Preformed metal crowns for primary and permanent molar teeth: review of the literature

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Abstract

The aim of this study was to carry out a review of the use and efficiency of preformed metal crowns (PMCs) for primary and permanent molar teeth. A literature search of English language journals was carried out using MEDLINE. Papers that addressed areas related to the use of PMCs regarding indications for use, placement techniques, risks, longevity, cost effectiveness and utilization were included in the review. Eighty-three papers were traced which fulfilled the above criteria, the majority addressing PMCs in primary molar teeth. Over half the papers were concerned with placement techniques and indications for use, with fewer papers reporting on clinical studies. The clinical data on PMCs spanned a considerable number of years and involved heterogeneous populations of patients, different makes and designs of crown, and differences among the operators and evaluators who were involved in the studies. The results, however, were in agreement that PMCs are superior to amalgam restorations for multisurface cavities in primary molar teeth.(*Pediatr Dent*. 2002;24:489-500)

KEYWORDS: PEDIATRIC RESTORATIVE DENTISTRY, PREFORMED METAL CROWNS, STAINLESS STEEL CROWNS, LITERATURE REVIEW

Preformed metal crowns (PMCs) for primary molar teeth were first described in 1950 by Engel,[1] followed by Humphrey.[2] Since then, design modifications have simplified the fitting procedure and improved the morphology of the crown so that it more accurately duplicates the anatomy of primary molar teeth. The morphology of a primary molar tooth differs significantly from its permanent successor, in part by having its greatest convexity at the cervical third of the crown.[3] The thin metal of the preformed crown margin is flexible enough to spring into and be retained by this undercut area.[4-6] The enamel and dentin of the primary molar crown are proportionally much thinner than in the permanent tooth[7] and are relatively susceptible to caries attack.[5] In addition, the primary pulp is large with prominent pulp horns and is situated in close proximity to the mesial surface of the tooth crown, particularly in mandibular primary molars, placing exacting demands on cavity design.[7-9]

The stainless steel crown for the permanent molar is designed so that it closely resembles the anatomy of a first permanent molar tooth and it also obtains its retention mainly from the cervical margin area.

The purpose of the study was to carry out an extensive literature review of the use and efficiency of preformed metal crowns for primary and permanent molar teeth.

A literature search of English language journals only was carried out using MEDLINE. Keywords used were stainless steel crowns, preformed metal crowns, primary molar crowns, permanent molar crowns. Copies of relevant references cited in the literature obtained were also acquired. Papers were considered appropriate to include in the review if they addressed one or more of the following areas related to use of PMCs: (1) indications for use, (2) placement techniques, (3) risks, (4) longevity, (5) cost effectiveness, and (6) utilization.

Eighty-three papers were retrieved, which fulfilled the review criteria. Twenty-five papers addressed indications for use, and 34 discussed placement of PMCs in primary molar teeth. Indications for use and placement techniques for PMCs in permanent molars were addressed by 15 and 12 papers, respectively. Twelve papers were traced which reported on clinical studies, 10 studies evaluated PMCs in primary molars, 1 study also included permanent molar teeth, and 2 of the papers were evaluations involving pulpotomies and PMCs in primary molar teeth.

Indications for use—primary molar teeth

The indications given in the literature for use of PMCs for primary molar teeth have been endorsed by a number of authors:

- after pulp therapy;[6,10-29]
- for restorations of multisurface caries and for patients at high caries risk;[6,10-15,17,18,20,22-24,27-31]
- primary teeth with developmental defects;[6,10,12,13,15-18,20-24,27-29,31, 32]
- where an amalgam is likely to fail (eg, proximal box extended beyond the anatomic line angles);[14,20-22,29,30,32]
- fractured teeth;[6,11-13,15,23,28,29]
- teeth with extensive wear;[6,24,29,31]
- abutment for space maintainer.[6,10-13,15,22,23,28,29,31]

Nash[20] made the point that carrying out a crown preparation of a tooth solely for use as an abutment is destructive to tooth tissue and that bands are preferable to support appliances to preserve arch space. When both a crown and space maintainer are required, the space maintainer should be attached to a band cemented over the crown; with this arrangement, subsequent removal of the space maintainer leaves an intact and smooth crown surface.[20]

In a recent editorial, Pinkerton[32] suggested that indications for placement of a PMC should include child patients who are unlikely to attend regular recall appointments or who are unlikely to be reliable preventive patients. Duggal[24] listed one exclusion criterion for fitting a primary molar crown—namely, an inability to fit one. This encompassed the amount of tooth tissue remaining and the ability of the patient to cooperate with the treatment. It has also been recommended that teeth approaching exfoliation within 6 to 12 months should not be fitted with a PMC.[20]

Indications for use—permanent molar teeth

Less literature was available that discussed indications for use for permanent molar PMCs:

1. interim restoration of a broken-down or traumatized tooth until construction of a permanent restoration can be carried out[12,13,16,28,33-39] or the eventual orthodontic status is established;[22, 38]
2. when financial considerations are a concern, permanent PMCs are useful as a medium-term, economical restoration in clinically suitable cases;[36,38,40]
3. teeth with developmental defects.[12,22,24,28,34,35,37-39] The crowns are beneficial for restoring the occlusion and reducing any sensitivity caused by enamel and dentin dysplasias in young patients;
4. restoration of a permanent molar which requires full coverage but is only partially erupted.[11,22,28]

Placement procedures for primary molar crowns

Primary molar tooth preparation

A number of authors recommended placement of wooden wedges before commencing tooth preparation. These serve both to separate neighboring teeth and to reduce the risk of iatrogenic damage to the enamel of these teeth. In addition, they help to depress the gingival tissues and rubber dam.[12,20,23,28,31] Care is needed, however, not to extrude the tooth during restoration. Full et al,[5] considered that preparing the occlusal surface first allows better access to the proximal areas of the tooth. Other authors recommended preparing the mesial and distal slices before reducing the occlusal.[12,21] The occlusal surface of the tooth should be reduced by about 1.5 mm, maintaining its occlusal contour[5,12,15,18,20,21,41] or until the tooth is out of occlusion with adequate room to fit a crown.[6,24] If much of the occlusal surface has already been lost to caries, then reference can be made to the marginal ridges of neighboring teeth in regards to the amount of further reduction needed to obtain space for the crown.[20]

Proximally, tooth reduction is made through the mesial and distal contact areas, the plane of the preparation being cut at a sufficient angle to avoid the creation of ledges or steps at the gingival finishing line,[12,15,20,21,24,29,41] with care being taken to avoid damage to the neighboring tooth.[6,12] Lastly, the clinician should ensure that all line angles are rounded.[6,12,15,18,20,21,28,41]

Effective local anesthesia of the tooth under preparation is generally recommended[5,6,12,13,15,16,18,20,24,29,31] with additional anesthesia of the palatal surfaces of upper teeth advised for some patients.[5] Even with a root-treated tooth, preparation of the mesial and distal contact areas will traumatize the local gingival tissues, and anesthesia is appropriate for these patients also.[5,12,24] A topical analgesic applied to the gingival area may be sufficient in these cases.[24]

Preformed metal crowns for primary molars are not close fitting, except at the margin, so the preparation coronal to the gingivae does not need to be precise.[16] The most bulbous part of the primary molar tooth is at its cervical third, and it is this undercut area at the gingival margin, particularly buccally and lingually, which gives retention to the crown.[18,21] The mesial and distal slices should end slightly below the gingivae, on enamel,[15] leaving an undercut area of intact enamel at the cervical circumference of the tooth.[18] The flexible crown wall allows it to spring into these undercut areas, thus gaining retention.

Some authors suggested preparing buccal and lingual walls to produce a gingivally inclined long bevel to facilitate placement of the crown.[5,16,42] Others, however, recommended that minimal or no preparation be carried out on the buccal and lingual sides of the tooth crown unless there is a pronounced enamel convexity, and, if present, this should be reduced by only a limited amount.[12,17,20,21,23,29,43,44] Duggal and Curzon[24] recommended trying the selected crown for size before carrying out any lingual or buccal reduction. Any ledge or step present at the mesial or distal finishing line will create difficulty in seating the crown[5,6,12,15] and the clinician may then trim the crown unnecessarily when it is the ledge or step that should be removed.

To obtain retention, the crown must seat subgingivally to a depth of about 1 mm[11,12,20,41,45] and a degree of gingival blanching seems to be inevitable,[6] although some authors[15,18]

interpreted gingival blanching as an indication that further contouring of the crown is necessary. A crown that is high in the occlusion (1-1.5 mm) is acceptable, as it is considered that primary teeth can spontaneously adjust for this amount of occlusal discrepancy over a week or so.[6,24,29]

Removal of caries, and any pulpotomy procedures, has been recommended to be carried out both before[12,18,29,44,46] and after the crown preparation has been completed,[5,20,22] although much of the crown preparation may be completed simply via the removal of caries. One author[28,44] suggested cutting vertical grooves around the prepared tooth crown periphery to increase the surface area and perhaps enhance crown retention by providing resistance against any rotational forces during mastication. The efficacy of this vs a conventional preparation has not been demonstrated, however. Placement of a PMC immediately after completion of a pulpotomy procedure was recommended in 2 papers.[6,46]

Selection of crown size

The selected crown should restore the contact areas and occlusal alignment of the prepared tooth. The crown selection can be done by trial and error,[5,12,15,17,20,28,44] or by measuring the mesiodistal dimension of the tooth space with dividers.[5,12,17,24,29,31,47] It can also be helpful to measure the dimension of the contralateral tooth.[29,47,48] A correctly fitting crown should snap or click into place at try-in.[13,15,24,29,31] More and Pink[15] recommended a bite-wing radiograph at the crown try-in stage to check for any margin overextension in the interproximal area. Radiographs should only be taken where clinically indicated, however, and exposure of the patient to ionizing radiation for assessment of a PMC margin may be considered inappropriate.

Crown modification

It has been reported that, in many instances, modern anatomically contoured crowns need no modification,[6,17,24] and, in one study involving placement of 104 PMCs, the authors trimmed the margins of only 15 of the crowns.[47] There is disagreement with this concept, however.[20,23,26,49] Croll and Riesenberger[23] stated that, in their view, the majority of PMCs, including the prebelled variety, do need adjustment to obtain optimal adaptation to the primary molar tooth. Crowns with little or no festooning at the margin will, of course, routinely need adjustment.[21] If the crown does not fit well, the preparation should be checked for steps at the finishing line, which could cause the crown to bind. The clinician also should ensure that the correct mesiodistal crown dimension has been selected.[28]

Crown trimming can be carried out with crown scissors or an abrasive wheel, the latter considered to give better control than scissors.[28,46,50] Brooke and King[21] added the sensible reminder to carry out all crown trimming procedures away from the patient's face, and to ensure that the patient has adequate eye protection. After trimming, the crown must be crimped to regain its retentive contour, and special crimping pliers are available for this procedure.

Once these adjustments are completed, the crown margins should be thinned and smoothed, final polishing being done with a rubber wheel,[15,18,21,24] followed by a mop and jeweler's rouge.[21,23,28,44] SEM evaluation of polishing procedures for PMCs has demonstrated that the use of rouge for the final polishing step results in the most evenly smooth surface.[51]

Crown adaptation in special cases

When multiple crowns are to be placed in the same quadrant, the adjacent proximal surfaces of the teeth should be reduced more than usual to facilitate placement of the crowns.[20,52] When there is no adjacent tooth, proximal tooth reduction should still be carried out to avoid an excessive crown margin overhang.[29] This is especially important on the distal surface of the second primary molar prior to eruption of the first permanent molar—any overhang here could displace the eruption path of the permanent molar[28,29,53] Mesiodistal drift of the teeth, resulting in loss of arch length and reduced mesiodistal dimension of the tooth crown to be prepared, may require that the PMC have its mesial and distal surfaces flattened a slight amount with pliers[6,20,29,41] or the contact area disced to thin it.[41] When approximating teeth are to be restored with PMCs and there is space loss, both the preparations should be modified to allow the teeth to be fitted with smaller sized crowns than normal. One recommendation was that further reduction of the buccal and lingual tooth walls is carried out rather than more tooth reduction proximally.[41,52]

If the tooth to be crowned is too small for the smallest size crown available, the metal edges of the best-sized crown can be cut and overlapped to reduce the crown circumference, with the overlapping margins being welded together.[20,54] Similarly for a tooth where a large enough crown size is not available, the crown wall of the best-fitting crown can be cut and an additional piece of orthodontic stainless steel band material welded over the space, this is then contoured to the required shape.[54]

Teeth with caries lesions extending apically to the crown margin can have these areas restored before preparing the tooth[12, 20, 41, 54] to permit an adequate finishing line for the crown; or an extension of stainless steel can be soldered to the crown to form a flange for this area.[18,20,45,54] For the bruxing patient, it has been recommended to add solder to the internal occlusal surface to augment wear resistance.[23,28,41,55] Crowns that have perforated from wear can be repaired using a resin composite or resin-modified glass ionomer.[44] Alternatively, they can be replaced with a new crown.

Cementation

PMCs need a generous mix of cement to adequately fill the crown space prior to seating.[5,6,13,20,24] There may be some resistance to seating the crown, however, and it is recommended that the crown be first seated over the lingual or buccal wall and rolled over onto the opposite wall,[15,20,21,24]

which will also help to minimize damage to the crown margin. Once seated onto the prepared tooth, the crown should be maintained under pressure while the cement sets. Excess cement should be seen to extrude from around the entire crown margin,[20] and this is removed after setting.

Removal of excess cement from the contact area is facilitated by means of a length of dental floss or tape with a single knot tied in it.[6,13,15,18,20,23,24,28,29] Croll has suggested removal of excess set resin-modified glass ionomer (RMGI) cement by means of an ultasonic scaler.[23,28] Over the time period of the literature surveyed, different authors have recommended various cements, for example, zinc phosphate,[12,16,18,20] fast-setting zinc oxide,[12,15,16] and polycarboxylate.[6,15,16,20,23,24,29,31,33] The most recent publications (1997 and 1999) recommended RMGI cements.[28,56]

Placement sensitivities

The general advice from the literature was that the use of rubber dam is preferred.[6,13,15,18,20,24,29,33] Difficulties may arise if the tooth being prepared for a PMC is the tooth to be clamped. In this instance, it is suggested that all necessary tooth preparation, except for the distal reduction, be carried out under rubber dam. The distal slice and crown fitting are then completed after rubber dam removal.[6] The amount of occlusal reduction obtained can be checked by comparison with neighboring teeth.[20] More and Pink[15] recommended cutting the interproximal portions of the dam to prevent entanglement of the bur in these areas.

Placement procedures for permanent molar crowns

Permanent molar tooth preparation

The preparation of a tooth for a permanent molar PMC is essentially the same as for a cast metal crown but with a reduction in the amount of tooth tissue removed. It is important that the future preparation needs for a cast restoration are kept in mind when preparing the tooth for a PMC.[28,35,36] Fitting a permanent molar PMC requires significantly more chairside time than a primary molar crown.[38] An occlusal reduction of about 1.5 to 2 mm is needed, and carrying this out first enables the proximal reduction to be done more easily.[35] The walls of the crown are prepared minimally so that they are slightly tapering with the finishing line ending in a smooth feather edge and placed just below the level of the free gingival tissue.[34-36] Sharp line angles should be smoothed to ensure that the crown does not bind on seating.[35] Radcliffe and Cullen[39] recommended preparation of proximal slices but no preparation of the buccal or lingual tooth walls. This procedure allows the extra option of future placement of an onlay, rather than only a full coverage crown.

It is helpful to measure the width between the mesial and distal surfaces of the neighboring teeth for an accurate indication of the crown size needed,[36] or to measure the dimension of the contralateral tooth.[48] Alternatively, preoperative study models can be utilized to give details of

crown width and height.[38-40] It has been suggested that study models should routinely be taken for patients who are to receive a permanent molar PMC, as this allows better evaluation of the patient's occlusion and whether occlusal adjustment is needed prior to preparation.[39] It is wise to check the size of crown needed before commencing the preparation, as there are fewer sizes of crown available for permanent teeth compared with the range for primary molars, and the size range available may not be adequate for all requirements.

Crown modification for permanent molar PMCs

The selected crown should establish a good contact area with neighboring teeth and snap into place cervically.[35,36] If required, the crown margin can be trimmed with crown scissors or by means of a dental stone. The crown gains its retention from the cervical margin area so the crown margin must be recrimped after any adjustments to ensure an accurate fit to the tooth. Specialized crimping pliers are available for this purpose and crown-contouring pliers can be used to improve interproximal contact area morphology and to modify the gingival margin contour.

Once recrimped, the crown margins should be thinned, smoothed, and polished to a high shine using rubber points and rag wheels. The occlusion should be carefully checked and adjustments made if needed. Unlike the primary molar crowns, those for permanent teeth cannot be left in hyperocclusion. Adaptation and finishing of the crown margins require particular attention to ensure maintenance of periodontal health.[28,35,38]

Where a crown is to be placed with a caries lesion that has extended subgingivally, the original tooth morphology should be restored with either a bonded composite resin or an amalgam restoration before commencing the crown preparation. It is not recommended to utilize only cement in these areas.[36] Alternatively, the crown margin can be contoured to extend subgingivally here.[35] In view of the potential longevity of these crowns, a bitewing radiograph is recommended at the final try-in stage, before cementation, to check the marginal fit mesially and distally as it is often not possible to check these areas adequately by means of an explorer.[28,35-38,53]

Cementation

RMGI cement has been recommended as the preferred material for cementation of permanent molar PMCs.[28,56] All excess cement at the margins should be carefully removed by means of an explorer, and a piece of knotted dental floss passed interproximally to dislodge excess cement in these areas.

Preformed crowns for permanent teeth can function as an interim restoration for many years before a more permanent restoration is placed. In some cases, the occlusal surface of the crown may become perforated from wear.[38] In some instances, repair can be carried out using amalgam or bonded composite resin, alternatively, the internal aspect of the occlusal part of the crown can be reinforced by the

addition of solder prior to cementing the crown.[55] Murray and Madden[40] describe a technique where, prior to fitting the crown, the occlusal surface is removed, retaining the marginal ridges. After cementation, a bonded amalgam core is built up within the crown to restore the occlusal surface. This technique minimizes the risk of occlusal perforation, however, a greater occlusal reduction in tooth height (of 3-4 mm, is required to provide adequate space for the amalgam.[40]

Developmental defects of teeth

Developmental defects can affect one or all of the teeth and numerous etiological factors have been considered to be causative.[57] Genetically determined tooth defects may be linked to a systemic disorder such as coeliac disease or be solely related to the teeth.[58] *Amelogenesis imperfecta* and *dentinogenesis imperfecta* are hereditary conditions. Teeth affected by *amelogenesis imperfecta* have poorly mineralized enamel with defects in the crystallite structure.[59] The teeth have a yellow or brown discoloration[60,61] and attrition and loss of enamel can lead to early destruction of the tooth crown. In *dentinogenesis imperfecta,* the enamel is normal but appears discolored due to the underlying abnormal dentin. There is malformation of the dentinoenamel junction with irregular dentin containing large areas of uncalcified matrix.[62] The enamel is lost early,[62] leading to rapid loss of dentin. In both disorders, the pulp space may become obliterated by secondary dentin formation.

The rapid loss of tooth tissue results in early wear and loss of occlusal height, and can cause sensitivity in some individuals. Varying degrees of severity of developmental defects are seen and PMCs are considered to be the treatment of choice for primary molar and permanent first molar teeth in those young patients significantly affected by these disorders.[6,10,12,13,15-18,20-24,27-29,31,33-35,37-39,63]

Risks

Periodontal concerns

A number of studies have reported on the gingival health of primary teeth restored with PMCs. Goto[30] reported the incidence of gingivitis in primary teeth restored with nickel-chromium crowns. He found the percentage of gingivitis associated with a crown to be higher in the posterior part of the mouth than the anterior and to be more strongly associated with poor fitting crowns. He did not report the incidence of gingivitis in control teeth.[30]

Henderson[14] reported that the plaque accumulation index for stainless steel crowned teeth was generally lower than that for the entire mouth. Levels of marginal gingivitis around crowns rated for fitting as 'good' or 'fair' were statistically similar, with a higher degree of gingivitis associated with crowns having a 'poor' fit. Data for control teeth, however, were not given.[14]

Webber[64] found no adverse change in the health of the gingivae after placement of PMCs. Myers[65] reported a close relationship between the presence of marginal gingivitis and defects in the adaptation of the crown margin, however, no data were given for control teeth. Paunio et al,[47] evaluated the gingival condition of 208 paired teeth over a period of 6 months—104 teeth had been restored with PMCs and, of the 104 controls, 86 had received amalgam restorations. They noted some thickening of the marginal gingivae around a number of the crowned teeth, but the average gingival index value was found to be similar for the test and control teeth at baseline and at the 2- and 6-month assessments.[47] Durr et al,[66] evaluated 101 crowns in primary teeth in 45 patients, all of which had been placed by predoctoral students. Ninety-five crowns were judged to be "non-ideal," many having a detectable gap between the crown margin and tooth surface. However the crowns were considered to be clinically functional and acceptable. The ginigival index and plaque accumulation scores reported for the crowned teeth did not significantly differ from those of the unrestored contralateral controls.[66]

Checchio et al,[67] measured crevicular fluid flow around 50 primary molar crowned teeth and 50 contralateral controls. They reported a similar rate of crevicular flow for all individuals with good oral hygiene regardless of the quality of fit of the crown. Patients with poor oral hygiene demonstrated an increased level of flow.[67] Einwag[68] evaluated 118 PMCs on primary teeth and 70 PMCs on permanent first molars compared with uncrowned adjacent teeth as controls over 3 years. He reported an insignificant, clinically acceptable irritation of the gingivae associated with primary PMCs. Permanent molar teeth with PMCs, however, demonstrated a noticeable increase in sulcular depth once the patient reached 15 years of age.[68]

In summary, the extent of plaque accumulation and frequency of gingival problems associated with stainless steel crowns in primary teeth seem to be unexceptional.[29] A well-adapted crown margin facilitates good oral hygiene and healthy gingivae,[6,68] but gingivitis can occur if the crown margins are inadequately contoured[14,15,21,30,65] or if residues of set cement remain in contact with the gingival sulcus.[15,29] Good- to moderate-fitting crowns seem to produce minimal gingival problems or plaque accumulation.[14,64-66,68] Patients in need of PMCs are likely to be at a moderate-to-high risk for caries, with a tendency to accumulate plaque and marginal debris. A preventive regime including oral hygiene instruction should be routinely included in the treatment plan for these patients.[6,14]

Nickel allergy

One paper was traced regarding nickel sensitization associated with PMCs. Feasby et al,[69] reported an increased nickel-positive patch test result in children 8 to 12 years of age who had received old formulation nickel-chromium crowns. A second group of children with conventional stainless steel crowns showed no statistically significant difference in patch test responses compared to a third control group with no history of nickel-containing dental appliance use.[69]

The nickel content in the discontinued formulation nickel-chromium crowns was around 70%, significantly greater than that of contemporary stainless steel crowns, which contain 9%-12% nickel, similar to that of many orthodontic bands and wires.

Nickel-containing alloys have been in use in orthodontic appliances for over 35 years, and there are a number of papers addressing sensitization issues related to this form of treatment. Evidence for direct sensitization of a patient from fixed-appliance orthodontic treatment, however, is scarce.[70] The incidence of adverse reactions attributed to orthodontic treatment is estimated as 1 in 100,[71] and the majority of these reactions are due to contact dermatitis from extraoral headgear.[72-74] Janson et al,[75] in a recent review of the literature, concluded that orthodontic treatment utilizing conventional stainless steel appliances does not, in general, initiate or aggravate a nickel hypersensitivity reaction.

Nickel hypersensitivity is more prevalent in females than males and is considered to be associated with pierced ears or metal buttons in clothing. Two studies[70,76] reported that orthodontic treatment with nickel-containing stainless steel appliances, if carried out before ear piercing, appeared to reduce the prevalence of nickel hypersensitivity. Higher concentrations of contact allergen may be required to elicit a response from the oral mucosa compared with skin,[77] but the type and duration of oral exposure needed to initiate this potential is not known.[70]

It is difficult to evaluate nickel release into the oral cavity,[78] and it is considered that salivary proteins may have a protective effect by acting as corrosion inhibitors on the surface of the alloy.[79] Adjustment of a crown by cutting or crimping the margin will leave a roughened surface. To minimize any likelihood of corrosion, it is important that these areas are then smoothed and polished to a high gloss.[80-82] In a similar way to orthodontic appliances, soldered or welded crowns are likely to be more susceptible to corrosion,[80,83] although this has not been well documented.

Esthetics

Improved standards of living and better education over the last 20 to 30 years have given rise to higher expectations of treatment.[84,85] Some parents have expressed dislike of the appearance of a PMC,[23,33] with crowns for the lower first primary molars causing the most comment. One case was described where parents refused a primary molar metal crown on the basis of appearance, and the tooth was restored using an acetate molar crown form and bonded composite resin.[86] There is no clinical data available, however, to indicate the success or otherwise of this procedure.

A well-known method of improving the appearance of metal crowns is to cut a window in the buccal wall of the cemented crown and to restore this with composite resin, the thick cement layer acting as a guide to prevent damage to the tooth surface. Such a procedure does improve the esthetics,[29,33,87] but metal is usually still visible,[28] and the result can be compromised by gingival bleeding when the composite is placed.[88,89] It is a time-consuming procedure[88,89] and there have been no formal studies to date reporting on the clinical efficacy of these modified crowns. Carrel and Tanzilli[90] evaluated a veneering resin for both anterior and posterior crowns with disappointing results—only 32% of the veneered crowns were intact at 1 year, 41% having debonded and 27% being partially retained.

Greater attention has been paid to improving the esthetics of anterior crowns than to molar crowns, although veneered molar crowns are available.[29,91] The need for improved esthetics in primary molar crowns by means of a strongly bonded, tooth-colored veneer, which is flexible enough to be adjusted, suggests that a significant research effort is needed in this area.

Longevity of preformed metal crowns

The earliest study that could be traced which compared preformed crowns with control restorations was by Braff in 1975.[92] who compared PMC with multisurface amalgams in primary molar teeth. He evaluated 76 crowns in 39 patients, and 150 amalgam restorations in 35 patients over 32 months, with a mean patient age of 4 years at placement. Of the amalgam group, there were 131 "true" failures (87%), and 19 "true" crown failures (25%). A "true" failure is considered to occur when the crown or restoration is directly involved in the failure, a "false" failure can result from a cause remote from the restoration, such as extraction of a crowned tooth resulting from an unsuccessful pulpotomy or replacement of an amalgam restoration because of caries remote from the restoration margins. Braff suggested that, for patients near 4 years of age, PMCs were more economical than multisurface amalgams.[92]

Dawson et al,[93] published a study along similar lines in which they followed 114 patient records over a minimum of 2 years, the average age of the patients at placement being 5.5 years. These authors compared 114 Class I and 102 Class II amalgam restorations with 64 PMCs in primary molar teeth. In total, 37% of Class I and 71% of Class II amalgam restorations were replaced over the course of the study, compared with only 13% of the PMC. The authors concluded that, for patients under 8 years of age, PMC were the treatment of choice for primary molars, particularly for multisurface lesions in the first primary molar.[93]

Eriksson et al,[94] evaluated 104 crowned teeth paired with antimere controls to exfoliation, the average age at placement being 6 to 7 years. Only 80 of the control teeth received amalgam fillings, the remaining 24 teeth being sound. Twenty-two of the crowned teeth (21%), and 66 of the 80 amalgam-restored teeth (83%) required further treatment. Based on a cost-per-patient visit, the authors estimated that the teeth restored with PMCs cost 35% less to treat than the controls.[94] Messer and Levering,[95] and Levering and Messer,[96] published retrospective data on 131 patients with 331 PMCs[95] and 226 patients with 1898 amalgam restorations[96] in primary molar teeth. Patient records were followed for up to 9 years. Of the 331 crowns

evaluated,[95] 88% (291) were successful to the end of the study period with 40 failures (12%). The group of failed crowns included 19 defective pulpotomies, and the authors did not distinguish between failures due to pulpotomy issues and failures due to breakdown of the crown, although they did distinguish true and false failures for the amalgam group. The average patient age at placement of the amalgam restorations was 5 years, and the authors recorded a success rate of 73% (1380) for Class I and II restorations combined. Of the Class II amalgams, those that were "true" failures lasted, on average, about 20 months, while those that were a success had a life span of at least 56 months. The authors concluded that PMC are more durable than Class II amalgam restorations in primary molars, with a Class II amalgam restoration approximately twice as likely to fail as a PMC.[95]

Roberts and Sherriff[97] reported a 10-year evaluation of 1024 amalgam restorations and 673 PMC in primary molar teeth, and 652 amalgams and 43 PMC in permanent molar teeth. This was the only clinical study traced which evaluated permanent molar PMCs with control restorations. The Class II amalgam restorations placed in primary molars were of minimal size. Any caries lesion requiring a cavity outline of greater than classical minimal proportions and any cavity involving both proximal surfaces was restored with a PMC. Among the primary molar crowns there were 13 "true" failures (2%) and one "true" failure for the permanent molar crowns (2%). The true failure rate among amalgam restorations in primary teeth was 9% overall, and the failure rate for amalgam restorations in permanent teeth was 11%. The authors gave a 5-year estimated survival rate of 92% for PMCs, 67% for Class II cavities in primary molars, and 82% for Class II amalgam restorations in permanent teeth. A 5-year estimated survival rate was not given for permanent molar PMC. Perhaps because of the minimal size of the Class II amalgam restorations placed in this study, no significant difference in survival rates between Class I and II restorations in primary or permanent teeth was seen. Also, no relationship was found between the patient's age and the age of replaced restorations,[97] unlike the 2 studies cited earlier where the percentage of successful amalgam restorations or PMC increased with increasing age at placement.[95,96]

O'Sullivan and Curzon[98] reported data over a minimum of 2 years from record cards of 80 child patients needing comprehensive dental care delivered under general anesthesia. The median age of the patients at restoration placement was 4.5 years, 55% of the children being between 3 and 5 years of age. The majority of the patients had severe behavior-management problems and extensive caries. Four hundred forty-five teeth were restored—210 received PMCs, 106 received amalgam restorations, and 113 received either a composite resin or glass ionomer restoration. The failure rates were 3% for PMCs, 16% for amalgams, and 29% for composite resin and glass ionomer restorations. The authors commented that the cost and time needed for placement of a composite resin restoration was approximately equal to that of a PMC. Their recommendation for treatment of young children with gross caries in primary molars under general anesthetic was the placement of a PMC.[98]

Papathanasiou et al,[99] carried out a 2-year retrospective evaluation of a random sample of patient record cards and also included restorations other than amalgam. They reported on 604 restorations placed in patients aged between 3 and 10 years of age, half of the restorations being in children aged 3 to 5 years, "true" and "false" failures rates for the groups of restorations were not given. The glass ionomer restorations had the highest frequency of failure at around 73% and a median survival time of 12 months. Composite resin and amalgam restorations had failure rates of approximately 43% and 30%, respectively; PMCs demonstrated the lowest failure rate of about 20%. The 4-year survival estimates for composite resin and glass ionomer were 40% and 5%, respectively; the 5-year survival estimated values for amalgam restorations and PMCs were 60% and 68%, respectively. It was not possible to distinguish between Class I and II amalgams from the data given in the paper.[99]

Einwag and Dünninger[100] retrospectively evaluated paired stainless steel crowns and 2-surface amalgam restorations in 66 patients over 8 years. The survival rate of PMCs was about 92% at 3 years, 90% at 4.5 years, and 83% at 8 years. The survival rates for amalgam restorations were 66% at 3 years and about 36% at 4.5 years. The authors concluded that, for primary teeth with caries involving 2 or more surfaces, placement of a stainless steel crown was superior to restoration with amalgam.[100] Tate et al,[101] carried out a retrospective comparison of success rates of PMCs vs amalgam and composite restorations placed under general anesthesia in young children with early childhood caries. Two hundred forty-one records of patient follow up over at least 6 months were reviewed. It was not possible to separate the results for anterior and posterior restorations from the data given in the paper. Overall failure rates for amalgam and composite resin were 21% and 30%, respectively, significantly higher than the 8% failure rate for PMC.[101]

Gruythuysen[102] reported on a 2-year follow up of pulpotomies in 106 primary molars in 57 children of mean age 5.5 years at placement. The success rate for pulpotomies at 2 years was significantly higher in teeth restored by means of PMCs (85%) than with an amalgam (68%).[102] Golan et al,[103] reported retrospective data comparing the success rates of pulpotomy in primary molars restored by means of PMC or amalgam restorations. Three hundred forty-one teeth were evaluated, 287 restored with PMC and 54 with amalgam, of which 34 were multisurface restorations. Failure rates for PMC and multisurface amalgam restorations were 36 (13%) and 9 (26%), respectively.[103] The authors reported no statistically significant difference between the groups, but the imbalance in sample numbers leads to some difficulties in interpretation, and the data may indicate a trend towards a higher failure rate for multisurface amalgam.

Papathanasiou et al,[104] in a survival analysis study of data from 128 patient records of treatment involving 604 restorations, showed PMCs to have the highest survival rate, followed by amalgam, composite resin, and glass ionomer. The authors calculated the 5-year survival estimate as approximately 68% for PMCs and 60% for amalgam restorations.[103]

A recent systematic review and meta-analysis[105] of clinical studies comparing PMCs with amalgam restorations in primary molars demonstrated evidence of the clinical effectiveness of treatment with PMCs over amalgam restorations. In the studies evaluated for the meta-analysis, the authors of 2 papers[94,97] indicated that PMCs were always used to restore the largest caries lesions, amalgam being reserved for the less extensively involved cavities. It is likely, however, that in all the studies evaluated this method of allocating treatments was adopted, adding a negative bias to the outcome for the crowned teeth and strengthening the evidence for the clinical performance of PMCs.

The primary molar PMC is usually reserved for treating multisurface or large caries lesions, and for restoring teeth after pulp therapy. In regard to this, the most appropriate studies to consider in terms of longevity are those where direct comparison can be made between PMCs and Class II amalgam restorations. Five sets of published data from the present review compared PMCs with multisurface amalgam restorations[92,93,95-97,100] (Table 1). The authors of these papers were in agreement in concluding that preformed crowns are superior to Class II amalgam restorations for multisurface cavities in primary molars.

Cost effectiveness and utilization of preformed crowns

Three papers addressing aspects of the cost benefit of PMC vs amalgam were traced.[94,106,107] Braff,[106] using fees in effect at the time, calculated that over an average of 2.6 years, the cost per tooth per month for PMCs was 94 cents, 30% less than the $1.34 cost per month for a multisurface amalgam. He concluded that PMC were more cost effective than multisuface amalgams for primary molar teeth.[106]

Eriksson et al,[94] reported a 7-year follow-up of PMCs and amalgam controls. They found that around 1 tooth in 5 in the PMC group needed further treatment, compared with approximately 2 out of 3 teeth restored with amalgam. They calculated that the total cost of treatment for the amalgam-restored teeth was 35% higher than for the PMC group.[94]

Levering and Messer[107] examined costs associated with first and subsequent placements of amalgam and PMC restorations followed to exfoliation, or the end of the study,

Table 1. Data from Studies Comparing Preformed Metal Crowns with Multisurface Amalgam Restorations in Primary Molar Teeth					
Study reference and date	Multisurface amalgam		Preformed metal crown		Study duration
	Number placed	Failures	Number placed	Failures	Years
Braff 1975[92]	150	131 (87%)	76	19 (25%)	2.5
Dawson et al 1981[93]	102	72 (71%)	64	8 (13%)	2 minimum
Messer[94]/Levering 1988[96]	1177	255 (22%)	331	40 (12%)	5
Roberts and Sherriff 1990[97]	706	82 (12%)	673	13 (2%)	10
Einwag and Dünninger 1996[100]	66	38 (58%)	66	4 (6%)	8
Raw data total (raw data %)	2201	578 (26%)	1210	84 (7%)	Mean=5 y

in 226 child patients. They reported that molar teeth restored with PMC needed a total investment of 3 cost units (CUs) compared with 2 CUs for amalgam restorations, a CU being linked to the cost of a single-surface amalgam. These authors included the cost of pulpotomy treatment in their cost calculations for PMC, which will have increased the estimated cost of PMC placement.

Data for failure rates from the 5 clinical evaluations which compared PMC with multisurface amalgam restorations are given in Table 1. The studies cannot be directly compared, as there will have been many differences in operator effect, patient selection, study methodology, and changes in caries rates over time. However, it is interesting to use these data to gain an idea of replacement costs. From Table 1, the average failure rates are around 4 times greater for amalgam compared with PMCs over approximately 5 years. Taking a hypothetical group of 100 Class II amalgam restorations and 100 PMCs in primary molars, with failure rates of 26% and 7%, respectively and at fees of $55 for a Class II amalgam restoration and $91 for PMCs (taken from Medicaid fees, 2000), replacement costs for the amalgam group would be approximately 2.2 times more than the PMC group. This is a conservative cost estimate for Class II amalgams and a generous estimate for PMCs, as it assumes that all the hypothetical PMC replacements would be new crowns, when a number would be a recementation of the original crown. It also assumes that the hypothetical Class II replacements would all be Class IIs, when it is likely that some would become 3-surface restorations or even PMCs.

Dentists spend approximately 50%- 60% of their time replacing restorations,[108,109] which creates added costs for the practitioner and involves extra time and costs for the patient and parent/caregiver to revisit the dental office. Use of a well-fitting PMC, where appropriate, could be expected to last the lifetime of the primary tooth,[12] and, in some cases, permit the tooth to have a lifetime.

PMCs are a valuable addition to the clinician's range of options for restoring broken-down primary molar teeth.[5,27,110,111] Many experienced practitioners can complete a crown placement in the same[94] or less time than they need for a multisurface amalgam.[24] In most cases, placement of a

PMC is a straightforward technique,[5,24,112] yet, a number of authors report its underutilization[16,24,27,46,111,112] In a mail survey of general dentists and pediatric specialists in the United States,[113] general dentists recommended restoring primary molars with amalgam more frequently than did the pediatric specialists—98% of the specialists recommended PMCs compared with 81% of general dentists, a statistically significant difference.[114] In the United States, greater utilization of PMCs by pediatric specialists is likely due to their additional specialist training.[114] In other countries such as the UK, underutilization could partly result from inadequate training in the area of skills needed for managing children who need more advanced restorative procedures, and some dentists may feel that they are unable to carry out these forms of treatment (M Duggal, Leeds Dental Institute, UK, personal communication, 1999).

A novel approach to restoring primary molars with PMCs has been put forward by Evans et al.[115,116] The crowns are cemented without prior caries removal or tooth preparation, and no local analgesia is necessary. In a pilot study of this technique, known as the Hall technique,[115] 49 patients were recruited and 45 crowns successfully fitted. The technique was considered acceptable to the dentists, patients, and parents involved. In addition, a retrospective evaluation of record cards of patients who had received crowns placed using the Hall technique documented 978 crowns in 259 patients for an average duration of 2.7 years. There was a 76% probability that a crown would survive for 1000 days, and a 65% probability for survival to 2000 days (DR Stirrups, Dundee Dental School, personal communication, 2001). A randomized clinical trial is now underway to compare longevity and effectiveness of PMC placed by means of the Hall technique with conventional restorations that the dentist would normally select for these primary molar teeth.

A substantial body of literature has been reviewed for the present study. It is possible that some papers were missed. However, the author is confident that the majority of all relevant published studies in English language journals were retrieved. The clinical evidence documented for use of PMCs has come from nonrandomized and retrospective studies. The best evidence on which to base treatment decisions is considered to come from prospective randomized clinical trials (RCT).[117] The data that we have, however, are important and of value, as it is unlikely that a treatment procedure, available since approximately 1947, could now receive ethics committee approval to be evaluated in a randomized control trial in children. The clinical data published on PMCs spanned 27 years from 1975 to 2002 involving heterogeneous populations of patients, different makes and designs of crown, and the inevitable differences among the operators and evaluators who carried out the studies. All the results, however, were in agreement that PMCs outperformed amalgam restorations for multisurface cavities in primary molar teeth.

Competing interests

Dr. Randall is employed by 3M ESPE, a manufacturer of preformed metal crowns.

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