What type of filling? Best practice in dental restorations

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Dental caries (tooth decay) is one of the most common diseases, with approximately 80% of the population in developed countries having experienced the condition. If decay has not been prevented cavities develop. To prevent considerable pain and tooth loss it may be necessary to remove the diseased tissues and restore the cavities (a filling).

Restorations have a limited lifespan and, once a tooth is restored, the filling is likely to be replaced several times in the patient's lifetime.¹ Studies in the UK suggest that much of restorative dentistry is replacement of existing restorations, accounting for around 60% of all restorative work.² Similar figures have been found in other parts of Europe,^{3 4} and the USA.^{5 6} (*Quality in Health Care* 1999;8:202–207)

There is a large choice of materials which can be used for fillings. Many are introduced into the market place and used on patients with limited evidence that they are more effective or robust than existing materials. Consequently, one of the key questions is, all other things being equal, what type of filling is best?

This paper summarises the results of a systematic review of the relative longevity and cost effectiveness of routine intracoronal dental restorations,⁷ which formed the basis of a recent issue of *Effective Health Care*.⁸

The reasons for replacing a restoration are numerous and vary with tooth type and restorative material.⁹ Once inserted, restorations may fail at variable rates due to various "objective" factors affecting both the failure of the filling material and further decay of the tooth around the filling. These factors include the characteristics of the filling material and effect modifiers related to operator skill and technique, patients' dental characteristics, and the environment around the tooth.

The decision to replace a restoration is also influenced by more subjective factors such as dentists' interpretation of the restoration's condition and the health of the tooth, the criteria used to define failure, and patient demand. These decisions are subject to much variation.^{1 10} A lack of standardisation exists, and no generally agreed criteria are used to decide when a restoration requires replacement.¹¹

Types of restoration

Tooth restorations may be classified as *intracoronal*, when they are placed within a cavity prepared in the crown of a tooth, or *extracoronal*, when they are placed around (outside) the tooth as in the case of a crown. Intracoronal restorations are usually placed *directly* into the tooth cavity and normally consist of a mouldable material that sets and becomes rigid; the material is retained by the surrounding walls of the remaining tooth tissue. An alternative intracoronal restoration uses an *indirect* technique; here an impression of the cavity is taken and a laboratory constructed inlay is produced and subsequently cemented into the prepared cavity.

The materials currently used to restore intracoronal preparations are: dental amalgam, composite resins, glass ionomer cements, resin modified glass ionomer cements, compomers and cermets, cast gold, and other alloys inlays and porcelain (box 1).

Research methods

The systematic review⁷ involved a wide search for studies in any language using many general and specialist databases, handsearching of key dental journals, and searching of abstracts from conference proceedings.¹⁴ Of the 652 relevant papers, 253 (representing 195 studies) had the minimum core of data required for inclusion.

INCLUSION CRITERIA

Use of objective outcome measures

Many authors did not state or use criteria for deciding when a restoration had failed and needed to be replaced. In these studies it is therefore impossible to distinguish between the objective factors influencing longevity (the main aim of the review) and subjective influences. For this reason, to be included, studies were required to have measured outcome (the decision to replace a restoration) using stated criteria.

Study design

Only studies that looked at performance in either experimental or clinical settings were included. The review included randomised controlled trials (RCTs), quasi-experimental

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Dental amalgam

Dental amalgam is an alloy of mercury with silver and other metals such as tin and copper to give a set material that does not adhere to tooth tissue and is not tooth coloured. It has been available for over 100 years, but the original formulation of the material has been modified considerably; in particular, the addition of copper and zinc to the alloy powder has enhanced its physical properties.

Concerns over the safety of amalgam appear to be unjustified.¹² The Department of Health's Committee on Toxicity concluded that dental amalgam is free from risk of systemic toxicity and only a very few cases of hypersensitivity occur.¹³

Composite resin

There are several groups of composite materials that can be classified on the basis of their resin and filler components. All are tooth coloured and are essentially a mixture of filler particles, consisting of various types of translucent glass, embedded in a matrix of resin that binds the filler particles together. The original generation of materials that set by a chemical reaction has been largely superseded by composites that set on the application of a bright light.

The use of composite materials has been supplemented with pre-treatment of tooth tissue with a mild acid which is then coated with a thin resin wetting agent before placement. More recently, application of acids and other agents to dentine has been advocated to reduce leakage and further improve retention. These dentine bonding agents are rapidly evolving.

Glass ionomer cements

Glass ionomer cements are tooth coloured and adhere chemically to tooth tissue. They are similar to composite resins in that they consist of a matrix and embedded filler particles; however, their formulation and setting reaction differ.

Resin modified glass ionomer cement and compomers

New generations of materials are essentially glass ionomer cements that contain resin. The resin modified materials are more akin to glass ionomer cements, whereas the compomers are more like composite. Again, these materials are tooth coloured and are available in various different formulations.

Cast gold and other alloys

Cast gold or alloy restorations are called inlays and are made outside the mouth in an indirect technique that requires laboratory facilities. The advantage of cast inlays is their strength in thin sections but they are more expensive. They are cemented in place with either traditional dental cements or can be used with more modern bonding systems.

Porcelain

Porcelain inlays can now be cemented into the prepared cavity. Various porcelains are available along with various production processes, all of which can be used with several cementing agents.

Box 1 Types of material used for restorations

designs, and non-experimental studies which surveyed the longevity of restorations in a cohort of patients with good follow up.

Cost effectiveness

To compare the cost effectiveness of different filling materials a review of the economic literature was undertaken. This was supplemented by information from nine general dental practitioners in Wales who provided data on the time taken to place a restoration and subsequent replacements. These times were multiplied by the estimated average cost of dental staff per hour (£62.50) for work preparing and completing a restoration. The cost of a filling was calculated by adding staff costs to the different material costs. Thus the costs used in the economic model were developed from the bottom up rather than by using the fee schedules. The costs for the initial filling were combined in an economic model with estimates of the number of years a dental restoration survives (tooth years) based on survival probabilities derived from the systematic review. The economic evaluation was undertaken from the perspective of the NHS and used *tooth years* as the outcome measure for each material

type and the cost per tooth life year as the cost effectiveness ratio.⁷

Direct methods

This section reports on the longevity of materials which are directly placed: amalgams, composites, and others materials such as glass ionomer cements.

AMALGAM RESTORATIONS

The studies of amalgam show good rates of survival compared with most of the other materials examined in this review.⁷ At 3 years, no study showed failure and at 10 years, fewer than 10% of restorations had been replaced (fig 1), although by this time no data existed for 52% of restorations. In addition, these results may shed the most favourable light on amalgam because patients were often pre-selected before entry into the study on criteria such as intact dentition, good oral hygiene, and absence of active periodontal disease.

There was some evidence to suggest that dispersed phase, high copper alloy amalgams were associated with greater survival than other amalgams.^{20 23 31 46 53 57 58}

Composite restorations

Forty eight studies involved composite restorations but without use of dentine adhesives.⁷

Figure 1 Survival of amalgam restorations for permanent teeth (paired and unpaired studies).¹⁵⁻⁵⁶

Figure 2 Survival of composites in cervical cavities by type of bonding agent.^{41 65-69}

Twenty five studies involved dentine bonding systems; in most cases these studies investigated cervical cavities where retention of the restoration relied exclusively on the bonding mechanism to resist loss. These studies rarely reported the site of the filling and thus it is impossible to assess whether survival is different for composites placed in the front or back teeth.

Composite without dentine bonding

Overall, the studies showed good short term survival (2 and 3 years).^{24 25 59-61} However, the few studies with at least 5 years follow up showed signs of significant failure, particularly the multicentre studies.^{62 63}

Survival of composite was influenced significantly by material type with light cured micro-filled and densified filled materials being more successful between 6.5 years and 8.5 years, whereas the older autopolymerising macro-filled composites were most successful up to 6.5 years.

Composite with dentine bonding

In the systematic review, dentine bonding agents were classified into 3 main groups⁶⁴: those evolved from the earliest resin materials which simply impregnated the smear layer (group 3), those modified to enhance impregnation and to alter the smear layer (group 2), and the more modern materials which use an acidic primer (group 1). Dentine bonding materials have often been tested in cervical cavities and in this situation the failure of these materials is rapid, beginning within 1 year (fig 2).⁶⁵⁻⁶⁸ More recent materials that use some form of acidic primer (groups 1a and 1b) show improved survival compared with groups 2 and 3. There appeared to be little difference between materials classed in group 1a (those which use phosphoric acid) and group 1b (those using other acids).

The results of these studies suggest that enamel etching (with or without enamel bevel)

Figure 3 Survival of porcelain and composite inlays.^{40 98 100 101 105-125}

is clinically effective for long term retention^{66 96}; clearly, mechanical retention is also effective for the retention of restorations.⁹⁷ Newer materials (group 1) appear to perform better than older materials (groups 2/3).^{77 87} Use of all dentine bonding systems reduced patient pain after placement.

Comparison of amalgam with composite

Twenty six studies in this review compared amalgam and composite restorations.⁷ In studies comparing the two materials in an unpaired design (teeth from different patients), amalgam was superior, always having greater survival. In similar studies using a paired design (teeth in the same person) the differences in favour of amalgam were less but still statistically significant.

The results of the studies on other materials, due to lack of space, are presented elsewhere.⁸

Indirect methods: inlays

Twenty seven studies were included which examined the longevity of inlays using ceramics, gold, and composites.⁷ These studies often had few patients and were of a weaker design. In addition, few undertook any form of comparison. Overall, there is no important difference between porcelain and composite inlays (fig 3). However, these studies (one of which compares both materials)^{98 99} suggested that some types of porcelain inlays were significantly better than composite inlays.

Limited evidence exists to support the use of a resin compared with a glass ionomer cement as luting cements.¹⁰⁰⁻¹⁰³ There is some evidence, although limited, to support the use of heat cure in addition to light cure in composite inlays.¹⁰⁴ There are some reports of post-operative pain with inlays and these need further investigation.¹⁰⁵⁻¹⁰⁸

Cost effectiveness

The 30 economic studies which were identified were of poor quality⁷ and did not provide sufficient information to enable the cost of restorations to be constructed with any degree of confidence. The data were therefore supplemented by information on times taken to complete restorations provided by dentists in order to undertake a cost effectiveness comparison of the filling materials. Table 1 shows a summary of the results.

Although these results are approximate and should be treated with caution, amalgam clearly dominates composite and inlays across all time periods considered because it is

Table 1 Cost per tooth year of three main classes of restoration (discounted at 5%)

	5-year time period			10-year time period		
	Tooth-years		Cost per tooth year	Tooth-years		Cost per tooth year
Amalgam	4.85	21.56	4.44 (5.05)	9.31	32.93	3.54 (3.92)
Composite	4.37	33.01	7.54 (8.19)	7.35	91.66 (69.32)	12.47
Inlay	3.30	130.00	39.39 (41.26)	—	—	—

cheaper and has better survival, a dominance which is robust to a wide range of assumptions. Composite was between 1.7 and 3.5 times more expensive than amalgam to generate one tooth year, a finding which is in line with previous estimates from better quality economic evaluations.^{126 127}

Discussion

The majority of studies of sufficiently high quality to be included in this review were undertaken in dental schools, whereas virtually all restorations are provided in a primary dental care setting. This affects the extent to which individual studies can be generalised to the wider population. Studies not included in the systematic review that used subjective criteria, and are more representative of general dental practice, make it clear that the longevity of amalgams,^{128–130} composite,¹²⁹ and glass ionomer restorations¹²⁷ is less than the survival periods achieved in the prospective studies included in the systematic review.

Wide variation both within and between dentists' treatment decisions has been reported, and is obviously an important issue when trying to identify the point at which a restoration is replaced.^{1 10 131 132} It is claimed that the likelihood of having a restoration replaced is more than doubled when a patient changes practitioner.¹³³ Appropriate criteria for replacement of restorations are needed, and dental schools should train dentists in their use to reduce unnecessary procedures and improve quality.¹¹ This would protect the public against unnecessary procedures, reduce costs, and improve the quality of professional decision making.

New restorative materials are often marketed and introduced into practice with limited evidence on their long term clinical performance. Mechanisms should be sought to ensure that the introduction of dental materials into clinical practice is incorporated into any new NHS regulatory structures designed to promote the quality of health care.¹³⁴

The longevity of restorations done in the better quality research studies suggests that routine clinical practice may be producing suboptimal results. Work is needed to establish means of improving the quality of routine practice, putting in place incentives to promote cost effective care, and identifying the resource implications. This is an area that might be worth considering for inclusion in the national performance framework.

Conclusion

Dental amalgam is the direct restorative material with the longest duration and from the perspective of the NHS is of lower cost. Unless

there is a contra-indication (which is usually aesthetics or pregnancy), it is recommended for routine use wherever possible.

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Glossary

Carious: describes a tooth affected by caries (decay).

Cavity: carious lesion or area of destruction in a tooth.

Cervical: (Class V) concerning the neck of the tooth, near the gum.

Dental caries (tooth decay): disease resulting in the demineralisation, cavitation and breakdown of calcified dental tissue by microbial activity.

Direct inlay: method of construction of an inlay using a wax pattern taken directly from a tooth preparation and not from a model.

Direct intracoronar restoration: involves a direct insertion of a pliable material (such as dental amalgam, composites, and glass ionomer cement) into the preparation which subsequently becomes rigid and is retained by the surrounding walls.

Dispersed phase: a specific formulation of amalgam alloy powder.

Effect modifier: a factor which modifies the effect of an intervention.

Enamel bevel: a sloping surface, at a cavity margin.

Etching: partial demineralisation of a selected area of tooth substance.

Erosion: irreversible loss of tooth substance by a chemical process that does not involve bacterial action.

Extracoronar restoration: a crown.

Fissure: a small groove or trough in the enamel of the tooth.

Glass ionomer cement lute: a cement used in the placement of an inlay.

Indirect inlay: method of construction of an inlay by using an impression of the tooth. Indirect technique is more suitable for complex cavities, preparations with veneers, and full crowns.

Pit: a small depression in the enamel of a tooth.

Recurrent caries: dental caries that extends either beneath or beyond the margins of a restoration.

Resin: a low viscosity liquid monomer that is applied to the cavity usually to improve adaptation of the filling material.

Root canal (or endodontic) treatment: the treatment of a damaged necrotic pulp in a tooth to allow the tooth to remain functional in the dental arch.

Secondary caries: see recurrent caries

Smear layer: the loosely attached mineral and organic debris left on the surface of, particularly, dentine after the surface has been mechanically instrumented.

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