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SYSTEMATIC REVIEW

# Outcomes of preformed metal crowns placed with the conventional and Hall techniques: A systematic review and meta-analysis

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## Abstract

**Background:** Preformed metal crowns (PMCs) have been used to restore carious primary molars and have a high success and survival rate. There are two methods currently employed for PMC placement - the conventional technique (CT) and Hall technique (HT).

**Aim:** This systematic review aims to compare the outcomes of PMCs placed using the CT and HT.

**Design:** This systematic review was conducted according to the Preferred Reporting Items for Systematic Review and Meta-analysis statement. A literature search of five databases was performed up to 23 August 2022. Clinical studies comparing carious primary molars restored with PMCs using either technique with a minimum 12-month follow-up were included. Risk of bias (RoB) assessment was performed using the National Institutes of Health Quality Assessment tool.

**Results:** Five articles met the inclusion criteria, and four were included for meta-analysis. The 12- and 24-month success and survival rates were above 85% for both groups, with no significant differences shown at 12 and 24 months. The HT requires a shorter treatment duration, is more cost-effective and has a high level of acceptability among parents when compared to the CT. Four articles were rated fair, and one article was rated good in the RoB assessment.

**Conclusion:** Greater consideration may be given towards using the HT as part of standard treatment procedures in managing carious primary molars. Future studies should standardise reporting of outcomes to facilitate a more homogeneous pool of data for future meta-analysis.

KEYWORDS

dental caries, hall technique, paediatric dentistry, preformed metal crowns, systematic review

## 1 | INTRODUCTION

Preformed metal crowns (PMCs) have been used to restore carious primary molars since the 1950s.[1] As PMCs consistently outperform direct restorative materials,[2] they are recommended as cuspal coverage for primary molars that undergo pulp therapy or have multisurface caries.[1,3] The conventional technique (CT) of PMC placement involves local anaesthesia administration, complete caries removal and tooth preparation, followed by fitting and cementation of a PMC.[4] In 2006, the Hall technique (HT), which involves the cementation of a PMC over a carious primary molar using only digital pressure by the dentist or the child's occlusal force, and without any local anaesthesia or caries removal, was introduced.[5] By sealing off the bacteria within the carious tooth with the PMC, the HT offers a biological method to arrest caries in primary molars.[6] Careful case selection must be employed so as to avoid placing a crown on a tooth with pulpal or periapical pathology.[6] Other proposed merits for the HT include its relative noninvasiveness and shorter treatment duration as compared to the CT, which may result in greater acceptance of this technique in children and their parents.[7] Studies in both primary and specialist care settings have shown that PMCs placed with the HT demonstrated superior outcomes than both direct restorations[8,9] and nonrestorative cavity treatment.[9] In recent years, studies have also reported comparable clinical success and survival between the HT and CT.[10,11]

Despite expanding literature on the HT, a global survey found that only 50.6% of paediatric dentists have used the HT, with identified barriers such as insufficient evidence to support its use, or the HT being perceived as substandard dentistry.[12] A systematic review evaluating the effectiveness of HT for primary molars found that the HT had a significantly higher success rate than direct restorations[13] but was unable to evaluate the effectiveness between HT and CT as only one study[10] was included. Furthermore, other outcome measures such as the child's behaviour, level of anxiety and reported discomfort during treatment, and patient and parental acceptance towards the HT were not evaluated. Therefore, this systematic review and meta-analysis aims to address the gap in the literature by assessing and comparing the outcomes of PMCs placed using either the HT or the CT.

**Why this paper is important to paediatric dentists**

- This paper provides evidence regarding the use of the Hall techniques as part of standard treatment procedures in managing carious primary molars.
- A classification for reporting outcomes after preformed metal crown placement is proposed to facilitate homogenous data collection for future meta-analysis.

## 2 | MATERIALS AND METHODS

This systematic review was registered in PROSPERO (ref. CRD42021251066) and conducted according to the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) statement.[14] The research question was formulated with the PICO framework[15]: 'When restoring carious primary molars with PMCs in children (Population), how does the HT (Intervention) compare against the CT (Comparison) in terms of overall success and survival, and other measures including but not limited to: the child's level of anxiety, cooperation, discomfort, changes in occlusion after PMC placement (Outcome)?'

### 2.1 | Search strategy

A systematic search was initially undertaken until 30 June 2021 and repeated on 23 August 2022. The following databases were searched: PubMed, Embase, Scopus, The Cochrane Central Register of Controlled Trials and Web of Science. Hand search of the references of the included studies was carried out to identify any additional eligible studies. Searches for unpublished yet inclusion-worthy research were carried out on the Open Grey and Google Scholar databases. The search strategy employed can be found in Appendix S1.

### 2.2 | Screening and selection

Two calibrated reviewers (DRC and BLT) independently carried out the title and abstract screenings, after which full-text manuscripts were retrieved and reviewed for inclusion in this review. Any conflicts were resolved by discussion with a third author (HJT). The agreement between reviewers was evaluated using Cohen's kappa. The following eligibility criteria were employed:

#### 2.2.1 | Inclusion criteria

a. Clinical studies with a control group involving children aged 2–12, with dental caries affecting primary molars indicated for PMC but without prior symptoms of pulp or periapical pathology.

b. Intervention group: PMCs placed with the HT, satisfying the indications described previously.[8,16]
c. Control group: PMCs restored with the CT.
d. Studies evaluating success and or survival of PMCs placed using HT versus CT over a minimum period of 12 months.
e. Studies assessing the following but not limited to: changes in occlusion, behaviour of the child, self-reported anxiety and discomfort of the child, parental satisfaction, treatment duration and cost-effectiveness.
f. Publications in the English language.

#### 2.2.2 | Exclusion criteria

a. Carious primary molars with pulpal inflammation.
b. Carious primary molars restored with other direct restorative materials or nonrestorative caries treatment.
c. Primary molars treated with PMCs due to other reasons (eg, hypomineralisation).
d. Editorial comments, guidelines, in vitro studies, clinical studies without a control group (eg, case series) and conference or presentation abstracts.

### 2.3 | Data extraction and quality assessment

Two independent reviewers (BLT and DRC) extracted data using standardised pretested electronic data collection forms. Two reviewers (DRC and HJT) independently assessed the included studies for quality of reporting and risk of bias (RoB). The National Institutes of Health Quality Assessment tool was used (https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools). Each criterion was graded either Yes, No, Not Reported, Cannot be Determined or Not Applicable. These tools use a quality rating based on 14 items, where a score of 0–4 = poor, 5–9 = fair and 10–14 = good quality.[17] Disagreements were resolved through discussion with a third author (HN), and the overall quality/RoB of each article was agreed upon by consensus. If clarification was necessary, attempts up to two times were made to contact the corresponding author of the relevant studies.

#### 2.3.1 | Heterogeneity assessment, summary measures and data synthesis

For quantitative synthesis, only randomised controlled trials (RCTs) were included. The clinical and methodological heterogeneity of included studies was assessed by examining the similarities in the study characteristics of the individual studies. Statistical heterogeneity was examined through visual inspection of the forest plot, by a chi-squared test (significant statistical heterogeneity when $p < .1$) and by $I^2$ test to quantify the extent of heterogeneity.

The primary objective was to compare the success rate and the overall survival rate between the HT and CT at 12 and 24 months. The primary outcome measures were defined as 'success or failure' and 'survived or not-survived' in accordance with the criteria of each included study and entered as dichotomous data. Success was defined as the presence of the PMC without any major or minor failure (Tables 3 and 4). Survival was defined as the presence of the PMC without any major failure (Table 4).

Meta-analysis was performed for the above-mentioned primary outcome measures at 12 and 24 months. The principal summary measure was odds ratio (log OR), and it was calculated by using a random-effects model and the restricted maximum likelihood method. If >10 studies were included in the meta-analysis, publication bias would be assessed through funnel plots. Sensitivity analysis was planned to explore and exclude the effect of studies judged as poor quality in the overall risk assessment. All the analyses were performed using the software STATA version 16 (StataCorp).

## 3 | RESULTS

### 3.1 | Search results

A total of 492 records were retrieved in the electronic search. After the removal of duplicates, a total of 200 records remained, of which 187 articles were excluded after title and abstract evaluation. Out of the 13 articles, four RCTs[18–21] and one retrospective cohort study[22] were included in this systematic review. The four RCTs were included in the meta-analysis. The search and screening process results, as well as reasons for exclusion of eight articles,[7,10,11,23–27] are presented in detail in the PRISMA flow chart (Figure 1) and Appendix S2. The interexaminer agreement was $k = 0.81$, indicating an excellent level of agreement.

### 3.2 | Study characteristics

The clinicians involved were either dental therapists,[19,21] a general dental practitioner[21] or paediatric dental residents[18,20,22] working in primary care clinics[19,21] or university hospitals.[18,20,22] The PMCs that were placed using

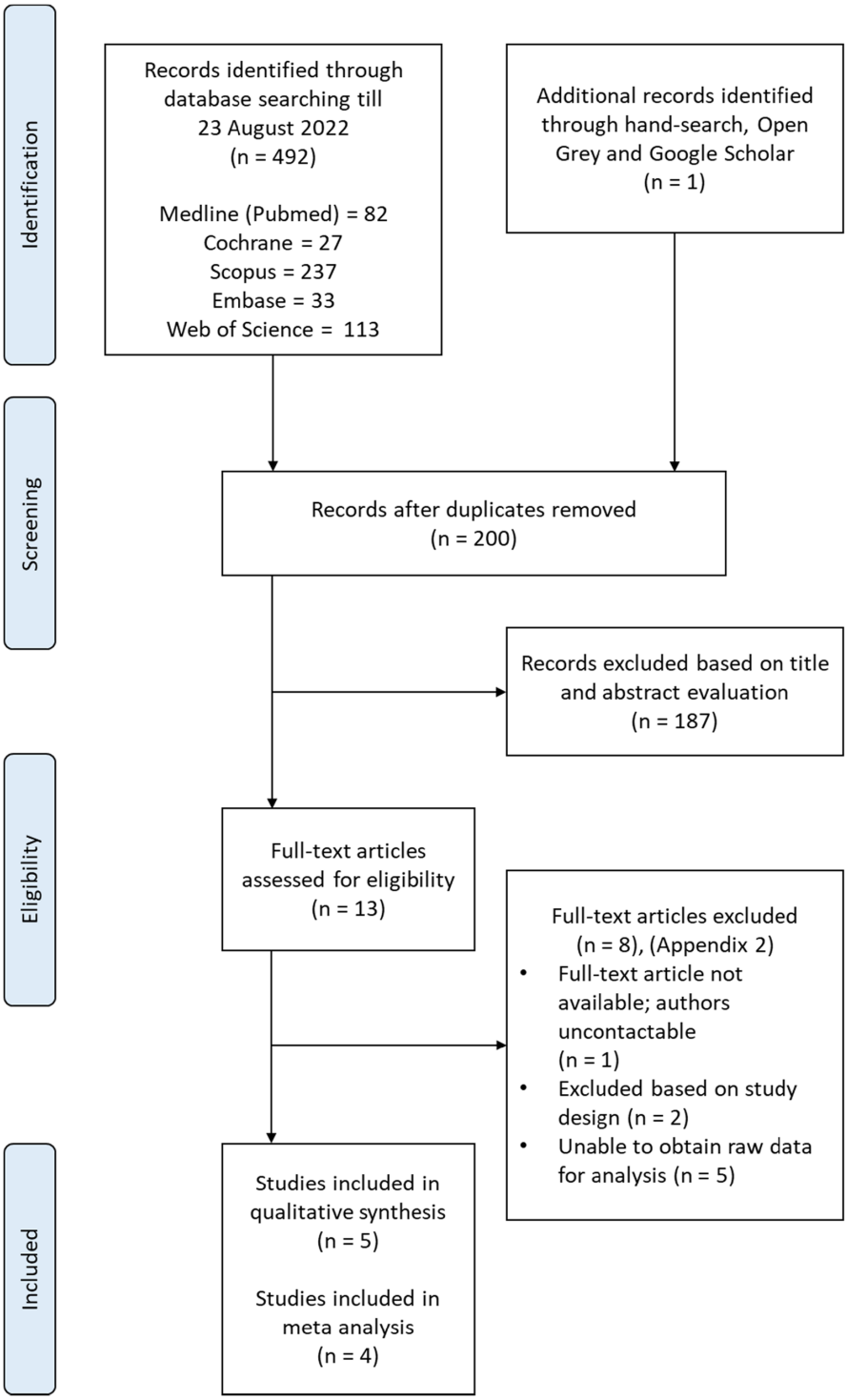


FIGURE 1 PRISMA flow chart

the CT and HT generally adhered to their respective treatment protocol[4,5,8] with variation such as the use of a selective caries removal,[19] duration of orthodontic separator placement[18,21] or trimming the PMCs.[20,21] The RCTs had a follow-up period of either one or two years,[18–21] whereas the retrospective cohort study had follow-up periods of 12, 18 and 24 months.[22] Detailed descriptions of the included studies, primary outcomes and prevalence of minor and major failures are shown in Tables 1–4.

### 3.3 | Primary outcomes

The descriptive outcomes for success and survival of the included studies are presented in Table 2. The forest plots with the pooled effect sizes for the primary outcome measures namely success and survival rates between HT and CT at 12 and 24 months were depicted in the analysis (Figure 2A–D). No significant heterogeneity was detected for all the above synthesis ($I^2 = 0\%$ for 3 syntheses

**TABLE 1** Study characteristics

| Study; Country | Design | Participants (number of teeth/Age range in years) | Sample size | Follow-up (months) | Primary outcomes | | | Secondary outcome(s) | Statistical analysis | Conclusions | Funding |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Success | Minor failure | Major failure | | | | |
| Clinical trials | | | | | | | | | | | |
| Ayedun et al. (2021) Nigeria | Split-mouth | 50 teeth Age: 3–8 | HT ($n = 25$) CT ($n = 25$) | 3, 6, 9, 12 | • Restoration satisfactory • No intervention required • No clinical sign or symptoms of pulpal pathology visible radiographically • Tooth exfoliated | • Crown loss and tooth restorable • Crown perforation • Marginal Caries • Reversible pulpitis | • Irreversible pulpitis • Dental abscess • Crown loss and tooth unrestorable • Peri-radicular radiolucency | • Treatment duration | • Yate's Chi-square • Significance at $p \leq .05$ | • HT compared favourably well to the CT • HT gave significantly shorter treatment duration as compared to CT | • None |
| Boyd et al. (2020) New Zealand | Parallel | 450 teeth Age: 3–8 | HT ($n = 273$) CT ($n = 177$) | 12, 24 | • Restoration satisfactory • No intervention required • No clinical signs or symptoms of pulpal pathology • No pathology visible on radiographs | • Restoration lost but tooth restorable • Restoration worn and needing intervention • Secondary or new carious lesions • Ectopic first permanent molar adjacent to crowned tooth | • Irreversible pulpitis/abscess requiring pulp treatment or extraction • Inter-radicular radiolucency • Restoration lost, pulpally involved and tooth unrestorable | • NA | • Cross-tabulations and $\chi^2$ • Analysis of variance (1-way analysis of variance) • Multilevel modelling | • HT and CT were both highly successful in the restoration of primary molars | • Funded by a grant from Cure Kids New Zealand • PMCs and cement were provided by 3M |

(Continues)

**TABLE 1** (Continued)

| Study; Country | Design | Participants (number of teeth/Age range in years) | Sample size | Follow-up (months) | Primary outcomes | | | Secondary outcome(s) | Statistical analysis | Conclusions | Funding |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Success | Minor failure | Major failure | | | | |
| Ebrahimi et al. (2020) Iran | Parallel | 81 teeth Age: 4–9 | HT ($n = 42$) CT ($n = 39$) | 6, 12 | • NR | • Recurrent caries<br>• Slight internal resorption and slight widening of periodontal ligament | • Sensitivity to percussion<br>• Spontaneous or nocturnal pain<br>• Loss of restoration<br>• Obvious furcation or periapical radiolucency<br>• Internal/external radiolucency | • Child's behaviour (Frankl scale)<br>• Treatment duration<br>• Self-reported postoperative pain and discomfort<br>• Parental satisfaction | • Fisher's exact<br>• Kruskal–Wallis<br>• Mann–Whitney<br>• Chi-square<br>• Significance at $p \leq .05$ | • The high success and shorter treatment duration of the HT support its use as an alternative to the CT in the treatment of primary molars with multisurface caries<br>• A decrease in canine overbite occurs at the time of placement of PMC by the HT, but it subsides by 6 months after treatment | • NR |
| Elamin et al. (2019) Sudan | Parallel | 212 teeth Age: 5–8 | HT ($n = 109$) CT ($n = 103$) | 6, 12, 18, 24 | • NR | • Dislodgement or perforation of crown without pain | • Teeth that caused pain and needed pulp therapy or extraction | • Cost<br>• Self-reported Anxiety<br>• Treatment duration<br>• Changes in Occlusion | • Pearson Chi-squared<br>• Fisher's exact<br>• Kaplan–Meier survival<br>• Log-rank test<br>• Significance at $p \leq .05$ | • PMCs placed with either HT and CT showed high survival rates<br>• HT is cost-effective and has a shorter treatment duration than CT<br>• HT induces less self-reported anxiety than CT | • None |
| Cohort study | | | | | | | | | | | |
| Binladen et al. (2020) Dubai | Retrospective | 187 teeth Age: 3–14 | HT ($n = 110$) CT ($n = 77$) | 6, 12, 18, 24 | • Satisfactory restoration<br>• No intervention required<br>• No clinical or radiographic signs or symptoms of pathology<br>• Tooth exfoliated naturally | • Crown loss and tooth restorable<br>• Crown perforated<br>• Reversible pulpitis | • Irreversible pulpitis<br>• Abscess/infection<br>• Crown loss and tooth unrestorable | • NA | • Kaplan–Meier survival<br>• Log-rank model<br>• Significance at $p \leq .05$ | • HT and CT were highly successful, with the HT showing slightly higher success at 24 months<br>• Mean survival time of both methods was the same | • None |

Abbreviations: CT, conventional technique; HT, Hall technique; NA, not applicable; NR, not reported; PMC, preformed metal crown.

**TABLE 2** Primary outcomes of included studies

| Study; Country | Follow-up (month) | Intervention | Dropout | Exfoliation | Overall success | Minor failure | Major failure | Survival |
|---|---|---|---|---|---|---|---|---|
| Clinical trials | | | | | | | | |
| Ayedun et al. (2021) Nigeria | 12 | HT | 2/25 (8.0%) | 4/25 (16.0%) | 23/23 (100.0%) | 0 | 0 | 23/23 (100.0%) |
| | | CT | 2/25 (8.0%) | 4/25 (16.0%) | 21/23 (91.3%) | 1/23 (4.3%) | 1/23 (4.3%) | 22/23 (95.7%) |
| Boyd et al. (2020) New Zealand | 12 | HT | 18/273 (6.6%) | 1/273 (0.3%) | 226/255 (88.6%) | 21/255 (8.2%) | 8/255 (3.1%) | 247/255 (96.9%) |
| | | CT | 6/177 (3.4%) | CD[a] | 158/171 (92.4%) | 7/171 (4.1%) | 6/171 (3.5%) | 165/171 (96.5%) |
| | 24 | HT | 32/273 (11.7%) | 19/273 (7.0%) | 208/241 (86.3%) | 23/241 (9.5%) | 10/241 (4.1%) | 231/241 (95.9%) |
| | | CT | 14/177 (7.9%) | CD[a] | 141/163 (86.5%) | 8/163 (4.9%) | 14/163 (8.6%) | 149/163 (91.4%) |
| Ebrahimi et al. (2020) Iran | 12 | HT | 8/42 (19.0%) | NR | 33/34 (97.1%) | 0 | 1/34 (2.9%) | 33/34 (97.1%) |
| | | CT | 9/39 (23.1%) | NR | 30/30 (100.0%) | 0 | 0 | 30/30 (100.0%) |
| Elamin et al. (2019) Sudan | 24 | HT | 25/109 (22.9%) | 2/109 (1.8%) | 74/84 (88.1%) | 3/84 (3.6%) | 7/84 (8.3%) | 77/84 (91.7%) |
| | | CT | 22/103 (21.4%) | 1/103 (0.9%) | 69/81 (85.2%) | 6/81 (7.4%) | 6/81 (7.4%) | 75/81 (92.6%) |
| Cohort study | | | | | | | | |
| Binladen et al. (2020) Dubai | 12 | HT | 0 | 0 | 109/110 (99.1%) | 1/110 (0.9%) | 0 | 110/110 (100.0%) |
| | | CT | 0 | 0 | 74/77 (96.1%) | 0 | 3/77 (3.9%) | 74/77 (96.1%) |
| | 18 | HT | 20/110 (18.2%) | 0 | 89/90 (98.9%) | 1/90 (1.1%) | 0 | 90/90 (100.0%) |
| | | CT | 15/77 (19.5%) | 1/77 (1.3%) | 59/62 (95.2%) | 0 | 3/62 (4.8%) | 59/62 (95.2%) |
| | 24 | HT | 26/110 (23.6%) | 0 | 82/84 (97.6%) | 1/84 (1.2%) | 1/84 (1.2%) | 83/84 (98.8) |
| | | CT | 15/77 (19.5%) | 0 | 58/62 (93.5%) | 0 | 4/62 (6.5%) | 58/62 (93.5%) |

Abbreviations: CD, cannot be determined; CT, conventional technique; HT, Hall technique; NR, not reported.

[a]Unable to contact author and derive information from study data.

and 36.4 for one synthesis; chi-squared: $p > .1$). Random effects meta-analyses, however, were chosen in order to compensate for variations among the included studies. Funnel plots and additional sensitivity analysis were not carried out due to the number of included studies.

### 3.3.1 | Overall success

The 12-month overall success ranged from 88.6% to 100% for the HT and 91.3% to 100% for the CT (three studies: log OR = −0.37; 95% CI: −1.03, 0.28; $I^2 = 0\%$) (Figure 2A).[18–20] The 24-month overall success ranged from 86.3% to 88.1% for the HT and 85.2% to 86.5% for the CT (two studies: log OR = 0.06; 95% CI: −0.43, 0.55; $I^2 = 0\%$) (Figure 2C).[19,21] No significant differences were found between HT and CT at 12 and 24 months ($p > .05$).

### 3.3.2 | Survival

The survival rates were 96.9%–100% for HT and 95.7%–100% for CT at 12 months (3 studies: log OR = 0.11; 95% CI: −0.87, 1.08; $I^2 = 0\%$) (Figure 2B),[18–20] and 91.7%–95.9% for HT and 91.4%–92.6% for CT at 24 months (2 studies: log OR = 0.41; 95% CI: −0.46, 1.28; $I^2 = 36.4\%$) (Figure 2D).[19,21] No significant differences were found between HT and CT at 12 and 24 months ($p > .05$).

### 3.3.3 | Failure

Failure was reported as either minor or major failures (Tables 2–4). The overall minor and major failure rates of teeth with PMCs placed with HT versus CT are shown in Table 2. The prevalence of specific minor and major failures is shown in Tables 3 and 4. Failures reported included crown loss[18] or crown perforation of a restorable tooth with no pain,[22] the development of irreversible pulpitis/pain,[21] abscess[22] and furcal or peri-radicular radiolucency.[18]

## 3.4 | Secondary outcomes

The secondary outcomes evaluated included changes in occlusion,[21] behaviour and level of cooperation of the child,[20] self-reported anxiety[21] and discomfort,[20] parental satisfaction,[20] treatment duration[18,20,21] and cost-effectiveness[21] (Table 5). No studies reported on oral health-related quality of life (OHRQoL). In summary, children in the HT group were less anxious[21]

**TABLE 3** Minor failures

| Authors | Intervention | Clinical | | | | | | Radiographic | |
|---|---|---|---|---|---|---|---|---|---|
| | | Crown lost, tooth restorable/ no pain | Crown perforated, tooth restorable/ no pain | Secondary caries | Reversible pulpitis | Ectopic 6 | Premature loss | Slight internal root resorption | Slight widening of periodontal ligament |
| Clinical trials | | | | | | | | | |
| Ayedun et al. (2021) | HT | 12 months: 0/23 (0.0%) | 12 months: 0/23 (0.0%) | 12 months: 0/23 (0.0%) | 12 months: 0/23 (0.0%) | | | | |
| | CT | 12 months: 1/23 (4.3%) | 12 months: 0/23 (0.0%) | 12 months: 0/23 (0.0%) | 12 months: 0/23 (0.0%) | | | | |
| Boyd et al. (2020) | HT | | | | | | | | |
| | CT | | | | | | | | |
| Ebrahimi et al. (2020) | HT | | | 12 months: 0/34 (0.0%) | | | | 12 months: 0/34 (0.0%) | 12 months: 0/34 (0.0%) |
| | CT | | | 12 months: 0/34 (0.0%) | | | | 12 months: 0/34 (0.0%) | 12 months: 0/34 (0.0%) |
| Elamin et al. (2019) | HT | | | | | | | | |
| | CT | | | | | | | | |
| Cohort study | | | | | | | | | |
| Binladen et al. (2020) | HT | 12 months: 0/110 (0.0%) 18 months: 0/90 (0.0%) 24 months: 0/84 (0.0%) | 12 months: 1/110 (0.9%) 18 months: 1/90 (1.1%) 24 months: 1/84 (1.2%) | | 12 months: 0/110 (0.0%) 18 months: 0/90 (0.0%) 24 months: 0/84 (0.0%) | | | | |
| | CT | 12 months: 0/77 (0.0%) 18 months: 0/62 (0.0%) 24 months: 0/62 (0.0%) | 12 months: 0/77 (0.0%) 18 months: 0/62 (0.0%) 24 months: 0/62 (0.0%) | | 12 months: 0/77 (0.0%) 18 months: 0/62 (0.0%) 24 months: 0/62 (0.0%) | | | | |

*Note*: Green: criteria were used in assessing minor failure; red: criteria were not used in assessing minor failure; orange: criteria were used however no data to calculate the specific number of cases/percentage of each criterion.

Abbreviations: CT, conventional technique; HT, Hall technique.

**TABLE 4** Major failures

| Authors | Intervention | Major failure | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Clinical | | | | Radiographic | | | |
| | | Irreversible pulpitis/ Pain | Abscess/ infection | Crown lost and tooth unrestorable | Required pulp therapy/ extraction | Peri-radicular radiolucency | Furcal/ Inter-radicular radiolucency | External root resorption | Internal root resorption |
| Clinical trials | | | | | | | | | |
| Ayedun et al. (2021) | HT | 12 months: 0/23 (0.0%) | 12 months: 0/23 (0.0%) | 12 months: 0/23 (0.0%) | | 12 months: 0/23 (0.0%) | | | |
| | CT | 12 months: 0/23 (0.0%) | 12 months: 0/23 (0.0%) | 12 months: 0/23 (0.0%) | | 12 months: 1/23 (4.3%)[a] | 12 months: 1/23 (4.3%)[a] | | |
| Boyd et al. (2020) | HT | | | | | | | | |
| | CT | | | | | | | | |
| Ebrahimi et al. (2020) | HT | | | | | | | | |
| | CT | 12 months: 0/30 (0.0%) | | 12 months: 0/30 (0.0%) | | 12 months: 0/30 (0.0%) | 12 months: 0/30 (0.0%) | 12 months: 0/30 (0.0%) | 12 months: 0/30 (0.0%) |
| Elamin et al. (2019) | HT | 24 months: 7/84 (8.3%)[b] | | | 24 months: 7/84 (8.3%)[b] | | | | |
| | CT | 24 months: 6/81 (7.4%)[b] | | | 24 months: 6/81 (7.4%)[b] | | | | |
| Cohort study | | | | | | | | | |
| Binladen et al. (2020) | HT | 12 months: 0/110 (0.0%) 18 months: 0/90 (0.0%) 24 months: 0/84 (0.0%) | 12 months: 0/110 (0.0%) 18 months: 0/90 (0.0%) 24 months: 1/84 (1.2%)[c] | 12 months: 0/110 (0.0%) 18 months: 0/90 (0.0%) 24 months: 0/84 (0.0%) | 12 months: 0/110 (0.0%) 18 months: 0/90 (0.0%) 24 months: 1/84 (1.2%)[c] | | | | |
| | CT | 12 months: 0/77 (0.0%) 18 months: 0/62 (0.0%) 24 months: 0/62 (0.0%) | 12 months: 3/77 (3.9%) 18 months: 3/62 (4.8%) 24 months: 4/62 (6.5%) | 12 months: 0/77 (0.0%) 18 months: 0/62 (0.0%) 24 months: 0/62 (0.0%) | 12 months: 2/77 (2.6%) 18 months: 2/62 (3.2%) 24 months: 3/62 (4.8%) | | | | |

*Note*: Green: criteria were used in assessing minor failure; red: criteria were not used in assessing minor failure; orange: criteria were used however no data to calculate the specific number of cases/percentage of each criterion. Green, evaluated as criteria for failure; red, not evaluated as criteria for failure; orange, evaluated as criteria for failure but not reported or unclear reporting on specifics of failure type.

Abbreviations: CT, conventional technique; HT, Hall technique.

[a]Major and minor failures occurred in the same tooth. In view of the presence of major failure, tooth was classified under major failure.

[b]Teeth with pain were the same teeth that required pulp therapy/extraction.

[c]Teeth with pain were the same teeth that required pulp therapy/extraction.

and had less discomfort.[20] The HT resulted in raised occlusion among all children immediately after treatment, but this resolved at 12 months.[21] The HT also required a shorter treatment time[18,20,21] and is more cost-effective.[21]

### 3.5 | Risk of bias

Among the four included RCTs, one was deemed to be of good quality[19] whereas three were graded as having fair quality (Table 6).[18,20,21] Bias due to lack of blinding of participants and treatment providers, as well as lack of intention-to-treat analysis, were of concern in the RCTs. The cohort study was deemed to be of fair quality.[22] Lack of blinding of participants and treatment providers, differing baseline characteristics between treatment groups, and poor reporting of sample size calculations contributed to bias in the cohort study.

## 4 | DISCUSSION

To the authors' knowledge, this is the first systematic review and meta-analysis that specifically compared the outcomes of PMC placed with the HT and CT. The current systematic review also evaluated secondary outcomes such as cooperation towards treatment, level of anxiety and discomfort, patients and parental acceptance towards the HT, changes in occlusion after HT treatment and cost-effectiveness of both techniques.

The studies included in this systematic review were largely comprised of RCTs, which typically rank high on the hierarchy of evidence. While two of the RCTs[18,20] had sample sizes of <50 in each treatment arm, the use of meta-analysis allowed us to combine the findings of the RCTs into a larger sample pool. The participants recruited in the RCTs had ages ranging from 3 to 9 years old, which is the typical age range for children undergoing PMC placement procedures.

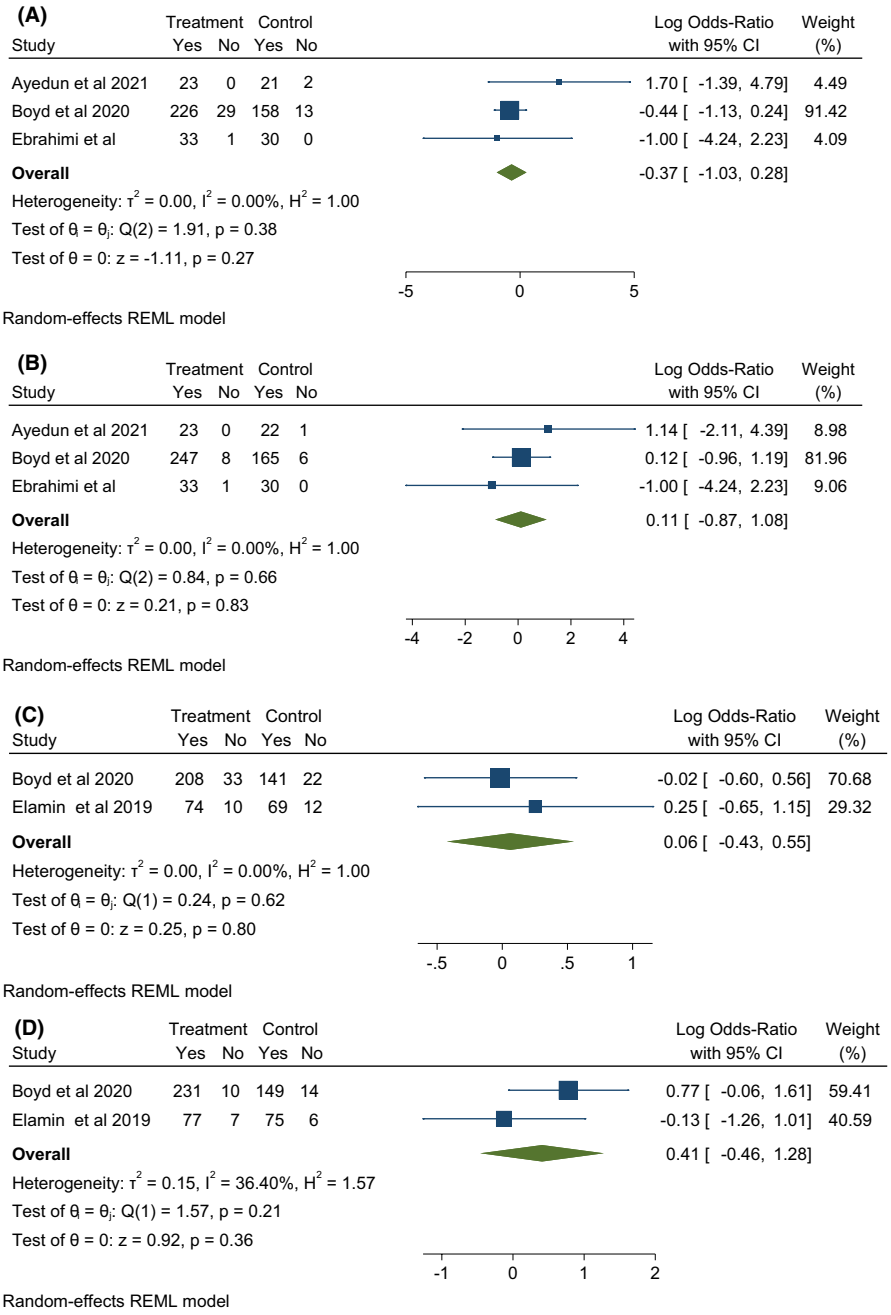


**FIGURE 2** Forest plots for meta-analysis of success and survival rates at 12 months ((A) and (B), respectively) and 24 months ((C) and (D), respectively)

## 4.1 | Primary outcomes: Success and survival

Traditionally, CT has been the recommended treatment for primary molars with extensive or multisurface caries.[1,3] Placement of PMCs using the CT, however, can be challenging especially in young children as it requires treatment under local anaesthesia and has thus been rated as one of the more uncomfortable treatments.[28] Hence, alternative treatment options with similar success and survival rates should be considered for those who find it difficult to cope with CT. In this systematic review, the overall success and survival rates for both techniques were similarly above 85% at both 12- and 24-month follow-ups. The variations in treatment techniques[19–21] are likely inconsequential to the treatment outcomes. PMCs confer a predictable and good seal to the carious lesion in the case of HT, or cavity in the case of CT.[6] Therefore, it is hypothesised that regardless of the state of carious tissue removal (ie, no removal versus selective/complete removal), the change in the environment will allow the carious lesion a chance to arrest and the pulp a chance to heal as long as a good seal is maintained.[6] As all included studies had strict inclusion criteria, the major failures obtained are likely due to the pulp failing to heal rather than operator technique error.

**TABLE 5** Secondary outcomes

| Outcome | Authors | Methods to record outcome | Outcome | | | Conclusion |
|---|---|---|---|---|---|---|
| | | | Time point Post-treatment | HT | CT | |
| Changes in occlusion (presence of raised occlusion) | Elamin et al. (2019) | Passing an occlusal strip between the contralateral posterior teeth when the child bites into maximum intercuspation<br>Occlusal strip passes = raised occlusion<br>Resistance to occlusal strip = normal occlusion | Immediate<br>6-month<br>12-month | 109/109 (100%)<br>3/105 (2.9%)<br>Occlusion is normal | 4/103 (3.9%)<br>Occlusion is normal | All children in the HT group, whereas some in the CT had raised occlusion immediately post-treatment. All children had normal occlusion at 12-month post-treatment |
| Behaviour and cooperation (mean score) | Ebrahimi et al. (2020) | Frankl score rated by treating clinician | Immediate | 2.20 ± 1.20 | 3.12 ± 1.17 | Children in the CT group had significantly better behaviour and cooperation |
| Self-reported discomfort (mean score) | Ebrahimi et al. (2020) | Faces Pain Scale-Revised<br>0 = no pain<br>10 = very much pain | Immediate | 2.15 ± 3.47 | 2.94 ± 4.24 | Children in the HT group had a significantly lower mean pain score |
| Self-reported anxiety (mean score[a]) | Elamin et al. (2019) | Facial Image Scale<br>1 = very happy<br>5 = very unhappy | Immediate<br>12-month | 2.60<br>2.86 | 2.84<br>4.02 | Children in the HT group were significantly less anxious at both time points |
| Parental satisfaction (mean score) | Ebrahimi et al. (2020) | Four-point Likert scale rating<br>1 = 'very low satisfaction'<br>4 = 'high satisfaction' | Immediate<br>6-, 12-month | 3.76 ± 0.63<br>4 | 3.45 ± 0.98<br>4 | Parents were both satisfied with both CT and HT |
| Mean treatment duration (minutes) | Elamin et al. (2019)<br>Ayedun et al. (2021)<br>Ebrahimi et al. (2020) | — | | 4.57 ± 1.47–9.1 ± 2.87 | 17.3 ± 5.10–33.9 ± 10.61 | CT required a significantly longer treatment duration |
| Cost-effectiveness (USD) | Elamin et al. (2019) | Mean cost per<br>Incremental cost-effectiveness ratio (USD/per year of survival) | —<br>— | 2.45 ± 0.14<br>— | 7.81 ± 1.41<br>136.56 | HT is significantly cheaper and more cost-effective |
| Oral health-related quality of life | — | No studies reported on this outcome | | | | — |

Abbreviations: CT, conventional technique; HT, Hall technique; USD, US Dollar.

[a]Calculated based on data provided in study.

(Continues)

## 4.2 | Secondary outcomes

### 4.2.1 | Changes in occlusion

It is generally accepted that in children there is significant capacity for occlusal equilibration when there is raised occlusion.[3] Elamin et al.[21] reported raised occlusion in the HT group immediately after treatment, which equilibrated by the end of the study at 24 months.

One concern over the use of the HT is that the raised occlusion resulting from no occlusal reduction would lead to changes in muscle activity, temporomandibular joint dysfunction and masticatory difficulties post-treatment. To address these concerns, bilateral masseter muscle activity on clenching measured with surface electromyography and bite force in children who had PMCs placed with the HT was evaluated.[29,30] There was increased muscle activity[29] and reduced bite force[30] immediately post-treatment, but both measures returned to baseline levels by 1 month. Temporomandibular joint dysfunction was also not reported after PMC placement using the HT[31] up to 12 months and CT[32] up to 3-month post-treatment. Although there are no studies on masticatory difficulties in children after HT treatment, studies in adults have shown that masticatory function was unchanged following an increase in occlusal vertical dimension.[33] Although PMC placement in children results in increased occlusal vertical dimension, however, given the short timeframe during which occlusal equilibration occurs regardless of technique,[32,34] it is postulated that any masticatory difficulties that may occur immediately post-treatment would be expected to resolve fairly quickly, with minimal risk towards temporomandibular joint dysfunction and limited impact on OHRQoL. The study by Elamin et al.[21] only measured the presence/absence of occlusal contact between the teeth contralateral to PMC-treated side, but did not measure other above mentioned parameters (eg, changes in bite force and/or muscle activity), which may be necessary to provide further clarity on the impact of changes in occlusion and the masticatory ability of the child following PMC placement. Future studies should consider investigating masticatory function following PMC placement with the HT via subjective (eg, food preference questionnaire) and objective measures (eg, mixing ability test).[35]

### 4.2.2 | Behaviour and level of cooperation of the child

One study reported that children in the CT group had significantly better cooperation than the HT group based on the Frankl scale, despite a lower mean pain score reported by children in the HT group than the CT group.[20] It was suggested that since local anaesthesia was administered, children in the CT group experienced less discomfort during treatment and therefore behaved better.[20] While the Frankl scale is a well-established and widely used measure of behaviour in children,[36] the behaviour of the children may have been better assessed and compared had it been rated at more time points during the treatment to give an aggregate score instead of a single score at the end of treatment, as the administration of local anaesthesia for the CT group, which is a key difference from the HT, may have resulted in discomfort thus impacting the children's behaviour. Furthermore, the lack of reporting of patient age ranges within each treatment arm and the lack of blinding of the clinician who assessed the child's behaviour to the treatment arm were sources of bias in this study. Hence, their findings should be taken with caution.

### 4.2.3 | Self-reported discomfort and anxiety

One study evaluated child-reported discomfort following PMC placement,[20] whereas other studies on discomfort were mainly single-arm studies relying on parental proxies,[37] or compared PMCs using the HT against direct restorations which relied on clinician proxy.[8] Ebrahimi et al.[20] found that children in the CT group experienced slightly more discomfort than children in the HT group immediately post-treatment. As treatment was rendered by a single operator, it is postulated that the differences in discomfort may be attributed to the additional use of local anaesthesia and caries removal.

When evaluating anxiety levels, children in the CT group also had significantly increased anxiety levels than children in the HT group immediately and at 1-year post-treatment.[21] The anxiety experienced immediately post-treatment could be attributed to exposure towards multiple dental instruments including local anaesthesia syringe,[38] whereas anxiety at the 1-year review visit could be due to sensitisation and anticipation of invasive dental treatment.[39] Additionally, operator training and experience could have affected the findings in this study, whereby one group of patients was treated by a dentist (CT) whereas the other was by a dental therapist (HT).[21] Hence, differential operator levels may account for differing patient experiences.

The accurate reporting of dental anxiety and discomfort requires a level of cognitive maturity from the child. This is often difficult and requires other measures such as proxies[40–43] or physiological parameters.[44] Although a child's dental anxiety can be predicted through direct clinical observation[40] or parental proxy,[41] this is not the case for dental discomfort.[42,43] The use of validated age-appropriate

**TABLE 6** Risk of bias assessment

| Items[a] | Randomised controlled trials | | | | Cohort studies[a] |
|---|---|---|---|---|---|
| | Ayedun et al. (2021) | Boyd et al. (2020) | Ebrahimi et al. (2020) | Elamin et al. (2019) | Binladen et al. (2020) |
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |
| 11 | | | | | |
| 12 | | | | | |
| 13 | | | | | |
| 14 | | | | | |
| **Overall Rating**[b] | Fair | Good | Fair | Fair | Fair |

*Note*: Green, yes; red, no; orange, cannot be determined/not applicable.

[a]See Appendix S3 for the relevant statements/questions.

[b]The overall judgement is determined by Good, Fair and Poor.[17]

scales to allow for self-reporting of dental anxiety[45] and pain[46] may overcome potential inaccuracies from proxies and avoid the use of physiologic parameters.[44] Future studies can assess the effect of operator experience or differing restorative treatment techniques on the child's level of discomfort and anxiety through a validated scale.

### 4.2.4 | Parental satisfaction

One study assessed parental satisfaction through a single question: 'What is the level of your satisfaction with the treatment your child received?'. The reliability of this evaluation is uncertain, and future studies should consider the use of multi-item self-reported parental questionnaires containing items such as level of communication by the dental team, the aesthetics of the PMC or the parent's satisfaction with the child's experience during PMC placement to measure parental satisfaction.[7,27]

### 4.2.5 | Treatment duration

It is expected that the CT required a significantly longer mean treatment time than the HT[18,20,21] due to local anaesthesia administration, caries removal and tooth preparation. The lack of a standardised start and finish time, however, would reduce the accuracy of treatment time calculation. Hence, future studies evaluating this should have a standardised start (eg, topical anaesthesia placement for CT and orthodontic separators removal for HT) and finish time (eg, removal of excess cement). If orthodontic separators were placed prior to placement of PMCs in the clinic, the additional treatment duration and the possible need for multiple visits should also be accounted for.[27]

### 4.2.6 | Cost-effectiveness

One study found that HT was more cost-effective than CT,[21] and this may be attributed to differences in treatment duration and need for additional materials. This finding was similarly reported in a study comparing biological treatment methods (mainly HT treatment) with conventional treatment methods, where the cost of the biological approach was found to be almost half the total cost of the conventional approach.[27]

## 4.3 | Limitations

This systematic review has several limitations. The authors only included publications in the English language. As such, there could be language bias as similar studies in other languages could have been excluded during the

initial search process. However, if the strict inclusion and exclusion study parameters are applied in these excluded studies, similar outcomes for the HT and CT are to be expected. Exclusion of these studies therefore would unlikely affect the results of the meta-analysis. Regardless, future studies should carry out the search without any language restrictions.

The inability of blinding study participants and treatment providers could result in performance bias among included studies, whereby clinicians might have been biased towards or against one of the treatment modalities, therefore, inadvertently affecting the outcomes of the study. The utilisation of appropriate randomisation techniques[47] and/or blinding study assessors[47,48] could have reduced such effect.

None of the RCTs used intention-to-treat analysis to account for the effect of dropouts on the reported success or survival rates. This issue was further compounded by the fact that two of the RCTs had high dropout rates (>20%)[20,21] whereas two[18,20] had insufficient sample size. Moreover, the studies included in this review were found to have varying criteria for treatment success, survival and failure[18–22] and incomplete reporting of results.[19–21] The primary authors were not able to provide more details when contacted. Thus, the risk of reporting bias due to selective reporting cannot be excluded. However, considering the generally high rates of success and survival of both the CT and HT reported in the literature, the impact of such reporting bias may not be large.

Another major difficulty faced was the heterogeneity of data in the included studies, such as differences in outcome criteria assessed and follow-up intervals. This posed a challenge in synthesising the data of these studies. Therefore, the authors would like to recommend a set of outcome criteria in reporting PMC-related outcomes (Table 7). Such recommended outcome criteria were a modification of those described by Innes et al.,[8] whereby the outcomes are split into two levels (Level 1 failure: PMC-related, where only minimal intervention such as the re-cementation or replacement of a PMC was necessary and Level 2 failure: pulpal and/or periapical pathology related, further divided into Level 2A where only minimal intervention such as monitoring was necessary, and Level 2B where the tooth required pulpal extirpation or tooth extraction) (Table 7). This classification would prevent the confusion arising from the use of terms such as minor and major failure. The loss of a Hall crown might be considered minor by some researchers due to the possibility of replacing this crown, whereas others might consider this a major failure due to the loss of coronal seal. Furthermore, researchers have to distinguish between physiologic exfoliation and pathologic loss of the tooth especially when exfoliation occurs more than 12 months before the expected exfoliation date without radiographic evidence of physiologic exfoliation.

Future studies should strictly report all clinical and radiographic outcomes and consider a longer follow-up period. The studies included in this systematic review had a follow-up duration of 12 months for two of the included studies and 24 months for the other three studies. Given that PMCs are expected to perform successfully for more than 5 years,[3] a longer follow-up duration would provide a better representation of the long-term success or survival of PMCs regardless of technique. Additionally, standardised measures should be utilised to evaluate

**TABLE 7** Outcome criteria for assessment of PMCs

| | | |
|---|---|---|
| Level 1 failure (PMC-related) | • Crown lost but tooth asymptomatic and restorable<br>• Crown perforated but tooth asymptomatic and restorable<br>• Ectopic eruption of permanent first molar as a result of the PMC<br>• Secondary caries but tooth is restorable<br>• Crown not seated properly | |
| Level 2 failure (pulp/periapical pathology related) | 2A<br>• Reversible pulpitis not requiring tooth extraction<br>• Asymptomatic internal root resorption<br>• Asymptomatic, nonprogressive slight widening of periodontal ligament space | 2B<br>• Secondary caries with unrestorable tooth<br>• Irreversible pulpitis or pain<br>• Abscess or fistula<br>• Pathologic mobility<br>• Peri-radicular and/or furcal radiolucency<br>• Symptomatic internal root resorption<br>• Infection-related external root resorption<br>• Other reasons leading to premature loss of the tooth |
| Success | • Absence of Level 1 and 2 failures | |
| Tooth survival | • Presence of the tooth at the time of the last review | |

secondary outcomes such as changes in OHRQoL, cost-effectiveness and acceptability of the HT among both parents and paediatric patients. Overall, standardised reporting will ensure clarity in both primary and secondary outcomes and facilitate a more homogeneous pool of data for future meta-analysis.

Within the limitations of this study, this systematic review found that, PMCs placed using either the HT or CT confers similar overall success and survival rates. The HT also requires a shorter treatment time, is more cost-effective and has a high level of acceptability among parents compared to the CT. Given the favourable outcomes, greater consideration may be given towards using the HT as part of standard treatment procedures in carious primary molars in children. Future studies assessing long-term outcomes, clinician's acceptability, cost-effectiveness, effect on OHRQoL, occlusion and permanent successors, using standardised outcome criteria, are recommended.

## AUTHOR CONTRIBUTIONS

DRC and BLT should be considered joint first authors. MSD, HJT and HN should be considered senior authors. BLT and MSD conceived the idea; DRC, HJT and BLT participated in data collection; DRC, BLT, HN, NS and HJT analysed the data; DRC and BLT led the writing; DRC, BLT, HN, NS, MSD and HJT revised the manuscript for important intellectual content. All authors have made substantive contribution to this study and/or manuscript, and all have reviewed the final paper prior to its submission.

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## CONFLICT OF INTEREST

The authors declare no conflict of interest.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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