group C that belonged to the control group and had been previously placed by different and nonstandardized clinicians. Despite this fact, all groups showed a similar trend of restoration downgrade during the observation period.

The application of pit and fissure sealant has been considered a good preventive agent for use against the development and progression of pit and fissure caries.[41] Sealants have also been used to successfully arrest occlusal caries lesions.[42] The present study shows an improvement in marginal adaptation of defective restorations sealed with pit and fissure sealants after five years when compared with restorations that were not treated. It also shows similar results to restorations that were replaced, therefore questioning the need for replacement when sealant is a viable option of treatment.

CONCLUSIONS

The application of a resin sealant at the margin of a defective restoration presented similar marginal adaptation results as restoration replacement after five years. The sealing of defective margins of Class I and II amalgam and RBC restorations is a viable alternative to the replacement of restorations. It increases the restoration longevity with minimal intervention, cost, and trauma to the adjacent tooth structures.

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Conflict of Interest

The authors of this article certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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REFERENCES

1. Manhart J, Chen H, Hamm G, Hickel R (2004) Buonocore Memorial Lecture. Review of the clinical survival of direct and indirect restorations in posterior teeth of the permanent dentition *Operative Dentistry* **29(5)** 481-508.
2. Mjor IA, Moorhead JE, Dahl JE (2000) Reasons for replacement of restorations in permanent teeth in general dental practice *International Dental Journal* **50(6)** 361-366.
3. Hickel R, Manhart J (2001) Longevity of restorations in posterior teeth and reasons for failure *Journal of Adhesive Dentistry* **3(1)** 45-64.
4. Mjor IA (1989) Amalgam and composite resin restorations: longevity and reasons for replacement In: *International Symposium on Criteria for Placement and*

Replacement of Dental Restorations Lake Buena Vista, Fla.

5. Tyas MJ, Anusavice K, Frencken JE, Mount GJ (2000) Minimal intervention dentistry—a review. *International Dental Journal* **50** 1-12.
6. Mjor IA, Gordan VV (2002) Failure, repair, refurbishing and longevity of restorations *Operative Dentistry* **27(5)** 528-534.
7. Gordan VV, Shen C, Mjor IA (2004) Marginal gap repair with flowable resin-based composites *General Dentistry* **52(5)** 390-394.
8. Gordan VV (2001) Clinical evaluation of replacement of class V resin based composite restorations. *Journal of Dentistry* **29(7)** 485-488.
9. Gordan VV, Garvan CW, Blaser PK, Mondragon E, Mjor IA (2009) A long-term evaluation of alternative treatments to replacement of resin-based composite restorations: results of a seven-year study *Journal of the American Dental Association* **140(12)** 1476-1484.
10. Gordan VV, Mjor IA, Blum IR, Wilson N (2003) Teaching students the repair of resin-based composite restorations: a survey of North American dental schools *Journal of the American Dental Association* **134(3)** 317-323.
11. Gordan VV, Riley JL, Blaser PK, Mondragon E, Garvan CW, Mjor IA (2011) Alternative treatments to replacement of defective amalgam restorations: results of a seven-year clinical study *Journal of the American Dental Association* **142(7)** 842-849.
12. Brantley CF, Bader JD, Shugars DA, Nesbit SP (1995) Does the cycle of rerestoration lead to larger restorations? *Journal of the American Dental Association* **126(10)** 1407-1413.
13. Mjor IA (2009) Dentin permeability: the basis for understanding pulp reactions and adhesive technology *Brazilian Dental Journal* **20(1)** 3-16.
14. Mjor IA (1981) Placement and replacement of restorations *Operative Dentistry* **6(2)** 49-54.
15. Fernandez E, Martín J, Angel P, Mjor IA, Gordan VV, Moncada G (2011) Survival rate of sealed, refurbished and repaired defective restorations: 4-year follow-up *Brazilian Dental Journal* **22(2)** 134-139.
16. Moncada G, Martín J, Fernandez E, Hempel MC, Mjor IA, Gordan VV (2009) Sealing, refurbishment and repair of Class I and Class II defective restorations: a three-year clinical trial. *Journal of the American Dental Association* **140(4)** 425-432.
17. Mjor IA (1993) Repair versus replacement of failed restorations *International Dental Journal* **43(5)** 466-472.
18. Setcos JC, Khosravi R, Wilson NH, Shen C, Yang M, Mjor IA (2004) Repair or replacement of amalgam restorations: decisions at a USA and a UK dental school. *Operative Dentistry* **29(4)** 392-397.
19. Blum IR, Lynch CD, Schriever A, Heidemann D, Wilson NH (2011) Repair versus replacement of defective composite restorations in dental schools in Germany. *European Journal of Prosthodontics and Restorative Dentistry* **19(2)** 56-61.
20. Blum IR, Lynch CD, Wilson NHF (2012) Teaching of direct composite restoration repair in undergraduate dental schools in the United Kingdom and Ireland. *European Journal of Dental Education* **16(1)** 53-58.
21. Blum IR, Lynch CD, Wilson NHF (2012) Teaching of the repair of defective composite restorations in Scandinavian dental schools. *Journal of Oral Rehabilitation* **39(3)** 210-216.
22. Erdfelder E, Faul F, Buchner A (1996) GPOWER: a general power analysis program *Behavior Research Methods, Instruments & Computers* **28(1)** 1-11.
23. Bratthall D, Hänsel Petersson G (2005) Cariogram—a multifactorial risk assessment model for a multifactorial disease *Community Dentistry and Oral Epidemiology* **33(4)** 256-264.
24. Ryge G (1980) Clinical criteria *International Dental Journal* **30(4)** 347-358.
25. Sarrett DC (2005) Clinical challenges and the relevance of materials testing for posterior composite restorations *Dental Materials* **21(1)** 9-20.
26. Moncada G, Fernandez E, Martín J, Arancibia C, Mjor IA, Gordan VV (2008) Increasing the longevity of restorations by minimal intervention: a two-year clinical trial. *Operative Dentistry* **33(3)** 258-264.
27. Frankenberger R, Roth S, Kramer N, Pelka M, Petschelt A (2003) Effect of preparation mode on Class II resin composite repair *Journal of Oral Rehabilitation* **30(6)** 559-564.
28. Bader JD, Shugars DA (1993) Agreement among dentists' recommendations for restorative treatment. *Journal of Dental Research* **72(5)** 891-896.
29. Mjor IA, Toffenetti F (1992) Placement and replacement of amalgam restorations in Italy *Operative Dentistry* **17(2)** 70-73.
30. Tveit AB, Espelid I (1992) Class II amalgams: interobserver variations in replacement decisions and diagnosis of caries and crevices *International Dental Journal* **42(1)** 12-18.
31. Maryniuk GA (1990) Replacement of amalgam restorations that have marginal defects: variation and cost implications. *Quintessence International* **21(4)** 311-319.
32. Gordan VV, Riley III JL, Geraldeli S, Rindal DB, Qvist V, Fellows JL, Kellum HP, Gilbert GH; for The Dental Practice-Based Research Network Collaborative Group (2012) Repair or replacement of defective restorations by dentists in The Dental Practice-Based Research Network. *Journal of the American Dental Association* **143(6)** 593-601.
33. Gordan VV, Garvan CW, Richman JS, Fellows JL, Rindal DB, Qvist V, Heft MW, Williams OD, Gilbert GH, for The DPBRN Collaborative Group (2009) How dentists diagnose and treat defective restorations: evidence from The Dental Practice-based Research Network *Operative Dentistry* **34** 664-673b.
34. McAndrew R, Chadwick B, Treasure ET (2011) The influence of a short training program on the clinical examination of dental restorations *Operative Dentistry* **36(2)** 143-152.

35. Blum IR, Jagger DC, Wilson NH (2011) Defective dental restorations: to repair or not to repair? Part 1: direct composite restorations *Dental Update* **38(2)** 78–80, 82-84.

36. Dennison JB, Sarrett DC (2012) Prediction and diagnosis of clinical outcomes affecting restoration margins *Journal of Oral Rehabilitation* **39 (4)** 301-318.

37. Van Nieuwenhuysen JP, D'Hoore W, Carvalho J, Qvist V (2003) Long-term evaluation of extensive restorations in permanent teeth *Journal of Dentistry* **31(6)** 395-405.

38. Bernardo M, Luis H, Martin MD, Leroux BG, Rue T, Leitao J, DeRouen TA (2007) Survival and reasons for failure of amalgam versus composite posterior restorations placed in a randomized clinical trial *Journal of the American Dental Association* **138(6)** 775-783.

39. Soncini JA, Maserejian NN, Trachtenberg F, Tavares M, Hayes C (2007) The longevity of amalgam versus compomer/composite restorations in posterior primary and permanent teeth: findings From the New England Children's Amalgam Trial *Journal of the American Dental Association* **138(6)** 763-772.

40. Larson T (2011) Why do we polish? Part two. *Northwest Dentistry* **90(4)** 31-38.

41. Simonsen RJ (2011) From prevention to therapy: minimal intervention with sealants and resin restorative materials *Journal of Dentistry* **39(Supplement 2)** S27-S33.

42. Bakhshandeh A, Qvist V, Ekstrand KR (2012) Sealing occlusal caries lesions in adults referred for restorative treatment: 2–3 years of follow-up *Clinical Oral Investigations* **16(2)** 521-529.