ABSTRACT

Background: Stainless steel crowns (SSCs) are unique coronal restorative materials used commonly in the management of primary teeth with extensive caries. Aim: The aim of this study was to perform a systematic review to evaluate the retentive strength of luting cements for SSCs. Materials and Methods: Two reviewers performed a database search of the studies published from 2004 till date. The inclusion criteria were papers published in the English language and in vitro studies on retentive strength of SSC on primary molars. All potentially relevant studies were identified by the title and the abstract. After the full-text analysis, the selected studies were included in the systematic review. Results: Sixteen nonduplicated studies were found. However, after reviewing the articles, only seven were included. Risk bias was assessed. Out of seven studies included in the systematic review, five studies presented medium risk of bias and two studies showed high risk of bias. Conclusion: Within the limitations of this study, the in vitro literature seems to suggest that the use of self-adhesive resin cements shows higher retentive strength, followed by resin-modified glass-ionomer cement (RM-GIC) and conventional GIC. However, RM-GIC can be a preferred luting agent due to its clinical advantages over resin cements. Thus, it can be concluded that choice of cement will depend on individual patient needs and clinical situation.

KEYWORDS: Luting cement, retentive strength, stainless steel crown

Introduction

Stainless steel crowns (SSCs) were first introduced in the 1950s by Dr. Humphrey. These are unique coronal restorative materials used commonly in the management of primary teeth with extensive caries. Many studies have reported that SSCs are most-efficient solution in managing multisurface carious lesions in primary teeth.

Although the clinical success rate of SSCs is high, the main reason for its lack of longevity is loss of the crown due to cementation failure. The key retentive feature of SSC depends on the close adaptation of crown margin to the tooth surface in undercut area and utilization of suitable luting cement which fills the gap between tooth structure and crown. The ideal properties of luting cement include biocompatibility, low solubility, good marginal seal, minimal film thickness, low viscosity, easy manipulation, and sufficient working time with rapid set. Other crucial properties for the overall success of luting cements are high tensile strength and maximum compressive and retentive strength.
There are various materials used for luting of crowns over the years, both nonadhesive (zinc phosphate cement and polycarboxylate cement) and adhesive cements (glass-ionomer cement [GIC], resin-modified [RM] GIC, and resin cement).[10]

Although there are several studies that investigate the retentive strength of various luting cements for SSC, they present heterogeneous methodology and results are variable.[12-18] Therefore, our aim was to systematically and critically review the studies that evaluated the retentive strength of various cements used for luting of SSC on primary molars.

Materials and Methods

Search strategy
This systematic review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.[19] The following electronic databases were used for the selection of the primary studies: PubMed and Cochrane (from 2004 till date). The population, intervention, comparison, and outcome as a search strategy are presented in Table 1.

The search was conducted using the following terms: “(Deciduous molar OR primary molar) AND (Stainless steel crown) AND (luting cements).” To ensure the wide search, no language filters were applied. In addition, the bibliographies of the final selected articles were hand-searched to identify any relevant publications that were not identified earlier.

Eligibility criteria
1. Papers published in the English language from 2004 till date
2. In vitro studies on retentive strength of SSC on primary molars.

Exclusion criteria
1. Studies conducted on luting cements for cast metal crowns
2. Studies comparing mechanical retention methods (sand blasting/grooves) with luting cements
3. Studies evaluating other than retentive strength (micro leakage, marginal fit, and tensile strength)
4. Unpublished manuscripts and thesis, book chapters, case studies, and literature reviews were excluded.

Literature search and search strategy

Study selection
Two reviewers independently screened all retrieved titles and abstracts. If one reviewer considered a publication as having met the inclusion criteria, the full text was obtained. Abstracts considered as potentially eligible, as well as those with not enough information, were considered for full-text assessment. Any differences regarding eligibility were resolved through consensus, and in case of disagreement, a third reviewer was consulted before a final decision was reached.[Figure 1].

Data extraction
Two reviewers independently extracted data simultaneously using a standardized outline. General information such as authors and year of publication were collected from each study. In addition, the following specific characteristics were also collected: (i) sample size, (ii) type of tooth, (iii) cements included, (iv) testing

Table 1: Population, intervention, comparison, and outcome as a search strategy in databases

| PICOS            | PICO’s definition            | Search terms used (MeSH and other terms with OR)          | Number of papers returned |
|------------------|------------------------------|----------------------------------------------------------|---------------------------|
| Population       | Primary molars               | Deciduous molar OR primary molar                          | 8633                      |
| Intervention     | Stainless steel crown        | Stainless steel crown                                     | 865                       |
| Comparison       | Luting cements               | luting cements                                            | 2170                      |
| Outcome          | Retentive strength           | Outcome not used in search strategy                       |                           |
| Terms combined   | “P” and “I” and “C”          | (Deciduous molar OR primary molar) AND (stainless steel crown) AND (luting cements) | 16                        |

PICOS=Population, intervention, comparison, and outcome as a search strategy; MeSH=Medical subject heading
method, and (v) results. Later, critical review of the included studies was performed by the authors [Table 2].

**Risk of bias**
Risk of bias was evaluated according to the article’s description of the following parameters for study quality assessment: randomization of teeth, teeth free of caries or restoration, materials mixed according to the manufacturer’s instructions, use of similar teeth, description of sample size calculation, testing method specified, and blinding of the operator. If the authors reported the parameter, the article had a “Y” (yes) on that specific parameter; if it was not possible to find the information, the article received an “N” (no). If the data were not reported clearly enough, the article received an NC (not clear). Based on the amount of Ys presented by the article, articles that reported one to three items were classified as having high risk of bias, four or five items as medium risk of bias, and six or seven items as low risk of bias.

**Results**

**Risk of bias**
Out of seven studies included in the systematic review, five studies presented medium risk of bias and two studies showed a high risk of bias. The results are described in Table 3, according to the parameters considered in the analysis.

**Discussion**
This systematic review is the first to evaluate retentive strength of various luting cements used for cementation of SSC on primary molars.

### Table 2: Details of the reviewed articles

| Authors/years          | Sample size | Type of teeth used       | Testing machine                      | Cements evaluated                          | Retentive strength (kg/cm²) |
|------------------------|-------------|--------------------------|--------------------------------------|--------------------------------------------|----------------------------|
| Yilmaz et al. (2004)   | 30          | Primary first molar       | Mechanical test machine               | GIC (Aqua Meron)                           | 24.16[^a,b]                |
|                        |             |                          |                                      | RM-GIC (RelyX luting)                      | 21.92[^a]                 |
|                        |             |                          |                                      | Resin cement (Panavia F)                   | 25.2[^a]                  |
| Yilmaz et al. (2006)   | 30          | Primary first molar       | Mechanical test machine               | GIC (Aqua Meron)                           | 24.88[^a]                 |
|                        |             |                          |                                      | RM-GIC (Vitremer)                          | 23.7[^a]                  |
| Subramaniam et al. (2010) | 45    | Deciduous molar          | Instron universal testing machine     | GIC (GC - Fuji I)                          | 12.34[^a]                 |
|                        |             |                          |                                      | RM-GIC (Fuji CEM)                          | 18.12[^a]                 |
|                        |             |                          |                                      | ARC (Relyx ARC, 3M ESPE)                   | 19.07[^a]                 |
| Raghunath Reddy et al. (2010) | 30   | Primary molar            | Instron universal testing machine     | Zinc phosphate                            | 21.28[^a]                 |
|                        |             |                          |                                      | Zinc polycarboxylate                      | 16.79[^a]                 |
| Veerabadhran et al. (2012) | 32     | Primary second molar     | Universal testing machine             | GIC                                        | 15.96[^a]                 |
|                        |             |                          |                                      | RM-GIC                                    | 19.36[^a]                 |
| Pathak et al. (2016)   | 30          | Primary molar            | Instron universal testing machine     | RelyX U 200 (3M ESPE)                      | 7.77[^a]                  |
|                        |             |                          |                                      | Smart CEM2 (Dentsply)                      | 3.63[^a]                  |
|                        |             |                          |                                      | RelyX luting 2 (3M ESPE)                   | 2.82[^a]                  |
| Parisay and Khazaei (2018) | 55    | Primary first molar      | Instron universal testing machine     | GIC (GC Gold Label I)                      | 29.24[^a]                 |
|                        |             |                          |                                      | Zinc phosphate (master dent)               | 35.89[^a]                 |
|                        |             |                          |                                      | Polycarboxylate (master dent)              | 21.5[^a]                  |
|                        |             |                          |                                      | Self-ARC (BISCEM)                         | 30.38[^a]                 |
|                        |             |                          |                                      | Control                                   | 2.96                      |

[^a,b]: If marked by the same letter, the difference between the groups is statistically insignificant;[^P]: 0.05. GIC=Glass-ionomer cement, RM-GIC=Resin-modified GIC; ARC=Adhesive resin cement

### Table 3: Risk of bias considering aspects reported in the materials and methods section

| Authors                        | Teeth randomization | Teeth free of caries | Materials mixed according to the manufacturer’s instruction | Whether all teeth used were same | Sample size calculated | Was testing method clearly defined | Blinding done of operator | Risk |
|-------------------------------|---------------------|----------------------|-------------------------------------------------------------|-------------------------------|------------------------|-----------------------------------|---------------------------|------|
| Yilmaz Y (2004)               | Yes                 | Yes                  | Yes                                                         | NC                            | No                     | Yes                               | NC                        | Medium |
| Yilmaz Y (2006)               | Yes                 | Yes                  | Yes                                                         | NC                            | No                     | Yes                               | NC                        | Medium |
| Subramaniam P (2010)          | Yes                 | NC                   | Yes                                                         | NC                            | No                     | Yes                               | NC                        | High  |
| Raghunath Reddy MH (2010)     | Yes                 | Yes                  | Yes                                                         | NC                            | No                     | Yes                               | NC                        | Medium |
| Veerabhadran MM (2012)        | Yes                 | Yes                  | Yes                                                         | No                            | No                     | Yes                               | NC                        | Medium |
| Pathak S (2016)               | NC                  | NC                   | Yes                                                         | NC                            | No                     | Yes                               | NC                        | High  |
| Parisay I (2018)              | Yes                 | Yes                  | Yes                                                         | Yes                           | No                     | Yes                               | NC                        | Medium |
There are several studies done to test the retentive strength of various luting cements such as zinc phosphate, zinc polycarboxylate, glass-ionomer, resin-modified glass-ionomer, and adhesive resin cements. Hence, this systematic review was done to obtain collective data which were analyzed together, giving support for the clinician on evidence-based decision-making.

Out of seven studies included in the systematic review, two studies have evaluated the retentive strength of zinc phosphate, zinc polycarboxylate, and GIC.\(^{[15,18]}\) The results showed that zinc phosphate presented the highest retentive strength compared to other two cements. The probable cause for the highest retentive strength of zinc phosphate cement is mainly due to three reasons: low solubility; low initial pH, which has an etching effect on enamel, thereby improving bond strength;\(^{[23]}\) and its thin film thickness (<25 μ), creating an intimate adaptation in interfaces and better setting of the crown.\(^{[22,24]}\)

However, the film thickness is of significance when tooth structure is sound and caries free; thus, the tooth can be prepared in a standardized manner. However, in most clinical situations, there is extended caries in teeth and conditions do not exactly represent those seen in an \textit{in vitro} condition. Furthermore, zinc phosphate is brittle, has a relatively high solubility in the mouth, and it does not adhere to tooth structure. They are also a potentially caustic substance, to vital pulp tissue due to their low pH.

The remaining five studies have compared glass-ionomer, RM-GIC, and adhesive resin cement. The results showed that adhesive resin cements had higher retentive strength compared to GIC, but no statistical significant differences was seen between adhesive resin cement and RM-GIC.\(^{[12‑14,16‑17]}\)

One of the studies has shown that GIC has better retentive strength over RM-GIC. The reason for this result could be because RM-GIC was used without a bonding agent as per the manufacturer’s instruction.\(^{[24]}\)

GIC may be a wise choice for crown cementation in pediatrics due to its advancements such as fluoride release, anticariogenic property, adhesion to tooth and base metal, optimum mechanical characteristics, and high compressive strength.\(^{[23]}\)

However, GIC shows variation in its retentive strength value due to its sensitivity during manipulation of powder: liquid ratio.\(^{[25]}\) Another reason for low retention of GIC could be due to spontaneous cohesive fracture of cement, due to stress created by contraction on setting and low tensile strength and fracture toughness.\(^{[24]}\)

Both conventional and RM-GIC dehydrate and contract in air or humidity.\(^{[27]}\) Addition of resin to the brittle composition of conventional GIC significantly increases its fracture toughness.\(^{[28]}\) Furthermore, if RM-GIC specimens are kept in extended storage in distilled water, it could improve the bond strength. It has been reported that water sorption and hygroscopic expansion of RM-GIC are useful in improving bonding ability and marginal seal.

Resin luting cements have higher mechanical properties than both GICs and RM-GICs.\(^{[25,27]}\) The resin cement contains a phosphoric acid ester monomer such as 10-MDP (10-methacryloyloxydecyl dihydrogen phosphate) and 5-NMSA (N-methacryloyl-5-aminosalicylic acid). When primer is applied on tooth structure, phosphate esters in the primer would decalcify dentin or enamel, thus improving the micromechanical bonding between the tooth and resin cement. In addition, ionic bonding may occur between the negatively charged phosphate ester monomer and the positively charged calcium ions on the tooth. Therefore, similar chemical interaction can occur between metal crown and phosphate ester monomer, resulting in improved retentive strength.\(^{[29]}\)

Furthermore, compressive strength, flexural strength, and modulus of elasticity of resin cements are significantly higher than conventional GIC and RM-GIC.\(^{[30]}\) However, this advantage is overlooked by the ability of RM-GIC to release fluoride and lesser clinical steps in the cementation of crown, low technique sensitivity, and low cost.\(^{[31]}\)

All the studies included in the review followed the same methodology. The teeth were tested in mechanical testing machine subjected to load until the first sign of dislodgement seen and the value was recorded. Only one study recorded two different values, i.e., first dislodgement which is recorded as retentive strength and complete dislodgement recorded as “peak force.” The difference between first dislodgement and “peak force” was recorded as “delta.” The higher this difference is, the more capable the cement is to tolerate intraoral forces. It is equally important that microleakage increases when first dislodgement happens and allows cement dissolution. If delta is low and is accompanied by delayed visit to a dentist, it may lead to failure in crown.\(^{[32]}\)

\textbf{Limitation}

The results of the present review should be interpreted considering the fact that \textit{in vitro} studies have intrinsic limitations when trying to simulate \textit{in vivo} conditions. Well-designed randomized controlled trials with long-term follow-up periods are needed to provide data for choosing better luting cements for cementation of SSCs.
Conclusion

Although the articles included in this systematic review showed high heterogeneity and medium to high risk of bias, the in vitro literature seems to suggest that self-adhesive resin cement is a superior luting cement compared with RM-GIC and conventional GIC. However, RM-GIC can be a preferred luting agent due to its clinical advantages over resin cements. Hence, the choice of cement will depend on the individual patient needs and clinical situation.

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Conflicts of interest

There are no conflicts of interest.

References

1. Humphery WP. Use of chrome steel in children’s dentistry. Dent Surv 1950;26:945-9.
2. Papathanasiou AG, Curzon ME, Fairpo CG. The influence of restorative material on the survival rate of restorations in primary molars. Pediatr Dent 1994;16:282-8.
3. Messer LB, Levering NJ. The durability of primary molar restorations: II. Observations and predictions of success of stainless steel crowns. Pediatr Dent 1988;10:81-5.
4. Einwag J, Dümmering P. Stainless steel crown versus multisurface amalgam restorations: An 8-year longitudinal clinical study. Quintessence Int 1996;27:321-3.
5. McDonald RE, Avery DR. Restorative dentistry. In: McDonald RE, Avery DR, editors. Dentistry for the Child and Adolescent. 7th ed. St. Louis: Mosby, 2000;384-412.
6. Garcia-Godoy F. Clinical evaluation of the retention of preformed crowns using two dental cements. J Pedod 1984;8:278-81.
7. Garcia-Godoy F, Bugg JL. Clinical evaluation of glass cementation on stainless steel crown retention. J Pedod 1987;11:339-44.
8. Roberts JF, Attari N, Sherriff M. The survival of resin modified glass ionomer and stainless steel crown restorations in primary molars, placed in a specialist paediatric dental practice. Br Dent J 2005;198:427-31.
9. Dahl BL, Olof G. Retentive properties of luting cements: An in vitro investigation. Dent Mater 1986;2:17-20.
10. Sahraneshin-Samani M, Samimi P, Mazaheri H. A review of adhesives and cements used in all-ceramic restorations and tooth-colored fiber posts. Dent Res J 2013;9:81-106.
11. Habib B, von Fraunhofer JA, Driscoll CF. Comparison of two luting agents used for the retention of cast dowel and cores. J Prosthodont 2005;14:164-9.
12. Yilmaz Y, Dalmis A, Gurbuz T, Simsek S. Retentive force and microleakage of stainless steel crowns cemented with three different luting agents. Dent Mater J 2004;23:577-84.
13. Yilmaz Y, Simsek S, Dalmis A, Gurbuz T, Kocogullari ME. Evaluation of stainless steel crowns cemented with glass-ionomer and resin-modified glass-ionomer luting cements. Am J Dent 2006;19:106-10.
14. Subramaniam P, Kondae S, Gupta KK. Retentive strength of luting cements for stainless steel crowns: An in vitro study. J Clin Pediatr Dent 2010;34:309-12.
15. Raghunath Reddy MH, Subba Reddy VV, Basappa N. A comparative study of retentive strengths of zinc phosphate, polycarboxylate and glass ionomer cements with stainless steel crowns – An in vitro study. J Indian Soc Pedod Prev Dent 2010;28:245-50.
16. Veerabadhran MM, Reddy V, Nayak UA, Rao AP, Sundaram MA. The effect of retentive groove, sandblasting and cement type on the retentive strength of stainless steel crowns in primary second molars – An in vitro comparative study. J Indian Soc Pedod Prev Dent 2012;30:19-26.
17. Pathak S, Shashibhushan KK, Poornima P, Reddy VS. In vitro Evaluation of stainless steel crowns cemented with resin-modified glass ionomer and two new self-adhesive resin cements. Int J Clin Pediatr Dent 2016;9:197-200.
18. Paraisy I, Khazaei Y. Evaluation of retentive strength of four luting cements with stainless steel crowns in primary molars: An in vitro study. Dent Res J (Isfahan) 2018;15:201-7.
19. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JP, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: Explanation and elaboration. BMJ 2009;339:b2700.
20. Sarkis-Onofre R, Skupien JA, Cenci MS, Moraes RR, Pereira-Cenci T. The role of resin cement on bond strength of glass-fiber posts luted into root canals: A systematic review and meta-analysis of in vitro studies. Oper Dent 2014;39:E31-44.
21. Gorodovsky S, Zidan O. Retentive strength, disintegration, and marginal quality of luting cements. J Prostheth Dent 1992;68:269-74.
22. Ergin S, Gemalmaz D. Retentive properties of five different luting cements on base and noble metal copings. J Prostheth Dent 2002;88:491-7.
23. Lad PP, Kamath M, Tarale K, Kusugal PB. Practical clinical considerations of luting cements: A review. J Int Oral Health 2014;6:116-20.
24. Powers JM. Cements. In: Craig RG, Powers JM, editors. Restorative Dental Materials. 11th ed. St. Louis: Mosby, 2002;593-634.
25. McLean JW. Glass-ionomer cements. Br Dent J 1988;164:293-300.
26. Mitchell CA, Douglas WH, Cheng YS. Fracture toughness of conventional, resin-modified glass-ionomer and composite luting cements. Dent Mater 1999;15:7-13.
27. Jokstad A. A split-mouth randomized clinical trial of single crowns retained with resin-modified glass-ionomer and zinc phosphate luting cements. Int J Prosthodont 2004;17:411-6.
28. Kumbuloglu O, Lassila LV, User A, Toksavul S, Vallittu PK. Bond strength of luting cement to casting and soldering alloy. Eur J Prosthodont Restor Dent 2006;14:18-22.
29. Eliades GC, Vougiouklakis GJ. 31P-NMR study of P-based dental adhesives and electron probe microanalysis of simulated interfaces with dentin. Dent Mater 1989;5:101-8.
30. Leevailoj C, Platt JA, Cochran MA, Moore BK. In vitro study of fracture incidence and compressive fracture load of all-ceramic crowns cemented with resin-modified glass ionomer and other luting agents. J Prostheth Dent 1998;80:699-707.
31. Mitchell CA, Abbariki M, Orr JF. The influence of luting cement on the probabilities of survival and modes of failure of cast full-coverage crowns. Dent Mater 2000;16:198-206.