What type of filling? Best practice in dental restorations

B L Chadwick, P M H Dummer, F D Dunstan, A S M Gilmour, R J Jones, C J Phillips, J Rees, S Richmond, J Stevens, E T Treasure

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. Studies in the UK suggest that much of restorative dentistry is replacement of existing restorations, accounting for around 60% of all restorative work. Similar figures have been found in other parts of Europe, and the USA. (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, which formed the basis of a recent issue of Effective Health Care.

The reasons for replacing a restoration are numerous and vary with tooth type and restorative material. 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. A lack of standardisation exists, and no generally agreed criteria are used to decide when a restoration requires replacement.

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, composites and cermet, cast gold, and other alloys inlays and porcelain (box 1).

Research methods

The systematic review 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. 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
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. 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.

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

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dental amalgam</td>
<td>An alloy of mercury with silver and other metals such as tin and copper.</td>
</tr>
<tr>
<td>Composite resin</td>
<td>Tooth coloured and essentially a mixture of filler particles.</td>
</tr>
<tr>
<td>Glass ionomer cements</td>
<td>Tooth coloured and adhere chemically to tooth tissue.</td>
</tr>
<tr>
<td>Resin modified glass ionomer cement and compomers</td>
<td>New generations of materials that contain resin.</td>
</tr>
<tr>
<td>Cast gold and other alloys</td>
<td>Called inlays and are made outside the mouth.</td>
</tr>
<tr>
<td>Porcelain</td>
<td>Inlays can now be cemented into the prepared cavity.</td>
</tr>
</tbody>
</table>

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.

Direct methods
This section reports on the longevity of materials which are directly placed: amalgams, composites, and other 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. 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.

Composite restorations
Forty eight studies involved composite restorations but without use of dentine adhesives.
3. There appeared to be little difference in survival compared with groups 2 and 3. It seems that acidic primer (groups 1a and 1b) show better results than those using other acids. Enamel etching (with or without enamel bevel) is a 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). However, the few studies with at least 5 years follow up showed signs of significant failure, particularly the multicentre studies.

Survival of composite was influenced significantly by material type with light cured microfilled and densely filled materials being more successful between 6.5 years and 8.5 years, whereas the older autopolymerising macrofilled 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 groups: 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). 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) is clinically effective for long term retention; clearly, mechanical retention is also effective for the retention of restorations. Newer materials (group 1) appear to perform better than older materials (groups 2/3). Use of all dentine bonding systems reduced patient pain after placement.

Comparison of amalgam with composite

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). However, the few studies with at least 5 years follow up showed signs of significant failure, particularly the multicentre studies.

Survival of composite was influenced significantly by material type with light cured microfilled and densely filled materials being more successful between 6.5 years and 8.5 years, whereas the older autopolymerising macrofilled 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 groups: 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). 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) is clinically effective for long term retention; clearly, mechanical retention is also effective for the retention of restorations. Newer materials (group 1) appear to perform better than older materials (groups 2/3). Use of all dentine bonding systems reduced patient pain after placement.

Indirect methods: inlays

Twenty seven studies were included which examined the longevity of inlays using ceramics, gold, and composites. 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) 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. There is some evidence, although limited, to support the use of heat cure in addition to light cure in composite inlays. There are some reports of post-operative pain with inlays and these need further investigation.

Cost effectiveness

The 30 economic studies which were identified were of poor quality 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...
Dental restorations

205

134

NHS regulatory structures designed to pro-
evidence on their long term clinical perform-
and introduced into practice with limited
making.

amalgams,128–130 composite,129 and glass iono-
mer 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 re-
ported, and is obviously an important issue
when trying to identify the point at which
a restoration is replaced.10 115 It is claimed
that the likelihood of having a restoration
replaced is more than doubled when a patient
changes practitioner.135 Appropriate criteria for
replacement of restorations are needed, and
dental schools should train dentists in their use
to reduce unnecessary procedures and improve
quality.17 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 perform-
ance. 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 pro-
mote 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 ma-
terial 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.

This review was commissioned and funded by the Scottish Office. The contents are the responsi-
bility of the authors. We are grateful to the large panel who advised us in the preparation of
the systematic review and to the referees who commented on the
Effective Health Care bulletin. We acknowledge with thanks the
support and advice of Trevor Sheldon, Andy Ugg, and staff of the
NHS Centre for Reviews and Dissemination.

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 den-
tal 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 iono-
er 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 re-
ported, and is obviously an important issue
when trying to identify the point at which
a restoration is replaced.10 115 It is claimed
that the likelihood of having a restoration
replaced is more than doubled when a patient
changes practitioner.135 Appropriate criteria for
replacement of restorations are needed, and
dental schools should train dentists in their use
to reduce unnecessary procedures and improve
quality.17 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 perform-
ance. 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 pro-
mote 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.

Conclusi
Dental amalgam is the direct restorative ma-
terial 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.

This review was commissioned and funded by the Scottish Office. The contents are the responsi-
bility of the authors. We are grateful to the large panel who advised us in the preparation of
the systematic review and to the referees who commented on the
Effective Health Care bulletin. We acknowledge with thanks the
support and advice of Trevor Sheldon, Andy Ugg, and staff of the
NHS Centre for Reviews and Dissemination.

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 den-
tal 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 iono-
er 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 re-
ported, and is obviously an important issue
when trying to identify the point at which
a restoration is replaced.10 115 It is claimed
that the likelihood of having a restoration
replaced is more than doubled when a patient
changes practitioner.135 Appropriate criteria for
replacement of restorations are needed, and
dental schools should train dentists in their use
to reduce unnecessary procedures and improve
quality.17 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 perform-
ance. 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 pro-
mote 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.

Conclusi
Dental amalgam is the direct restorative ma-
terial 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.

This review was commissioned and funded by the Scottish Office. The contents are the responsi-
bility of the authors. We are grateful to the large panel who advised us in the preparation of
the systematic review and to the referees who commented on the
Effective Health Care bulletin. We acknowledge with thanks the
support and advice of Trevor Sheldon, Andy Ugg, and staff of the
NHS Centre for Reviews and Dissemination.

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 den-
tal 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 iono-
er 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 re-
ported, and is obviously an important issue
when trying to identify the point at which
a restoration is replaced.10 115 It is claimed
that the likelihood of having a restoration
replaced is more than doubled when a patient
changes practitioner.135 Appropriate criteria for
replacement of restorations are needed, and
dental schools should train dentists in their use
to reduce unnecessary procedures and improve
quality.17 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 perform-
ance. 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 pro-
mote 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.

B L Chadwick, P M Dummer, F D Dunstan, A S Gilmour, R J Jones, C J Phillips, J Rees, S Richmond, J Stevens and E T Treasure

Qual Health Care 1999 8: 202-207
doi: 10.1136/qshc.8.3.202

Updated information and services can be found at:
http://qualitysafety.bmj.com/content/8/3/202.citation

These include:

Email alerting service
Receive free email alerts when new articles cite this article. Sign up in the box at the top right corner of the online article.

Notes

To request permissions go to:
http://group.bmj.com/group/rights-licensing/permissions

To order reprints go to:
http://journals.bmj.com/cgi/reprintform

To subscribe to BMJ go to:
http://group.bmj.com/subscribe/