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The Dental Amalgam Phasedown in New Zealand: A 20-year Trend

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Clinical Relevance

This research reports how amalgam has reached the verge of elimination from clinical service in New Zealand's dental education system. New Zealand's national school of dentistry is prepared for New Zealand's expected ratification of the Minamata Convention on Mercury.

SUMMARY

Background and Objectives: Information on the choice of material and performance of restorations placed in a dental practice annually is limited. The Minamata Convention on Mercury is likely to affect the use of amalgam worldwide. The objective of this research was to investigate the use of restorative materials at the University of Otago Faculty of Dentistry in New Zealand from 1998 to 2017.

Methods: Data from the Faculty of Dentistry's database from the years of interest were compiled. These data included information on the characteristics of restorations, including information on the material used and number of surfaces involved for each restoration. The tooth in which each restoration was placed was categorized by arch, tooth type, and deciduous or permanent dentition.

Results: Records identified 227,514 permanent restorations placed from January 1998 to December 2017, of which 91.7% were direct restorations. Among direct restorations, composite resin was the most commonly used material, followed by amalgam, glass ionomer, and compomer. The use of amalgam for direct restorations decreased from 52.3% of direct restorations in 1998 to 7.1% in 2017. A corresponding increase was observed in the use of tooth-colored direct restorations, particularly composites. Among indirect restorations, porcelain fused to metal, gold, and stainless steel

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(in pediatric applications) were the materials most frequently used.

Conclusions: Despite having no official policy on reducing the use of dental amalgam, the Faculty of Dentistry is following the global trend in reducing its use, with composite resin now well established as the predominant restorative material used. If the current rate of decline persists unchecked, the Faculty of Dentistry could transition to being amalgam free by 2020, although it seems likely that the characteristics and principles of use of the material (and its removal) will be taught for some time to come. This knowledge is important to planning curriculum changes needed to prepare graduates for clinical practice.

INTRODUCTION

The annual cost of dental care in New Zealand was estimated at $1.1 billion in 2008 (New Zealand Ministry of Health, personal communication, April 15, 2011) and is attributable mostly to the placement and maintenance of dental restorations. The materials used for these dental restorations vary in their range of characteristics, including biocompatibility, longevity, aesthetics, and cost. Despite the important differences among these dental restorative materials, few data have been reported on changing practitioner and patient preferences regarding their use in New Zealand. There is a lack of published information on how many restorations are placed annually in a typical dental practice and what materials are typically used.

Historically, dental amalgam was the material of choice in restorative dentistry worldwide. The use of alternative dental materials was limited by a lack of satisfactory options. Early tooth-coloured restorations were not considered to be as reliable as amalgam, with 10-year failure rates reported as high as 50%.[1] Modern tooth-colored restorations have improved reliability, and clinical experience suggests that amalgam is now giving way to alternatives, but data are lacking on the extent to which these changes have occurred. Many New Zealand dental practices have chosen to become amalgam free and advertise as such, while others continue to use amalgam in a wide range of clinical applications.

A limited number of international studies have reported on changes in the use of dental restorative materials over time. A British study reported on changes at the University College Cork when their dental faculty was in the process of change from dental amalgam to composites as the material of first choice. The investigators noted a substantial shift toward the use of composites in place of amalgam,[2] but since they were making an active transition, this finding is unsurprising. Evidence is lacking on what changes are happening in wider dental practice where an active transition has not been implemented.

New Zealand's signing of the Minamata Convention on Mercury in October 2013 has the potential to substantially affect the use of amalgam in dentistry in this country. New Zealand's eventual ratification of the convention will require dentists (and the dental education system) to take steps to reduce population exposure to mercury. These steps include requirements to

1) set national objectives aiming at dental caries prevention and health promotion, thereby minimizing the need for dental restoration;
2) set national objectives aiming at minimizing use of dental amalgam;
3) promote the use of cost effective and clinically effective mercury-free alternatives for dental restoration;
4) promote research and development of quality mercury-free materials for dental restoration;
5) encourage representative professional organizations and dental schools to educate and train dental professionals and students on the use of mercury-free dental restoration alternatives and on promoting best management practices;
6) discourage insurance policies and programs that favor dental amalgam use over mercury-free dental restoration;
7) encourage insurance policies and programs that favor the use of quality alternatives to dental amalgam for dental restoration;
8) restrict the use of dental amalgam to its encapsulated form; and
9) promote the use of best environmental practices in dental facilities to reduce releases of mercury and mercury compounds to water and land.

Concerns about environmental effects of mercury (as indicated in the Minimata Convention on Mercury), combined with the increasing availability of products with qualities that surpass dental amalgam in most respects, mean it is very likely that dental amalgam will be phased out of use in the foreseeable future. Indeed, the phasedown of the use of dental amalgam as part of the Minimata Convention on Mercury is one of the five main projects of the

World Health Organization's Oral Health Workplan 2018-2020. The World Health Organization intends to provide assistance to low-income countries to accelerate their phasedowns of amalgam use over the timeline of April 2018 to December 2023.

The aim of this research was to identify whether patterns changed in the use of dental amalgam relative to other dental materials during the period 1998-2017 at New Zealand's only dental faculty and to compare this with available data from private clinical dental practice. The authors hypothesized that the use of amalgam would have decreased considerably in favor of tooth-colored alternatives, even in the absence of an active effort to reduce the use of amalgam. This research was conducted to inform possible teaching and curriculum changes at the faculty and to promote debate on the how the New Zealand dental profession should prepare for the imminent amalgam-free future of dentistry.

METHODS

Data on restorations placed at the University of Otago Faculty of Dentistry were obtained by extracting this information from the faculty's database (Titanium, Spark Dental Ltd, Auckland, New Zealand). Data were managed and analysed in Intercooled Stata 15.1 (Statacorp LP, College Station, TX, USA). Data on nonrestorative procedures were not included in analyses. Restorations with a valid recorded date of completion between January 1998 and December 31, 2017 were included.

Information on the material used for each restoration was categorized based on the service code recorded for each restoration. Where recording was ambiguous and it was not possible to ascertain the material used, the restoration was included in counts of total number of restorations but excluded from the specific restoration material category. Restorations of unknown material types are reported in summary data and totals. All temporary restorations were excluded from analyses. Where glass ionomer cement restorations were not coded as temporary restorations, they were included in analyses of glass ionomer cement restorations. Inlay, onlay, veneer, and crown restorations were included, but restorations involving tooth replacement (such as fixed partial dentures bridges and implant crowns) were excluded.

The number of surfaces involved in a given restoration was categorized based on the restoration surface code. Student year of study was categorized; analyses of student output were restricted to the years of undergraduate study to avoid misclassification of work completed by individuals returning to the faculty for postgraduate study or as staff. Teeth were categorized by arch, tooth type, and dentition (permanent vs deciduous). Where data were missing on the specific tooth that had been restored, those restorations were excluded from the analyses.

As part of a survey of dentists conducted in New Zealand during 2016, we included some questions on their use of dental materials. The survey sample included 353 New Zealand oral health practitioners (65.7% dentists and the remainder allied oral health practitioners) and methods used for that research have been described previously.[3] As part of the questionnaire, participants were asked to estimate the percentage of restorations they had placed during the past year using a range of restorative materials (composite, amalgam, glass ionomer cement, ceramic, other) and to rank their relative preference for restorative material to work with. These data were contrasted with faculty results for 2016 to provide wider context of the use of dental materials in New Zealand dental practice.

RESULTS

Records were available for 311,306 restorations placed from 1998 to 2017. This number included 83,792 temporary restorations, leaving a total of 227,514 permanent restorations, of which 91.7% were direct and the remainder indirect. Most indirect restorations were gold (of which over 90% were crowns and the remainder inlays or onlays), stainless steel (deciduous) crowns, and porcelain-fused-to-metal crowns, as well as a number of cast core restorations and all-ceramic crowns (Table 1). During the 20 years, over half of direct restorations were placed using composite resin, while amalgam was used for just under a third, while the remainder included glass ionomer cement, compomer, nonmetallic materials of unspecified type and unspecified materials. Wide differences in the use of dental materials were observed over time. The use of amalgam for dental restorations became less common, decreasing from over half of direct restorations placed in 1998 to fewer than one in 10 restorations placed in 2017 (Figure 1).

Respondents to the survey of New Zealand dental practitioners estimated that an average of 14.5% of direct restorations they had placed within the previous year were amalgam (Figure 1). Among dentists (n=158), 63.5% rated composite as their most preferred restorative material, while amalgam was favored by 12.6%. Among dental therapists

Table 1: *Restorations Placed by Material Type by Year as a Percentage of Total Restorations Placed per Year*

Year	% of Total Direct Restorations						
	Amalgam	Composite	Glass Ionomer Cement[a]	Compomer[b]	Nonspecific Material	Nonspecific Nonmetallic	Total Number of Direct
1998	52.3	47.5	0.0	0.0	0.2	0.0	**9760**
1999	48.3	50.8	0.0	0.6	0.3	0.0	**9911**
2000	47.4	51.1	1.0	0.3	0.3	0.0	**10,725**
2001	43.0	47.7	8.5	0.6	0.3	0.0	**11,744**
2002	39.3	44.1	13.1	1.1	2.3	0.1	**11,471**
2003	36.2	41.8	17.4	1.1	2.9	0.6	**10,607**
2004	34.3	38.7	15.1	0.9	7.4	3.7	**10,232**
2005	36.4	38.5	13.9	0.5	6.5	4.3	**11,173**
2006	34.5	45.9	13.3	2.7	0.2	3.4	**10,564**
2007	33.4	48.0	12.6	2.4	0.6	3.0	**10,020**
2008	30.4	51.0	12.7	3.2	0.0	2.7	**10,957**
2009	30.1	52.3	12.8	2.2	0.0	2.7	**10,358**
2010	26.7	55.6	13.0	2.1	0.0	2.7	**11,218**
2011	28.2	54.0	14.0	1.5	0.0	2.3	**10,030**
2012	24.2	56.3	15.0	2.4	0.0	2.1	**10,137**
2013	21.5	58.0	15.5	2.6	0.0	2.5	**10,838**
2014	16.5	61.4	15.4	3.3	0.2	3.2	**10,135**
2015	14.4	59.2	16.9	0.9	3.9	4.7	**10,122**
2016	11.7	63.8	16.4	0.1	3.8	4.3	**9286**
2017	7.6	67.9	16.1	0.0	4.1	4.4	**9376**

[a] *Prior to 2001 placement of glass ionomer cement restorations may not have always been recorded.*
[b] *After 2015, compomer restorations started to be coded as nonspecific material restorations and are recorded as a "nonspecific material." It is likely that these are compomer, but data are unavailable.*

(n=70), composite was most preferred by 31.4% and amalgam by 15.7%.

The number of single surface composite resin restorations placed annually remained relatively constant through the 20-year period, but the number of 2- and 3+-surface restorations for which composite resin was used increased markedly. In particular, the latter increased from 10% of 3+-surface restorations in 1998 to 90% of those in 2017. By contrast, there was a decrease in the use of dental amalgam for direct restoration of all sizes (Figure 2).

Major changes were seen in the student learning experience in recent years. Prior to 2013, nearly every Bachelor of Dental Surgery (BDS) student placed at least one amalgam restoration on a patient during each year of study, and most had placed a complex (3+ surfaces) restoration. However, complex amalgam restorations were placed by only 19.5% of BDS3, 38.2% of BDS4, and 80.2% of BDS5 students during 2017, and a small number of students had gone through all years of education having placed amalgam only in a "simulation clinic" context without placing any amalgam restorations at all in a clinical setting (Figure 3). Within the BDS graduating class of 2017, an average of 77.6 restorations had been placed throughout their clinical education (BDS years 2-5); of those, an average of 7.8 were amalgam (10.1%), an average of 3.1 being complex 3+ surface amalgam restorations. On the other hand, among those in BDS5 during 2003, the average total number of restorations was 121.4; of those, an average of 53.3 were amalgam (43.9%), of which 20.0 were complex 3+ surface amalgam restorations. These differences were statistically significant ($p<0.0001$, Wilcoxon rank-sum test).

By tooth type, the greatest decline in the use of dental amalgam was in its use as a restorative material for deciduous teeth, dropping from over 80% in 1998 to 0% in 2017. Dental amalgam was used for over 80% of restorations in permanent molars in 1998, but this decreased to fewer than 20% in 2017 (Figure 4).

DISCUSSION

This descriptive study reports a marked decrease in the use of dental amalgam at New Zealand's only dental faculty over the 20-year period 1998-2017.

Table 1: *Restorations Placed by Material Type by Year as a Percentage of Total Restorations Placed per Year (ext.)*

Year	% of Total Indirect Restorations						
	Gold	Porcelain	Porcelain Fused to Metal	Belle Glass or Acrylic	Stainless Steel	Cast Core	Total Number of Indirect
1998	20.4	5.7	38.1	0.5	24.7	10.7	**778**
1999	16.9	4.3	34.8	1.5	36.5	6.1	**1007**
2000	19.3	4.8	27.9	0.9	39.2	8.0	**1019**
2001	16.8	3.6	32.2	1.8	37.6	8.1	**916**
2002	18.2	3.5	29.1	1.5	39.6	8.0	**1020**
2003	19.7	5.3	33.5	1.4	32.1	8.0	**865**
2004	21.2	3.0	38.5	0.8	26.9	9.7	**920**
2005	24.2	10.8	37.8	0.0	20.1	7.1	**986**
2006	25.1	9.1	41.4	0.0	18.4	6.0	**1048**
2007	28.4	6.8	39.7	0.1	17.7	7.4	**843**
2008	28.4	5.8	43.5	0.3	15.5	6.5	**904**
2009	28.9	9.4	46.2	0.0	10.6	4.9	**1251**
2010	27.2	6.2	38.3	0.0	22.8	5.6	**1307**
2011	27.4	7.1	30.3	0.0	30.2	5.1	**1015**
2012	27.3	5.1	37.2	0.0	26.8	3.6	**889**
2013	34.6	3.8	30.8	1.3	25.8	3.9	**955**
2014	37.2	9.0	29.0	0.1	22.0	2.7	**996**
2015	32.2	9.0	26.2	0.7	29.2	2.6	**832**
2016	31.1	8.3	24.8	0.0	33.0	2.9	**701**
2017	34.6	10.5	20.9	0.0	31.9	2.0	**598**

Although the total number of restorations placed per year remained relatively constant, the choice of dental material used, specifically amalgam, shifted markedly with the passage of time. The pace of increase in the use of composite resin appeared to be greater after 2005.

Before considering the implications of these findings, it is important to consider the relative strengths and limitations of this research. One limitation is the change in coding of dental restorations over time, affecting the comparability of data from 1998 to 2001 with the data from subsequent years; however, categories were similar and this is unlikely to have had any impact on the research findings. Another change in coding made surface-level data less accessible after 2015. Variation in the number of students (particularly those enrolled in postgraduate programs) and staff may have affected the service mix for certain years, and this has not been considered in this analysis. The period 2002-2005 featured a large number of restorations that were coded using identifiers from which it was not possible to identify the restorative material type used; these were mostly one- and two-surface restorations and were likely to have used composite or amalgam. Notwithstanding these limitations, the study has a number of strengths, chief of which is the fact that no similar information is available.

The scope of this study did not include survival rates of those restorations included in the analysis; details of techniques used, such as dental dam use, bonding system, curing protocols, and case selection; or the specific brands that had been used.

In the past, the choice of dental material was generally based on operator and patient preferences, which relate to factors such as an individual's caries risk, lesion size and location, and material-related factors such as strength, wear resistance, moisture tolerance, and stability. New Zealand's signing (and expected future ratification) of the Minamata Convention on Mercury will play an important role in this decision making in the future, hastening an existing global change within the dental profession, which, to date, has largely been in response to the growing evidence base for (and continuing clinical experience with) the use of composite resins.

It is important that dental education be informed by high-quality research and also consider the future environment in which graduates will practice. Crucial to this approach will be that new cohorts of dental students are taught considering both the

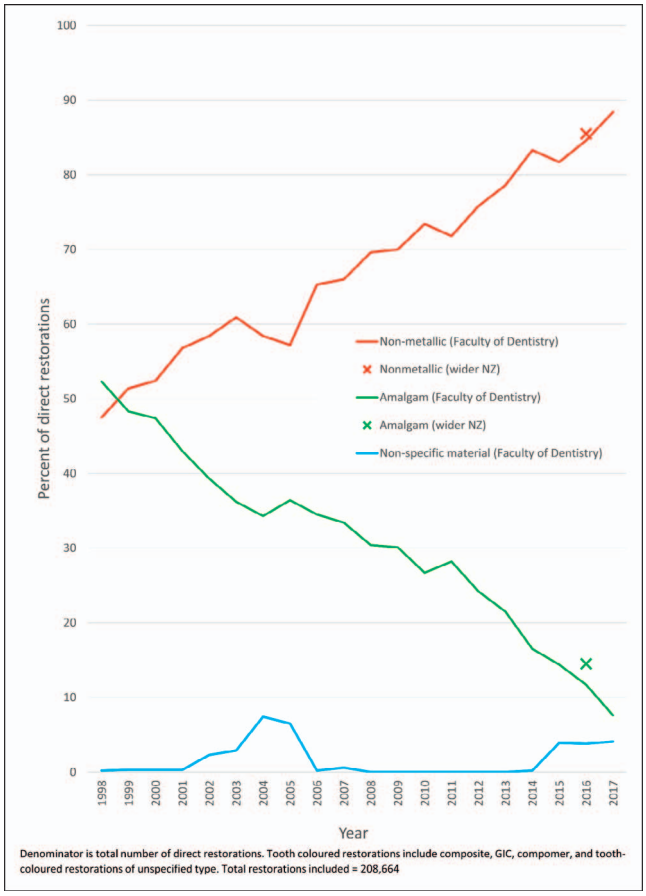

Figure 1. *Annual placement of direct restorations by material type.*

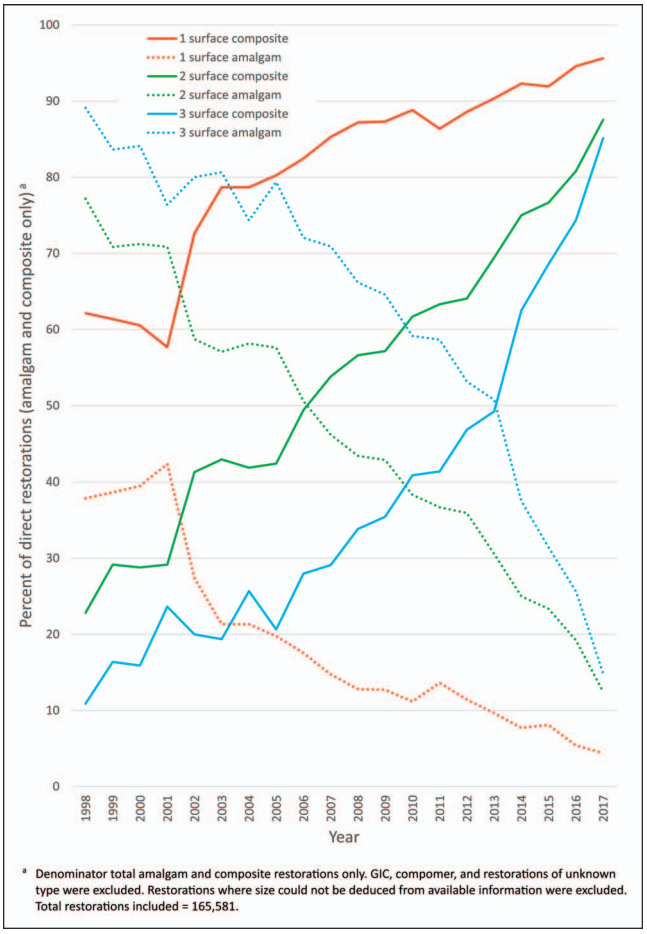

Figure 2. *Percent of restorations placed per year by material type and restoration size.*

obligations outlined in the Minamata Convention and the requirement for evidence-based clinical practice: theoretical teaching needs to be matched to clinical teaching. Based on a projection from the current decline in the use of dental amalgam (Figure 1), the material is unlikely to be used at all by the early 2020s. The teaching curriculum needs to be updated accordingly to enable teaching to adapt to this likely outcome.

Dental education can influence both material selection and the associated techniques used by future members of the dental profession. Experience suggests that some new dental graduates initially continue to use the materials and techniques with which they have become familiar and competent during their dental education. Moreover, the provision of continuing professional education courses by the faculty may affect material selection decisions by established practitioners. Such an approach should be informed by research into the contemporary material selection and techniques used by New Zealand dental practitioners.

Median survival times for amalgam restorations have been reported to be as long as 22.5 years,[4] meaning that amalgam restorations have historically been considered the benchmark by which to compare composite restorations. The use and clinical performance of composite resin restorations placed in posterior permanent teeth have improved greatly. Some consider that composite now performs better than amalgam. Although composite resin has many disadvantages—such as marginal staining and poorer wear strength, fracture resistance, and compressive strength than amalgam—it does have a number of important advantages. Cavity preparation for the restoration of a carious lesion with composite resin can be more conservative than with dental amalgam because mechanical retention does not need to be incorporated into the cavity design. This lowers the biological cost to the tooth. It also has superior esthetics and the ability to bond to both enamel and dentin (via a suitable adhesive system), thus sealing the tooth-restorative interface and reducing occlusal

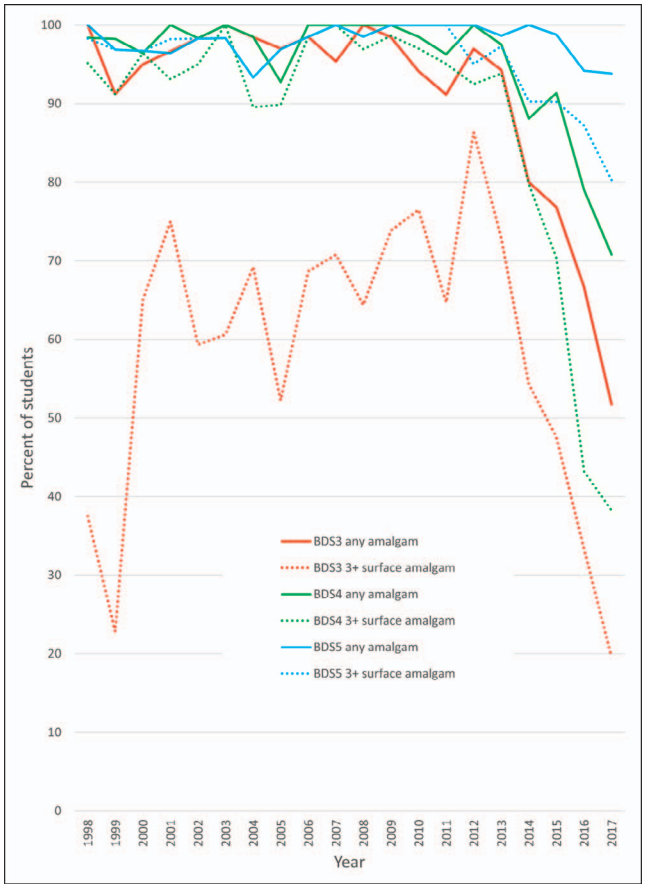

Figure 3. *Percent of students to have placed one or more amalgam restorations during each year of study. Solid lines = any; dotted lines = three+ surfaces.*

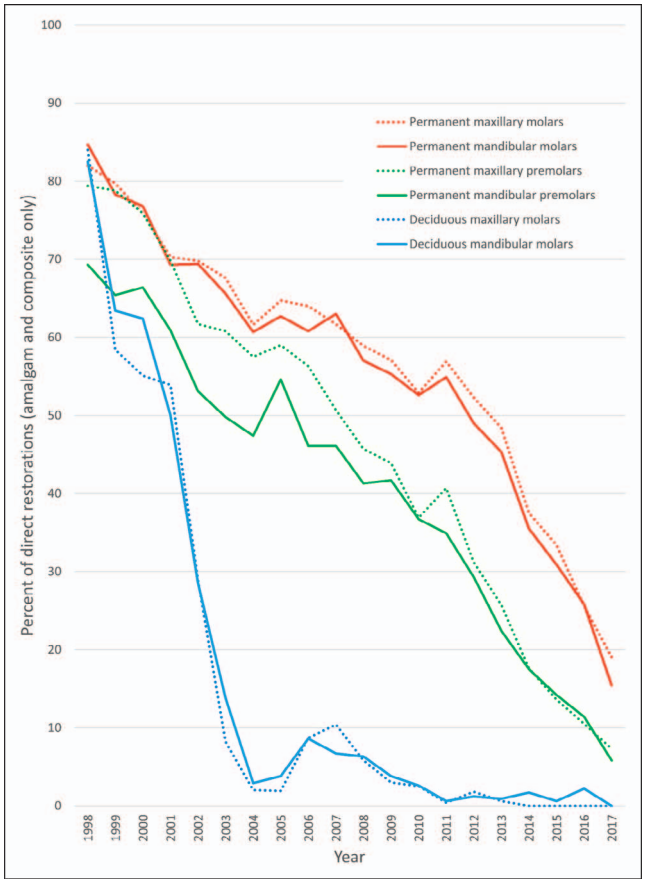

Figure 4. *Percent of restorations placed using amalgam per year by tooth type.*

stresses on both the composite resin and the restored tooth.[5] Although composite resin restorations may require more frequent repair,[6] the ability to successfully repair and/or refurbish a restoration avoids its complete removal and the associated further loss of tooth structure.

In deciduous teeth, short crown heights affect the retention of intracoronal restorations, as does a child's ability to cope with treatment. Preformed metal crowns show very high success rates, with greater longevity and lower rates of retreatment than amalgam restorations in primary molars.[7] They are of particular use in teeth that are extensively broken down or have severe enamel defects. Although amalgam is a forgiving material where moisture control is a problem and it can be placed without using dental dam, the National Health and Medical Research Council of Australia (1999) has recommended that placing or removing amalgam from children's dentitions be avoided. While effective moisture control is essential in the placement of high-quality composite restorations, those can be successful in class I and class II restorations in children. According to the 2014 guidelines of the American Academy of Pediatric Dentistry, there are not enough data comparing compomers to other restorative materials in children's permanent teeth for them to be considered the treatment of choice; however, they can be used as an alternative to other restorative materials in class I and class II restorations in primary teeth. A review of the evidence concluded that amalgam, resin-modified glass ionomers, and compomers showed similar longevity in primary teeth but that conventional glass ionomers showed significantly shorter longevity.[8] Conventional glass ionomers should be used only as either a temporary measure to stabilize a carious dentition in the early stages of treatment or an interim restoration when a tooth is close to exfoliation. For amalgam, its material physical properties are least often the source of problems, with most failures attributable to lack of attention to cavity design or handling of the material in use.[9]

Although dentists are often more concerned with the disadvantages of composite resin, patient concerns about the risks of amalgam toxicity and their greater esthetic awareness may supersede these concerns. When preferences for the choice of material differ between patient and dental professional, dentists tend to defer to patient choice in favor of composite resin.[10] Norwegian dentists tend to favor composites when treating younger patients, except where more complicated restorative challenges are encountered. In such cases, dentists are more likely to select amalgam as the restorative material.[11] Experience from practice suggests that where direct placement of composite resin is problematic due to the extensive nature of the preparation, many dentists may now select an indirect tooth-colored restoration rather than default back to dental amalgam. In the past, high caries risk was often considered a contraindication to the use of composite resins. In an amalgam-free clinical service, material choice is no longer a factor. Instead of relying on case selection to identify high-caries patients where composite is not appropriate, clinicians must instead focus solely on managing caries risk. Good caries risk management is now the single most important factor in determining the long-term success of direct restorations. Some practitioners place very extensive direct composite resin restorations with satisfactory clinical results, at least in the short term.

More research is required to investigate the long-term success of these types of treatments. A recent Cochrane systematic review of restoration performance found that composite restorations are associated with a higher risk of failure and greater risk of secondary caries than amalgam restorations,[12,13] and long-term evidence supporting composite performance is weak. Mechanical causes of failure, such as fractures, start appearing from about the two-year mark, reflecting the appropriateness of decisions made to use the material for individual situations and limitations with respect to the physical properties of these materials in terms of compressive strength, tensile strength, and fracture toughness. Biological causes of failure, such as dental caries, tend to increase more gradually over time.[14] Marginal failure at the bond interface is associated with a significant proportion of these infection-related failures reported. With the rapid evolution of successive generations of resin bonding systems, findings from clinical trials quickly become obsolete as technology advances supersede the limitations of previous product generations. Although it is expected that continued advances in dental materials should inform improved bonded restoration longevity, direct evidence demonstrating so remains relatively weak considering dentin to resin bonds degrade much faster than clinical restorations take to fail.[15]

Larger composite restorations have a higher risk for failure, with each additional surface involved increasing the risk by 30%-40%.[14] A systematic review and meta-analysis indicated annual failure rates of 2.4% for posterior composite restorations after 10 years,[14] informing cause for optimism to expect favorable performance over the medium to long term. Clinician skill is considered very important when placing composite restorations, with younger practitioners more likely to have had a greater proportion of their training focused on placing composite resins rather than amalgam.[16]

Since this study has examined the changing patterns in the use of dental amalgam in favor of tooth-colored alternatives in a dental school setting in New Zealand, it is important to look at what is happening in teaching facilities elsewhere. Much of the available literature is dated, with surveys of the teaching of posterior composites in dental schools worldwide carried out from the late 1980s to the mid-2000s.[17-24] More recently, however, a survey of 100 dental schools was conducted to obtain information on preclinical teaching and material preferences for the restoration of posterior teeth as well as expected future changes.[25] All 46 respondents reported that they taught composite resin for restoring posterior teeth, with nearly two-thirds of these not teaching amalgam as the preferred material and one Swedish school not having taught amalgam use since 2005.

The increasing use of composite resin observed at the University of Otago Faculty of Dentistry is similar (although more marked over the long term) to that which was reported by an Israeli dental school where the use of composite resin increased from 36.8% of restorations placed in 2004-2005 to 48.5% in 2008-2009.[26] That study found that the preferred dental material among younger dental instructors was composite resin, but veteran instructors were more likely to select amalgam. This pattern is mirrored in general dental practice,[22] and older practitioners may be less likely to opt for a more contemporary restorative material.

The current New Zealand government intends to ratify the Minamata Convention on Mercury, but more pressing legislative priorities mean this is unlikely to occur before the end of 2019 (New

Zealand Ministry for the Environment, personal communication, November 23, 2018). Thus, New Zealand's dental education system does not yet have an obligation to phase down dental amalgam; however, considerable progress in advance of its future obligations under the Minamata Convention have already been made. The University of Otago Faculty of Dentistry is arguably already engaged in all the nine strategies identified in the text of the convention that are likely to reduce the use of mercury dental amalgam in New Zealand. For example, the faculty is involved in dental caries prevention and health promotion training and research (objective 1) and conducts a considerable amount of research on the properties of amalgam alternatives (objective 2), while research and development of mercury amalgams has effectively ceased (objectives 3 and 4), students receive more training on amalgam alternatives than amalgam (objective 5), publicly funded services (particularly pediatric dental care) allow for the use of amalgam alternatives (objectives 6 and 7), the use of amalgam is restricted to its encapsulated form (objective 8), and appropriate environmental strategies are employed to minimize the environmental release of mercury (objective 9). It would appear that the Faculty is already meeting these obligations, although action in certain areas may be enhanced.

The University of Otago Faculty of Dentistry is following global trends in the phasedown of dental amalgam, and available private practice data suggest that this is also occurring throughout New Zealand. Dental composites have replaced dental amalgams as the major alternative material of choice. Ongoing curriculum changes are recommended to ensure that graduates are prepared for contemporary clinical practice, and ongoing training of teaching staff is necessary to ensure that experienced practitioners adapt their teaching with the changing curriculum.

Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of the University of Otago. The approval codes for this study are D16/065 and HD15/017.

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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