THE USE OF AMALGAM, COMPOSITE RESIN, AND GLASS IONOMER FOR POSTERIOR RESTORATIONS, AND THE CRITERIA FOR REPLACING RESTORATIONS IN THE NORTH YORK PUBLIC DENTAL PROGRAM

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The use of composites in small non-aesthetic posterior restorations and the criteria for restoration replacement have received considerable attention in the literature. Restoration guidelines for the Dental Division of the North York Public Health Department state that amalgam should be used in all cases except for aesthetic, temporary, or caries control restorations; in these cases, Acid Etch Composites and IRM/ZOE should be used. However, the current literature often recommends using composite resin in posterior restorations, making it appropriate to examine the North York Guidelines. A more conservative attitude to restoration replacement has also become popular in the literature and should also be examined.

Background

Most of the recent discussion in the literature concerning posterior restorations has focused on three general types of material, amalgam, composite resin, and glass ionomer. Amalgam is a cement composed of predominantly silver, copper, and/or tin that is chemically bound together with mercury. Amalgam restorations are retained in the tooth through mechanical means determined by the cavity preparation. Because amalgam is very weak when placed in thin sections, very shallow occlusal cavity preparations are unable to withstand the masticatory forces applied to them. Composite resin is a synthetic organic resin mixed with glass or ceramic filler particles, which improve the restoration's resistance to wear. Composite resin itself does not bind to the cavity wall but this can be accomplished using a bonding agent (e.g. Scotchbond). Glass ionomers consist of a polyalkenoic acid and an ion-leachable

aluminosilicate glass, and will adhere chemically to the enamel and dentin without the use of bonding agents.

In 1991, the North York Dental Program examined a total of 22,823 children and placed 15,316 restorations of which 934 were composite restorations. Because North York reserves composite for anterior or aesthetic restorations (see North York Guidelines below), it can be assumed that most of the remaining 14,382 (94%) amalgam restorations were posterior restorations. Of the amalgam restorations, 7,255 (50%) were one surface restorations, 5,688 (40%) were two surface restorations, and 1,439 (10%) were three surface restorations.

Composite resin is generally accepted as a suitable anterior restorative material because it can be colour matched to the tooth being restored. Although anterior composite resin does not have the compressive strength or wear resistance of amalgam, anterior teeth are subjected to relatively low stresses and so composites are suitable in this location. However, many recent articles have discussed using posterior composites to restore posterior teeth. A common recommendation is that posterior composites be used as a supplement to amalgam in low stress posterior restorations, but not as a universal replacement for amalgam (e.g. Moffa 1989; Mjor 1989; Roulet & Noack 1991; Mazer & Leinfelder 1992). These recommendations need to be examined if they are to be implemented in a public dental program.

A second item of interest concerning restorations is the criteria used to determine which restorations require replacing (e.g. Anusavice 1989; Soderholm *et al.* 1989; Kidd & O'Hara 1990). Much of the restorative work now performed in

dentistry involves replacement of restorations rather than initial placement (Nuttall & Elderton 1983; Marynuik & Brunson 1989). Many of these restorations are replaced because of their external morphology or cosmetics rather than their ability to function. Thus, restorations that were functional, were without secondary caries, and were satisfactory to the patient, could be replaced because the restorations had slight surface or marginal deficiencies. These, perhaps unnecessary, replacements are costly for the patient or for the public if the patient is treated by a publicly funded dental program. Therefore, the criteria for restoration replacement in any public program should be evaluated.

Even after implementing suitable guidelines for restoration replacement, most restorations will eventually need replacing. For a public health program with a limited budget, the time period between placement and replacement of a restoration and the restorations cost may be the major factors determining which restorative material is used. A cost analysis incorporating each material's properties, survival rate, and cost is required to decide which material is most suitable for use in North York's Public Dental Program.

The current North York Guidelines for the placement and replacement of restorations are listed on the following page (North York Public Health Department, Dental Division Policy and Procedure Manual, p.10.3.130).

Guidelines For The Use Of Restorative Services

Anterior Restorative Material (Acid Etch Composite) for:

- all final Aesthetic restorations in the permanent dentition.

IRM/ZOE

- a temporary or caries control restoration on permanent teeth only.

Amalgam for:

- all other situations.

Standards for Restorations with Amalgam and Anterior Restorative Material Unsatisfactory:

- restoration cracked or absent
- margin is greater than 0.5mm overhang
- contour does not deflect food
- contact is open or at incorrect height
- extension for prevention - grooves not included
- occlusion - high, showing wear marks, or otherwise interfering in normal occlusal movements
- surface is chipped from margin
- colour does not match the natural tooth.

Purpose

Because of the recent recommendations in the literature supporting an increased use of posterior composites, dental guidelines for what restorative material to choose when restoring a posterior tooth should be examined. In a publicly funded dental program where funds are limited, the choice of materials used should be based chiefly on each materials survivability. However, restoration survival can be affected by many material properties such as strength, resistance to wear and, margin quality, as well the restoration size, and the technique required to use each material. Therefore, each of the factors affecting restoration survival should be examined along with the actual survival estimates for each material.

Survival of a restoration may also be a function of the criteria used to establish which restorations have failed and need replacing. Because replacement of restorations is inevitable and represents a large percentage of all the restorative work performed, the criteria for replacement should also be examined.

The purpose of this study is to examine the current scientific literature and determine (A) what material to use when placing a posterior restoration and (B) what criteria to use when determining if a restoration needs replacing.

Methods

The literature review included in this paper is not intended to represent an exhaustive search of the literature. The intention of the literature search performed for this paper was to review any current standards and opinions found in the literature, but not to include all published articles and studies that discuss the various standards and opinions. Therefore, reference will not be made to all recent publications concerning dental restorations, dental amalgam, composite resin, or glass ionomer.

To identify references pertaining to materials used in dental restorations and the replacement of dental restorations, a computer-aided literature search was performed. Using CD/ROM, MEDLINE and various Medical Subject Headings (MeSH), five searches of the dental literature were performed for the years of 1987 through to early 1992.

The first search, using the MeSH of dental restorations, was restricted to

articles dealing with standards and limited to articles written in english and involving human subjects.

The second, third, and forth searches used the same MeSH, but the limitations of each search were slightly different. All three searches scanned the literature for articles involving at least two of the three restoration materials examined in this paper, amalgam, composite resin, or glass ionomer. The actual MeSH search command read as follows: amalgam and composite resin, OR amalgam and glass ionomer, OR composite resin and glass ionomer. All three searches were limited to articles written in english and involving human subjects. However, one additional limit was placed on each search: the second search was limited to review articles; the third search was limited to articles involving clinical trials; the third search was limited to children aged 2-18 years.

The fifth search also used the MeSH of amalgam, composite resin, and glass ionomer, but it scanned the literature for articles that discussed all three materials. The results of this search were limited to articles written in english and involving human subjects.

In total, the five searches listed 94 articles. Relevant papers were obtained and examined to locate additional references. Additional information and references were also obtained from a 1987 conference on restoration placement and replacement. The findings of this conference were published in a book entitled, Quality Evaluation of Dental Restorations: Criteria for Placement and Replacement (Anusavice 1989).

A physical factor limiting the results of all five searches was that the identified

articles had to be available from the Faculty of Dentistry Library at the University of Toronto.

Guidelines from the University of Toronto and the University of Western Ontario were also examined. Information on paediatric dentistry, restorative dentistry, preventive dentistry, radiology, and clinics was gathered using teaching manuals and interviews. Further mention of these guidelines is made only when they were found to present opposing views to the findings of the current literature. It should be noted that the University of Western Ontario's Paediatric Dental Clinic follows the guidelines proposed by the American Academy of Pediatric Dentistry (1992).

Some data from North York's school-based dental program were also included in this study. These data were acquired by examining dental records and program summaries.

To determine which restoration materials were most suitable, clinical studies and literature reviews were informally evaluated according to several factors. Studies that received more favourable evaluations were more influential when overall conclusions were being drawn. Personal opinions or procedures that were untested clinically were excluded from this paper.

When evaluating clinical studies, the overall study design, as well as it explanation, was examined. Experimental studies, such as randomized, controlled, clinical trials, were considered superior to observational studies, such as case controls. Preference was given to comparative studies, where two or more material

types, such as amalgam and composite resin, were tested in the same study. Poor explanation of the study design or omission of relevant information (e.g. who performed the restorative work), were considered to be design faults. Other factors considered when evaluating the studies were study duration, sample size, patient recall, method of restoration evaluation (quantitative or qualitative), who placed or evaluated the restorations, and the presence of independent examiners. Each factor was assessed and rated as either good, fair or poor.

Literature reviews were assessed in much the same way as clinical studies. Literature cited as support for the conclusions of a review was examined for scientific merit. More extensive and scientifically based literature reviews were weighted more heavily when the conclusions and recommendations of this paper were written. In general, the conclusions of this paper were based mostly on literature reviews. However, constant changes in the materials available in dentistry made it appropriate to include recent clinical studies.

Using the available scientific evidence practice guidelines for the use of restorative materials and when to replace a restoration were drafted. When scientific evidence was lacking, expert opinion and other existing guidelines were considered.

After drafting the revised guidelines, this literature review and its guidelines were reviewed by two panels. An internal (staff) panel, consisting of three dentists and one hygienist, all of whom work in North York's school-based dental program, initially reviewed the critical appraisal of the literature and the recommended guidelines. Concerns and recommendations of the internal panel were discussed with

members of the CDHSRU and necessary changes were made to accommodate those providing the dental services. The document was then reviewed by an external panel of experts consisting of a representative of the Royal College of Dental Surgeons (the 1991-93 President), a representative of the Ontario Dental Association (the 1992-93 President), an epidemiologist, an ethicist, a paedodontist, a general practitioner, and a member of the internal panel. Concerns and recommendations of the external panel were discussed with members of the CDHSRU and any recommended changes were made. The literature review and its respective guidelines were then finalized after approval by both the internal and external panels.

Findings

(A) What Material to Use

(1) Factors Affecting Restoration Survival

A number of factors can affect the survival of amalgam, posterior composite, and glass ionomer restorations. This section will address many of these factors, such as material strength, resistance to wear, and margin quality as well as the effect of restoration type and size.

American Dental Association (ADA) guidelines for strength of restoration materials are based on laboratory tested compressive strength, and require a posterior restoration material to be able to withstand 80 megapascals (MPa), one hour after placement. Williams and Billington (1989) compared compressive strengths of glass ionomers, composite resins and amalgams *in vitro*. They found

amalgam to be the strongest compound followed by composites, and finally glass ionomers, but at least one sample from each of the three materials met the 80 MPa ADA requirement.

Strength of the restored tooth should also be considered. Recent studies indicate that glass ionomers and composite resins may actually strengthen a restored tooth compared to an amalgam restored tooth or a prepared but unfilled tooth (McLean 1987; Jagadish and Yogesh 1990; Fasbinder *et al.* 1991).

Rankings of each restoration material's resistance to wear and margin quality are shown in Table 1. These rankings are from recent clinical studies that compared two of the restorative materials reviewed in this study. A ranking of 1 indicates which material was found to be superior in that study. Studies listed in Table 1 were also given a relative score, rating each study's "quality" when compared to the other studies in the table. Scores range from A to E with an A representing the best studies in the table and E representing the worst. Higher scoring studies carried more weight when determining overall conclusions.

The results of the studies in Table 1 suggest that resistance to wear is greatest in amalgam, followed by composites, and finally glass ionomers. Many reviews of the literature have concluded that glass ionomers and posterior composites are deficient in the area of wear resistance (ADA Council on Dental Materials, Instruments, and Equipment 1989; Leinfelder 1989b; Jones 1990; Newman 1991). However, recent studies suggest that wear of composites may be improved by placing sealant over a composite restoration (Dickinson *et al.* 1990; Mertz-Fairhurst *et al.* 1991a,1991b;

Newman 1991).

Table 1. Rankings of amalgam, posterior composite resin, and glass ionomer (gl. ion.) posterior restorations in terms of resistance to wear and margin quality.

STUDY	STUDY DURATION (years)	RANK OF MATERIAL			RANK* OF STUDY	RESTORATION CLASS
		AMALGAM	COMPOSITE	GLASS IONOMER		
RESISTANCE TO WEAR						
Moffa 1989	12	1	2	-	C	??
Leinfelder 1989a	1	1	2	-	C	??
Hung & Richardson 1990	1	1	-	2	B	II
Mair et al. 1990	3	1	2	-	C	??
Welbury et al. 1991	5	1	-	2	A	I & II
MARGIN QUALITY						
Levy et al. 1989	1	-	1	2	C	root
Moffa 1989	5 12	1 2	2 1	- -	C	II ??
Hung & Richardson 1990	1	1	-	2	B	II
Norman et al. 1990	5	2	1	-	A	I & II
Barr-Agholme et al. 1991	2	2	1	-	D	II
Welbury et al. 1991	5	1	-	2	A	I & II
Tyas 1991	5	-	2	1	E	V

* relative ranking compared with other studies in the table, A=best, E=worst
?? information not published

None of the three materials are consistently superior in terms of marginal quality (Table 1). Both composite and amalgam appear to provide better marginal quality than glass ionomer, except in the case of class V restorations. Newman (1991) and Tyas (1991) also suggested that glass ionomer is ideal for class V

restorations because it offers some aesthetic value, releases fluoride, and additional tooth tissue does not need to be removed if the restoration needs 'replacing'.

Posterior composites appear to provide a better margin than amalgam (Roulet 1989), except for class II restorations. However, reviews of the literature indicate that it is difficult to achieve good margins using a composite resin (Leinfelder 1989b; Krejici *et al.* 1991), especially for a class II restorations (Roulet and Noack 1991). A study by Roulet *et al.* (1991) reported problems concerning wear and submargination of class II composite restorations after only 7 months, and did not recommend routine replacement of class II amalgams with posterior composites. Sealing composite and amalgam restorations was also shown to decrease the number of open margins compared to an unsealed amalgam restoration (Mertz-Fairhurst *et al.* 1991a).

Restoration strength, resistance to wear, and margin quality can all be affected by the size and type of the restoration placed. Generally, investigators feel that composites should not be considered as a universal replacement for amalgam, and that amalgams should still be used in situations where the restoration will be subjected to relatively high stress (Leinfelder 1989a,b; Roulet 1989; Goldberg 1990; Jones 1990; Mair *et al.* 1990; Newman 1991; Osborne 1991; Roulet & Noack 1991; Roulet *et al.* 1991). However, where the cavity preparation is kept small, wear and margin deterioration of composites and glass ionomers can be reduced, making them more suitable for some posterior restorative work than previously believed (ADA Council on Dental Materials, Instruments, and Equipment 1989; Norman *et al.* 1990; Roulet & Noack 1991).

As was mentioned earlier, composite and glass ionomer restorations can be bonded to the cavity wall, allowing the operator to remove less tooth tissue than when placing an amalgam restoration (Welbury *et al.* 1990; Smales *et al.* 1990; Barnes *et al.* 1991). Since most restorations will eventually be replaced, which often results in an increased cavity size, the need to conserve tooth structure in the first instance is very important. Because of this and the increased wear resistance of composites when cavity sizes are reduced, composites are recommended for smaller, low stress, posterior restorations or when aesthetics are of primary importance (ADA Council on Dental Materials, Instruments, and Equipment 1986; Anusavice 1989; Mjor *et al.* 1990; Newman 1991). The recommendation of the American Association of Paediatric Dentistry (1992) is slightly less conservative and recommends the use of posterior composites for all restorations up to 2 surfaces.

Restoration quality is also affected by the operator's skill and experience. Amalgam has been identified as very 'forgiving' to use, but composite resin is very technique sensitive (Leinfelder 1989b; Moffa 1989; Roulet & Noack 1991); a small mistake will have a profound effect on a composite restoration's quality (Roulet & Noack 1991). Composites are also more difficult and time-consuming to place than amalgam (Newman 1991; Roulet & Noack 1991), and if the incremental composite placement technique is used in an effort to reduce polymerization shrinkage, more time and equipment are needed (Roulet & Noack 1991). Glass ionomers are also more difficult to place than amalgam, but when mastered, the placement technique is short and simple (Newman 1991).

Conclusion: Based on material characteristics alone, amalgam should be used in all posterior restorations except small, low stress, restorations such as a small class I or class V. In the class V and small class I restorations, composites may be considered because of their superior margins and/or the reduced amount of tooth tissue that is removed when using these two materials. Glass ionomer may also be considered for class V restorations. However, survival and cost must also be considered before any final decision is made.

(2) Restoration Survival

A major goal of dentistry is to place a restoration that never needs to be replaced, but at the moment most restorations will eventually need to be replaced. For a public health program, scientifically based estimates of restoration survivability or longevity may be the major factor in determining which restoration material is most cost-effective to use. Although restorations may fail for a number of reasons, these reasons may not be as important to a public health program as how often a certain material needs to be replaced.

Because restorations are usually expected to last for a relatively long period of time, any clinical tests or studies should occur over a period of years. American Dental Association guidelines for acceptance of materials in class I and II restorations stipulate clinical evidence must be acquired over 3 years for provisional acceptance and 5 years for full acceptance. Because of this guideline, many recent studies on restorative materials have reported 3 or 5 year results, but few longer-term results for posterior composites are available (Mjor *et al.* 1990; Newman 1991), and fewer still regarding glass ionomers.

Table 2 is a compilation of recent studies that estimated restoration longevity

in the permanent teeth of adults. Studies listed in Table 2 were also given a relative score rating each study's "quality" when compared to the other studies in the table. Scores range from A to E with an A representing the best studies in the table and E representing the worst. Higher scoring studies carried more weight when determining overall conclusions.

Overall Table 2 shows that amalgam is superior to composite and glass ionomer in terms of survival, but the degree of superiority varies according the type of restoration studied. Class I amalgam and composite restorations appear to be almost equal, with a slight edge going to amalgam. Both amalgam and composite resin are superior to glass ionomer. Amalgam is superior to both composite resin and glass ionomer when used in class II restorations. However, in the studies that looked at class I and II restorations combined, amalgam is only slightly superior to composite perhaps reflecting the relative equality of the two when used in class I restorations. Glass ionomer appears to be slightly better than composite resin for class V restorations, although survival of both was fairly high after 5 years and the study was not very conclusive (Tyas 1991).

Table 2. Survival of posterior restorations in teeth of adults.

STUDY	STUDY DURATION (years)	RESTORATION			BASELINE NUMBER OF RESTORATIONS, (RECALL %)	RANK* OF STUDY
		MATERIAL	CLASS	SURVIVAL (%)		
Bentley & Drake 1986	≥ 10	amalgam	I	92	168, (??)	D
			II	65	265, (??)	
Letzel 1989	5	amalgam	I + II	92	232, (69)	C
	5	composite	I + II	86	932, (67)	
Moffa 1989	5	amalgam	I	89	314, (??)	C
			II	77		
	5	composite	I	81	356, (??)	
			II	58		
	12	amalgam	??	82	1517, (??)	
		composite	??	52	609, (??)	
Norman et al. 1990	5	amalgam	I + II	94	53, (100)	A
	5	composite	I + II	92	107, (75)	
Osborne & Norman 1990	13	amalgam	??	89	600, (30)	B
Smales et al. 1990	3	amalgam	I	100	13, (38)	C
	3	composite	I	100	251, (30)	
	3	glass ionomer	I	57	132, (16)	
Jokstad & Mjor 1991	4	amalgam	II	91	468, (77)	D
	9.5	amalgam	II	81	468, (25)	
Tyas 1991	5	composite	V	89	67, (??)	E
	5	glass ionomer	V	98	65, (??)	

* relative ranking compared with other studies in the table, A=best, E=worst
?? information not published

Table 2 also shows a high degree of variability between studies of restoration survival. Variation across studies may be due to a number of factors such as the subjects used, the operators that placed the restorations, the difference in the specific type or brand of each material used, or the criteria used in the clinical studies to determine a failed restoration. This variability makes it difficult to determine an average period of time that each material will last. However, using studies which

compare two or more materials makes it possible to determine which material is superior in certain situations.

In spite of the variability, the studies in Table 2 suggest that the average class I or II amalgam restoration can be expected to last more than 10 years. Leinfelder (1989b) supports this finding, reporting that many amalgams may survive well past 10 years, although Mjor *et al.* (1990) estimates average amalgam longevity at only 7-8 years. Posterior composites do not appear to survive as long as amalgams lasting between 5 to 10 years, but this depends on the type of posterior restoration that is placed. Longevity of composites can be expected to increase as the size of the cavity decreases, with smaller, low stress restorations comparing more favourably to amalgam. Glass ionomers should not be considered for most posterior restorations, except class V, where its longevity may be slightly greater than composite resin.

Up to this point, the restoration survival results have dealt with the permanent teeth of adults, but restoration survival in children and adolescents appears to be much lower. A number of studies (Table 3) have shown that the average survival period of restorations in children may be only be 2 or 3 years, and is related to the child's age at the time of placement.

The results in Table 3 show that little difference exists between the survival of amalgam restorations in deciduous and permanent teeth of same age children (Holland *et al.* 1986). Survival of amalgam restorations appears to be related to the age of the child when the restoration was placed and increases as the child's age increases. The median survival age for an amalgam restoration placed in children

aged 5-6 years is approximately 2 years. This figure increases to about 3 years for ages 7-8, 6 years for ages 9-11, and about 7.5 years for ages 12-14. In the middle and later teens, the survival of amalgam restorations is similar to amalgam survival in the permanent teeth of adults.

Table 3. Survival of posterior restorations in teeth of children.

STUDY	TOOTH TYPE	RESTORATION TYPE	CHILD'S AGE (years)	MEDIAN SURVIVAL TIME (years)
Hunter 1985 *	permanent	amalgam & silicate, all classes	8	3.9
			9-11	6.0
			12-14	8.0
			15-17	9.8
			18-20	12.2
		amalgam & silicate, occlusal	8	3.2
			9-11	5.9
			12-14	6.9
			15-17	9.0
			18-20	10.0
Walls et al. 1985	permanent 1st molar	amalgam, occlusal	5-6	2.2
			7-8	2.8
			9-10	6.4
			11-12	8.9
			13-14	6.4
Holland et al. 1986	deciduous molars	amalgam, class I & II	3-4	1.9
			5-6	2.8
			7-8	3.7
			9-10	5.6
Dawson et al. 1981 **	deciduous 1st molar	amalgam, class I	5.5	1.8
		class II	5.5	1.9
		stainless steel crown	5.5	3.4
	deciduous 2nd molar	amalgam, class I	5.5	2.4
		class II	5.5	1.9
		stainless steel crown	5.5	3.2
Mjor et al. 1990 ***	deciduous	amalgam	not reported	2.0
		composite	not reported	< 1.0
Welbury et al. 1990	permanent	amalgam, occlusal	12-17	5.0
		composite, occlusal	12-17	5.0
Welbury et al. 1991	deciduous	amalgam, class I & II	5-11	3.5
		glass ionomer, class I & II	5-11	2.8

* survival times estimated from graph
** survival time = "average longevity", s.s. = stainless steel
*** literature review

Retrospective studies comparing large amalgam restorations to stainless steel crowns in deciduous teeth appear to favour crowns. Dawson *et al.* (1981) found that crowns lasted about one third longer than class I and II amalgams in children with an average age of 5.5 years. A study by Braff (1975) involving 76 crowns and 150 multi-surface amalgams also determined the stainless steel crown to be superior. Braff's retrospective study showed that only 30% of crowns needed retreatment but 89% of amalgams needed retreatment and 20% of the teeth initially treated with amalgam were subsequently restored with crowns. However, the time before the tooth is exfoliated should also be considered before opting for a crown over an amalgam.

Other recent studies have also examined the performance of composite resin and glass ionomer restorations in primary molars, but did not present their data in a way that it could be included in Table 3. A two year study by Leifler and Varpio (1981) showed that proximal composite resin restorations in primary molars of children aged 5-11 years (mean age=7.4 years) had a mean failure rate of 32% after two years.

Two studies have compared the performance of posterior composites to amalgam in primary molars using a spilt or half mouth design (each subject receives at least one restoration of each type). Tonn *et al.* (1980) carried out a two year clinical study comparing an experimental composite resin to amalgam when used in class II restorations of primary molars. Nelson *et al.* (1980) carried out a three year study. In both studies amalgam was found to be superior to composite resin in terms

of anatomic form, and equal in terms of marginal adaptability and caries.

A 6.5 year study by Houpt *et al.* (1988) examined the use of composite resin to conservatively restore permanent molars with minimal or moderate occlusal caries in children aged 6-14 years (mean age=8 years). Only 104 (31%) of the initial 332 restorations placed were evaluated after 6.5 years, of which 41 were sealant and 63 were sealant + composite. Complete retention was achieved in 68 (65%) of these restorations and only two of the lost or partially lost sealants resulted in recurrent caries. Past studies have indicated that sealant retention may be reduced in primary molars when compared to permanent molars (Hinding & Sveen 1974), but more recent studies have shown more comparable rates of retention (Hardison *et al.* 1987).

Three recent articles have also compared the performance of glass ionomer and amalgam in deciduous molars using the split mouth design. When placed in children aged 5-7 years, Hung and Richardson (1990) found that 100% of the amalgam class II restorations survived a period of one year, but only 60% of the glass ionomers class II restorations survived the same period of time. Clinical trials including both class I and class II restorations have been carried out by Walls *et al.* (1988) and Hickel and Voss (1990), using children aged 5-11 years and 4-10 years, respectively. The results of both of these studies were very similar; in terms of anatomical form amalgam was superior to glass ionomer, but no significant difference in marginal integrity or overall failure existed after two years. Hickel and Voss' 2 year survival rate for glass ionomer and amalgam restorations was 64% and 56%, respectively.

Although Hung and Richardson (1990), Walls *et al.* (1988), and Hickel and Voss

(1990) all did not recommend glass ionomer in permanent teeth because of its high failure rate, Walls *et al.* and Hickel and Voss did recommend it for certain situations when restoring deciduous teeth. Glass ionomer may be appropriate to use in young children who will not tolerate general anaesthesia or the extensive drilling necessary when placing an amalgam (Hickel & Voss 1990). Because restoration survival has been shown to increase as the age of the patient at the time of placement increases, glass ionomer may be considered for very young children as an interim restoration until a more permanent and longer lasting restoration can be placed (Croll 1990). This will conserve tooth structure and possibly reduce dental anxiety of the patient. Although a 1 year trial by Stratmann *et al.* (1989) concluded that glass ionomer is a suitable class II restorative material in primary molars, it is not generally recommended in situations of high occlusal stress (Croll 1990; Hickel & Voss 1990).

Conclusion: Based on longevity, amalgam should be used in all posterior restorations of permanent teeth, except small class I restorations where composite may be used and class V restorations where composite or glass ionomer may be considered. In primary molars amalgam should also be used except small class I and class V restorations where composite resins and glass ionomers may be used; however, in this case, the cost of the material and the estimated length of time before the tooth is shed should receive considerable attention.

(3) Cost

Costs and time required to place amalgam and composite restorations, and occlusal sealants were taken from the 1992 Ontario Dental Association Fee Guide and are shown in Table 4. Costs and placement time for small resin restorations were estimated using the values for an occlusal sealant.

TABLE 4. Ontario Dentists Association (1992) costs and time required for amalgam and composite dental restorations.

DENTAL SERVICE	COST/SERVICE ($)	TIME/SERVICE (min)
Sealant	16.63	7.5
Primary Teeth		
Amalgam, 1 surface	26.26	15
Amalgam, 2 surfaces	57.51	26.25
Amalgam, 3 surfaces	65.65	30
Composite*, 1 surface	52.52	30
Permanent Teeth		
Amalgam ,1 surface	32.83	18.75
Amalgam, 2 surfaces	65.65	30
Amalgam, 3 surfaces	82.19	37.5
Composite*, 1 surface	59.09	33.75

* ODA Fee Guide lists price for tooth coloured/plastic material

Table 4 shows that the cost and the time required to place a one surface composite restoration is much greater than the cost and time required for a one surface amalgam. A 1990 study by Dilley *et al.* confirmed this, finding that composite class I restorations required an average of 35% more time than amalgam to place in primary and permanent molars of children aged 7-9 years of age. Because of this difference and the limited resources available to a public dental program such as North York's, composite restorations should not be placed in primary molars. Composite resin restorations could be considered for small one surface (class I) restorations in permanent molars because of their conservative preparation. No prices

or times for glass ionomer are listed in the 1992 ODA Fee Guide but the price may be similar to that of composite since it could also be listed as a tooth coloured material (see Table 4).

Use of occlusal sealant may also be considered for small pit and fissure caries. Table 4 shows that the cost and time required for a sealant is less than for an amalgam and past studies have proven sealants to be an effective caries prevention measure. More recent studies have also shown sealants alone, or in conjunction with composite resin, to be successful as restorations for small pit and fissure lesions (Smales *et al.* 1990; Welbury *et al.* 1990; American Academy of Paediatric Dentistry 1992), even when placed over a carious lesion (Mertz-Fairhurst *et al.* 1991a; Roulet & Noack 1991). Known in the literature as "preventive resin restorations" (Swift 1987; Anusavice 1989; Roulet & Noack 1991), sealants used in this way do not always require the use of a drill during cavity preparation and may be placed at the same time as preventive sealants are being administered.

Overall Conclusion

After considering all of the factors involved, amalgam should be used in all posterior restorations of permanent teeth except small class I and class V restorations. In small class I and class V restorations, composite resin may be used, which is comparable to amalgam in terms of longevity and conserves more tooth tissue than amalgam. Glass ionomer may also be considered for class V restorations. As has been suggested in the recent literature (Swift 1987; Anusavice 1989; Roulet & Noack 1991), the "preventive resin restoration" should be used for small class I pit and fissure lesions.

When restoring a primary molar, amalgam should again be the material of choice. Sealants or glass ionomer may be considered for small class I lesions or class V lesions in extreme circumstances when the child is very young and will not tolerate long chair-times or drilling. This may reduce dental anxiety in the child and temporarily restore the tooth until the tooth is shed or another restoration can be placed.

(B) When to Replace a Restoration

Although many studies have investigated the reasons for restoration replacement (e.g. Jokstad & Mjor 1991; MacInnis *et al.* 1991) and the variability of replacement decisions by practitioners (e.g. Boyd and Richardson 1985; Thorton & Linden 1987; Marynuik 1990), few studies have established useable standards for restoration replacement.

One area of concern when evaluating a restoration is the quality of the margin that is formed between the material and the tooth. It has been suggested that inadequate margins may result in microleakage into the gap between the tooth and the filling, penetration of toxins/microorganisms into the gap, and increased plaque retention (Roulet 1987, 1989). These margin problems may lead to secondary caries and possible pulpal diseases (Roulet 1987, 1989).

A number of studies addressed the proposed relationship between gaps at the restoration margin and secondary caries. Jorgensen and Wakumoto (1968) suggested an increase in caries likelihood as the gap size of amalgam restorations increased; a threshold gap size of 50 um existed, below which no caries occurred. The results of a more recent *in vitro* study by Derand *et al.* (1991) also found an increase in caries likelihood as gap size increased. The possible correlation between margin gap size and secondary caries, has led to it being used as justification for restoration replacement.

Two recent studies, however, do not support the margin-caries association. After examination of extracted teeth, Soderholm *et al.* (1989) found that the highest

frequency of caries occurred in the narrow gaps, and reported no significant difference in the gap size of restored teeth with and without caries. Histological examination by Kidd and O'Hara (1990) of 30 extracted teeth revealed that lesions were present in 54% of specimens, regardless of whether the margin was defective or sound. Goldberg (1990) suggested that these findings may be due to an oversimplification of the gap-caries correlation; many other factors, such as oral hygiene status and caries history, also affect the occurrence of recurrent caries. The presence of an imperfection in the margin may not be a suitable criterion for restoration failure and replacement.

Guidelines for restoration replacement were developed after the 1987 conference on restoration placement and replacement (Anusavice 1989). Below is a condensed version of the conference guidelines on criteria for restoration replacement.

(1) Problems associated with a marginal gap, but the presence of a gap alone is not a criterion for replacement.

(2) Carious lesions which exist directly adjacent to the restoration and extend into the dentin, are judged to be active.

(3) Failed or defective restorations are associated with clinically significant loss of function, tissue inflammation, or pulpal pathology. These restorations may be repaired, adjusted, or replaced if this treatment is expected to overcome the problem. Surface deficiencies alone are not adequate reason for replacemen t.

(4) Allergic responses to the restoration material appear. Mild allergic responses should be monitored for 2 or more weeks before replacement.

(5) Patient requests replacement because of psychological stress caused by poor aesthetics, inadequate function, and actual or perceived biological hazards. Advantages and deficiencies of alternative treatment should first be fully explained to and accepted by the patient.

Based on the findings of this study, the recommended guidelines concerning what restoration materials to use and when a restoration should be replaced are listed below and have been used to construct two decision trees (see Figures 1, and 2).

Recommendations for Use of Restorative Materials

Temporary or Caries Control Restorations

IRM/ZOE should be used for all temporary or caries control restorations.

Anterior Restorations

Anterior restorative material (Acid Etch Composite) should be used for all final aesthetic restorations in permanent dentition.

Posterior Restorations

Permanent Teeth - amalgam should be used in all posterior restorations except, small class I or V restorations, where posterior composite resin or occlusal sealant should be used. Glass ionomer may also be used for class V restorations.

Primary Teeth - amalgam should be used.

Recommendations for When to Replace a Restoration

Restorations should be replaced if:

(1) the restoration is cracked or absent;

(2) there is active caries associated with the restoration's margin;

(3) there are problems with the restoration directly resulting in,
(i) clinically significant loss of function,
(ii) tissue inflammation,
(iii) pulpal pathology;

(4) there is an allergic response to the recently placed material (mild allergic responses should be monitored for at least 2 weeks before replacement).

Restorations should only be replaced if the procedure is expected to improve or overcome a problem. The presence of morphological imperfections alone, such as a marginal gap or surface deficiencies, are <u>not</u> cause to replace a restoration.

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