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Dissertação apresentada à Universidade Católica Portuguesa para obtenção do grau de Mestre em Medicina Dentária

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Orientadora: Prof.ª Dr.ª Anna Carolina Volpi Mello-Moura
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ABSTRACT

The aim of this study was to evaluate, through an umbrella review, whether primary and permanent teeth can be definitively restored with glass ionomer cements. A systematic search of the studies available in the literature was conducted in the electronic databases MEDLINE/Pubmed, Scopus and Web of Science. Two independent, calibrated examiners. The eligibility criteria were: (1) to be a systematic review (2) to evaluate the clinical longevity of glass ionomer cements (GICs) in primary and permanent teeth (3) to be clinical trials. The systematic reviews that met these criteria were reviewed in their entirety and those who presented at least one of the following exclusion criteria were then considered ineligible: (1) not being a systematic review of clinical trials; (2) not evaluating the longevity/clinical performance of GICs; (3) studies of dental restorative materials in teeth with enamel alterations. Methodological quality was measured using the AMSTAR-2 tool and the risk of bias of the included systematic reviews by the ROBIS tool. The level of evidence analysis was performed using the GRADE tool. Twenty-four eligible articles were identified, only 13 articles were included. Glass ionomer cements seems to be a viable choice in both dentitions, but primary dentition presents more evidence, especially regarding the ART technique. There is conflicting evidence on which type of glass ionomer is the best and comparisons to other dental materials are lacking. In conclusion, more high-quality studies are needed with longer follow up periods (>6 years), especially in permanent teeth.

Keywords: glass ionomer cement, umbrella review, primary teeth, permanent teeth

SUMMARY

Umbrella Review

1. INTRODUCTION

General considerations

Over time, the evolution of dental materials has occurred because of the change in patient needs and professional perception, as well as industrial development. During the 1920s, the focus was mostly on purely mechanical characteristics, thus limiting the development of potential new dental materials. During the 1950s, this approach changed, placing greater emphasis on biocompatibility and adhesion to dental tissues. This led to the development of new materials such as glass ionomer cements, whose origin is associated with this change of approach regarding the qualities demanded in a dental material and the development of new techniques have permitted a better use of it[1].

It is the idea of a physicochemical adhesion to dental tissues in the 1960s that led to the invention of these materials, in fact the glass ionomer cements can form a specific adhesion with hydroxyapatite and have various clinical applications[2]. The constant need for novelty in the field of dentistry is the result of this change in professional and patient needs, and with the passage of time, it has been shown that caries treatment is not only technical but requires a broader approach. For example, the use of less invasive techniques, biocompatibility of materials, aesthetics, lower costs for the patient, are all factors that must be taken into consideration for greater clinical success and patient satisfaction[3].

In ancient times, an ideal restorative material was seen as stable and passive, without any kind of interaction with the oral cavity. Over time, the idea began to take hold that active materials, such as the release of fluoride, could have useful effects. They are called "smart materials", which, by definition, are “materials that have properties which may be altered in a controlled fashion by stimuli, such as stress, temperature, moisture, pH, electric or magnetic fields”[4]. There is a growing interest in these so-called "smart materials" especially for the enamel remineralization.

They have numerous advantages such as fluoride release for a prolonged period, excellent adhesive strength, high compressive strength, low stimulation, low solubility, the equivalent thermal expansion coefficient to tooth structure, versatility, inhibition of caries and what distinguishes them from other restorative materials is the usage in cavities without needing bonding agents. The main disadvantages of GICs (glass ionomer cements) are lack of sufficient strength, toughness, and moisture-sensitivity. The clinical applications of glass ionomers are varied: restoration, lining material, sealing, hyper sensibility care and temporary cavity restoration[5,6].

Therefore, modern Dentistry is increasingly moving away from metal restorations, to make room for more aesthetic materials, which in clinical terms means switching from amalgam to composites and glass ionomers associated to minimally invasive techniques[3].

In 2020, a survey was conducted in Germany between dentists, gathering information about the type and durability of their permanent molar restorations. Of 1719 molars from 288 dentists, only the 0,8% were restored with glass ionomer cements (GIC)[38]. This is a very low percentage in the sample population, which leads to the question of whether these materials are viable for definitive restorations or not.

In another study conducted by Ho et al. (1999), two conventional GICs were used as restorative materials for 110 small occlusal restorations in molars. There was a 7% early loss of GICs from the occlusal pits and fissures next to the restorations. Only 2,3% percent of the sealants were totally kept after two years, with 63,2% percent partially retained. Carious lesions were seen in 5,3% percent of the fissures where sealants had been lost. The original colour matching was maintained by very few restorations and others darkened in following recalls. One tooth fracture was reported, two failures from irreversible pulpitis, seven from wear and fracture of the cement, one bulk fracture, three shallow restorations completely lost and three cases of recurrent marginal carious lesions[39].

In 2018, a study included 1.6 million GIC restorations to evaluate their survivability and the factors that might influence it. Specifically regarding molars, the survival to re-intervention rate was 81% at 1 year, 52% at 5 years, 36% at 10 years, 28% at 15 years in upper molars and 81%, 49%, 34% and 26% at 1, 5, 10, 15 years in lower molars. This large study involving all types of teeth, showed that the performance of GICs is highly tooth-dependent[40].

Frankenberger et al. (2009) conducted a study where 55 patients received 108 GICs restorations in permanent molars, 21 occlusal, and 94 occlusal-proximal restorations. After 24 months, 8% occlusal restorations failed, while 40% occlusal-proximal. Of these occlusal-proximal failures, 17 were material-associated (9 bulk fractures, 4 hypersensitivities, 3 gap formations, 1 tooth fracture and 1 complete loss of the restoration). Already after 12 months, 34% of the occlusal-proximal cavity restorations failed. In the 24 months period, the annual failure rate resulted 20%. Occlusal-proximal restorations carried out the extensive wear, fatigue behaviour and insufficient flexural strength[41].

Due to the lack of physical properties, over time modifications of GICs were experimented and studied by the addition of metals, fibers, ceramics to the GIC powder in the attempt to overcome these problems and improve the material and clinical performance.

Glass-Ionomer Cement (GIC) Types

Nowadays there are many variants of GICs, because over time changes have been made in their composition, both in the amount of powder and water, that have allowed to bring to light the limitations and advantages of these materials.

Resin-Modified GICs (RMGICs)

RMGICs were created to overcome the disadvantages of conventional glass ionomers, such as moisture sensitivity and low initial mechanical strength. They are produced as conventional GIC but also include a small addition of light-curing resin, 2-hydroxyethyl methacrylate (HEMA), but due to the release of this monomer, biocompatibility is compromised. RMGICs possess the advantages of GICs and the mechanical and physical properties of composite resins. Clinical applications are the same as conventional GICs and they are also used in Class I, Class II and Class III restorations (mostly in primary dentition), Class V restorations, as liners and bases, fissure sealants and bonding agents for orthodontic brackets[7].

Metal Reinforced GICs

These GICs are obtained by the addition of amalgam alloy powder and sintered silver particles to the glass component in the attempt to improve the diametral tensile strength, hardness, and abrasion resistance[8,9]. Despite these improvements, it also showed frequency of failure as adhesive, cohesive, incidence of brittle fracture in the surface and less fluoride release[8].

Hydroxyapatite and Zirconia reinforced GICs

Hydroxyapatite (HA) has been incorporated in GICs due to its excellent biocompatibility and biological behaviour, because its structure and composition are similar to those found in human natural teeth[10].

It showed a significant improvement in flexural strength, without any significant changes in compressive strength (CS), diametral tensile strength (DTS)[11], while higher amounts of HA powder (12 and 28%) showed a decline in CS and DTS[11,12].

Instead, addition of nano-HA and nano-fluorapatite (nano-FA) showed improvements in CS, DTS and biaxial flexural strength (BFS)[13].

Zirconium (ZrO_2) and its subclasses have been used to improve the toughness and strength of brittle HA bioglasses. Studies showed that the ZrO_2 addition improved mechanical properties due to the uniformity of particles distribution in the matrix. Also, HA did not dissolve in distilled water. The main weakness was in the interface between ZrO_2 and the glass particles, where propagation of cracks around the glass appeared[10,14]. More recent studies showed that addition of nano-zirconia-silica-hydroxyapatite (nanoZrO_2-SiO_2-HA) to GIC powder improved mechanical and aesthetical performance[15,16].

Fiber reinforced GICs

Reactive glass fibers are known for their ability to promote healing and incorporate into hard tissues. Various studies have been made to see if their addition to GICs could improve mechanical properties. It has been demonstrated that addition of short glass fibers (CaO–P_2O_5–SiO_2–Al_2O_3) was able to increase the DTS value[17]. There was an increase in fracture toughness (FT) by the addition of 20% vol short fibers as demonstrated by Lohbauer[18]. In 2017 *Garoushi et al.* studied the effect of addition of hollow and solid discontinuous glass fiber fillers, and they observed an increase in FT and flexural strength (FS), but no significant difference in CS[19]. This beneficial improvement in mechanical properties was mostly obtained when these GIC modifications were used as filler agents[18,19].

Zinc reinforced GICs

Zinc reinforced Glass Ionomers (ZRGIC) were introduced to improve FS, hardness, FT, and abrasive wear of conventional GICs.
Studies demonstrated that the incorporation of zinc improved fracture toughness and abrasive wear[22], but inferior surface roughness and hardness[23].

GICs containing YbF_3 and $BaSO_4$

Prentice *et al.* carried out a study regarding the addition of Ytterbium fluoride and Barium sulfate (YbF_3 and $BaSO_4$) nanoparticles to GICs. The aim was to increase the radiopacity of the cement ($BaSO_4$) and to modify working and setting times (YbF_3). It showed a decrease in surface hardness and compressive strength, mostly correlated to $BaSO_4$ addition, and a decrease in working and setting times[10].

Niobium pentoxide modified GICs

Another modification consists of the addition of niobium pentoxide to GICs.
A study was conducted by Bartolini *et al.*, where the effects of niobium silicate addition were evaluated. The result highlighted the increase of GICs setting time, that resulted in a negative impact on mechanical properties[24]. In another study it was observed a reduced value in microhardness of the GIC modification by 10-20% niobium addition, while no changes in physical and chemical properties and improved radiopacity at 5%[25].

Casein Phosphopeptide-Amorphous Calcium Phosphate (CPP-ACP) modified GICs

Various studies have been made on CPP-ACP effects in dentistry, because of its characteristics of preventing demineralization and promoting remineralization of the enamel. Addition of CPP-ACP in GICs powder showed an increase of both

CS and microtensile bond strength (MBS)[26]. Also, CPP-ACP addition increased fluoride, calcium, and phosphate ions release, proving its potential effects on preventing caries formation[27].

Silica reinforced GICs

The addition of silica to conventional GICs was attempted to improve their mechanical properties. Shiekh et al. conducted a study to evaluate the effects of a nano-hydroxyapatite-silica addition to the powder. The results showed a 73% increase in microhardness value[28]. Other studies (Tjandrawinata et al, Felemban N.H., Ebrahim M.I., Huiyi Yan et al.) showed important results in term of mechanical improvements: increase in CS, FS and shear bond strength (SBS), increase of modulus of elasticity, but also decreased microleakage and water solubility[10,29].

SrO reinforced GICs

Strontium (SrO) is another material that has been added to GICs powder. A significant increase in mechanical properties was observed in two different studies: in the first one, 5, 10 and 20% of the glass was replaced by SrO resulting in an increase of CS and both working and setting times. In the second study, magnesium (Mg) was partially substituted by SrO and the result was an increase in mechanical properties, decreasing with further increase in SrO[10,29].

Fluorinated Graphene modified GICs

Fluorinated Graphene was added to conventional GICs to improve mechanical and antibacterial properties. It was observed an enhancement in those properties, without compromising the solubility, color and F ion release[30]. Another study showed similar results, where the addition of FG increased hardness, wear resistance (WR) and enhanced bacteriostatic properties[31].

Cellulose Nano-Crystals (CnCs) modified GICs

Silva et al. conducted a study where they added a small concentration of CnCs in the GIC powder to observe possible mechanical properties modifications. It showed that even with a small percentage, CnCs increased DTS, CS and elastic modulus (EM)[32]. The same results were shared by another study conducted by Moradian et al., where bacterial CnC were added to resin-modified GICs. The results showed an increase in DTS, CS and EM[33].

Cellulose Nano-Crystals (CnCs) and Titanium Oxide modified GICs

In combination to CnC, titanium oxide was added to conventional GICs to observe the resulting effects. This combination was studied recently (2019) and mechanical properties showed a great improvement: SBS and CS were increased respectively by 151% and 18,9%[34].

Montmorillonite Clay modified GICs

An experiment was conducted by Dowling et al., where a conventional GIC was modified by the addition of 12-amino-dodecanoicacid montmorillonite (ADA-MMT) and inorganic calcium montmorillonite (Ca-MMT) at 0.5 to 2.5 wt%. This resulted in an increase of CS with the addition of ADA-MMT and a decrease with the addition of Ca-MMT[35]. More recently, the effects of polymer-grade montmorillonite clay (PGV and PGN nanoclay) in addition to conventional GICs were evaluated. In this case, 2 wt% was used and it resulted in better mechanical properties. This study highlighted that the dispersion of nanoclay inferior to 2 wt% could produce a material with improved mechanical performance[36].

Forsterite modified GICs

Forsterite is another mineral that has been experimented in medical applications. The impact of nano-forsterite particles on mechanical properties was observed in a study, and the results were promising: the addition of 1 wt% forsterite to conventional GIC powder increased the values of FS, CS and DTS, but on the other hand, the fluoride release was slightly decreased[29].

Yttria stabilized Zirconia modified GICs

Yttria stabilized Zirconia (YSZ) is a ceramic that has been experimented as an addition to GICs due to its good mechanical properties. A study conducted in 2014 tried to evaluate the effect of hydroxyapatite/YSZ (HA/YSZ) addition to conventional GICs. In comparison, the modified version showed an increase in CS, DTS, microhardness and the mechanical properties were satisfactory even when being soaked for 7 days[37].

In 2018, an international meeting of GICs experts was held, with the objective to discuss about several laboratory studies and achieving a consensus on the ideal mechanical properties' threshold for a glass-ionomer cement to be successful in long-term restorations. A reliable GIC should possess some fundamental thresholds requirements to achieve this clinical success[42].

Those are:

- compressive strength: the ISO 9917-1:2016 specification of 100 MPa
- microhardness: 70 KHN
- acid erosion: the ISO standard, of maximum 0.17 mm
- fluoride release: the highest possible value[42]

Aim of the study

As we can see, there are several types of glass ionomer as well as different indications due to different clinical situations. Knowing how to identify the best GIC for each case is important for the success and longevity of the treatment. Therefore, the objective of this study was to evaluate, through an umbrella review, whether primary and permanent teeth can be definitively restored with a GIC.

2. MATERIALS AND METHODS

Outline

This study was designed as an “umbrella review”, which was registered on the PROSPERO (International prospective register of systematic reviews) (CRD42022320602) and reported according to PRIO (Preferred Reporting Items for overview of systematic reviews).

Two researchers independently participated in all processes (AL and ACVMM), from article checking, data collection and risk of bias analysis. A researcher with experience in systematic reviews (TG) resolved cases of conflict or doubt.

Study sources

A systematic search of available studies in the literature was conducted in the electronic databases MEDLINE/PubMed, Web of Science and Scopus to identify articles. In addition, the reference list of potentially eligible studies was also screened to verify all relevant articles that may not have been identified during the database searches. There was no restriction for the language of publication in the inclusion criteria.

Search strategy

The search strategies were based on the PICO(S) question “What is the clinical performance in primary and permanent teeth restored with glass ionomer cements?”, developed for the MEDLINE/Pubmed database and adapted for each consulted database. The results of the different bases were crossed to locate and eliminate the duplications.

Below is the defined PICO (S) question:

(Patient/Problem): primary and permanent teeth with restorations I (intervention): glass-ionomer cements restorations C (comparison): comparison between different types of glass-ionomers, composite, and amalgam O (outcome): restoration longevity, S (study type): systematic review.

The complete search strategy for MEDLINE / PubMed is shown below:

((“dental restoration” OR restoration OR “atraumatic restorative treatment” OR “permanent teeth” OR “primary teeth”) AND (“glass ionomer cement” OR “glass ionomer”) AND (“success rate” OR “pulp vitality” OR survival rate) AND ("systematic review” OR "Syst Rev” OR overview OR review))

For the Web of Science database, the following strategy was used:

TS= ((“dental restoration” OR restoration OR “atraumatic restorative treatment” OR “permanent teeth” OR “primary teeth”) AND (“glass ionomer cement” OR “glass ionomer”) AND (“success rate” OR “pulp vitality” OR survival rate) AND ("systematic review” OR "Syst Rev” OR overview OR review))

For the Scopus database, the following strategy was used:

TITLE-ABS-KEY== ((“dental restoration” OR restoration OR “atraumatic restorative treatment” OR “permanent teeth” OR “primary teeth”) AND (“glass ionomer cement” OR “glass ionomer”) AND (“success rate” OR “pulp vitality” OR survival rate) AND ("systematic review” OR "Syst Rev” OR overview OR review))

Eligibility Criteria

All titles and abstracts of studies found were initially evaluated by one reviewer based on the inclusion criteria: (1) to be a systematic review (2) to evaluate the clinical longevity of GICs in primary and permanent teeth (3) to be clinical trials. After the first evaluation, the articles that met the inclusion criteria were reviewed in their entirety, with those that presented at least one of the following exclusion criteria being excluded: (1) not being a systematic review of clinical trials; (2) not evaluating the longevity/clinical performance of GICs; (3) studies of dental restorative materials in teeth with enamel alterations.

The full papers of the included studies were read to ensure that they were about restoration of permanent molars with GICs and were not critical/narrative reviews, letters to the editor or guidelines.

Data collection

The same reviewers (ACVMM and AP) collected the data independently, in tables structured in Excel spreadsheets. The information extracted was: title, year, authors, PICO, protocol record (yes or no), number of included studies, meta-analysis, databases used, search strategy, search date, number of reviewers, inclusion and exclusion criteria, language, type of materials, treatment type, follow-up period, objective of the study, quality analysis and risk of bias (yes or no and which tool were used), main results and conclusions.

Assessment of methodological quality and risk of bias

Two reviewers (ACVMM and AP) independently performed the quality and risk of bias analyses. The methodological evaluation was carried out using the AMSTAR-2 tool (Shea et al., 2007), while the ROBIS tool (Whiting et al., 2016) was used to assess the risk of bias. The level of evidence was evaluated by the GRADE tool[43,44].

3. RESULTS

PROSPERO registration was performed (CRD42022320602), the PICO question was established, the search strategy determined, and in April 2022 data collection was performed. A systematic literature search identified 132 references potentially relevant, with 37 publications from the MEDLINE/PubMed database, 51 from Scopus and 44 from Web of Science. Duplicates were excluded, for a total of 41. Based on the information provided in the title and abstract, 67 articles were considered ineligible. The main reasons for non-inclusion were: 1) not a systematic review, 2) not evaluating clinical performance/longevity of GICs, 3) teeth with enamel alterations were observed. Twenty-four articles were analysed in full to collect more detailed information. Eleven studies were excluded for the following reasons: 1) not being a systematic review of clinical trials, 2) not evaluating clinical performance/longevity of GICs. Finally, 13 studies were included in the following review. The study selection process is shown in Figure 1.

3.1 STUDY SELECTION

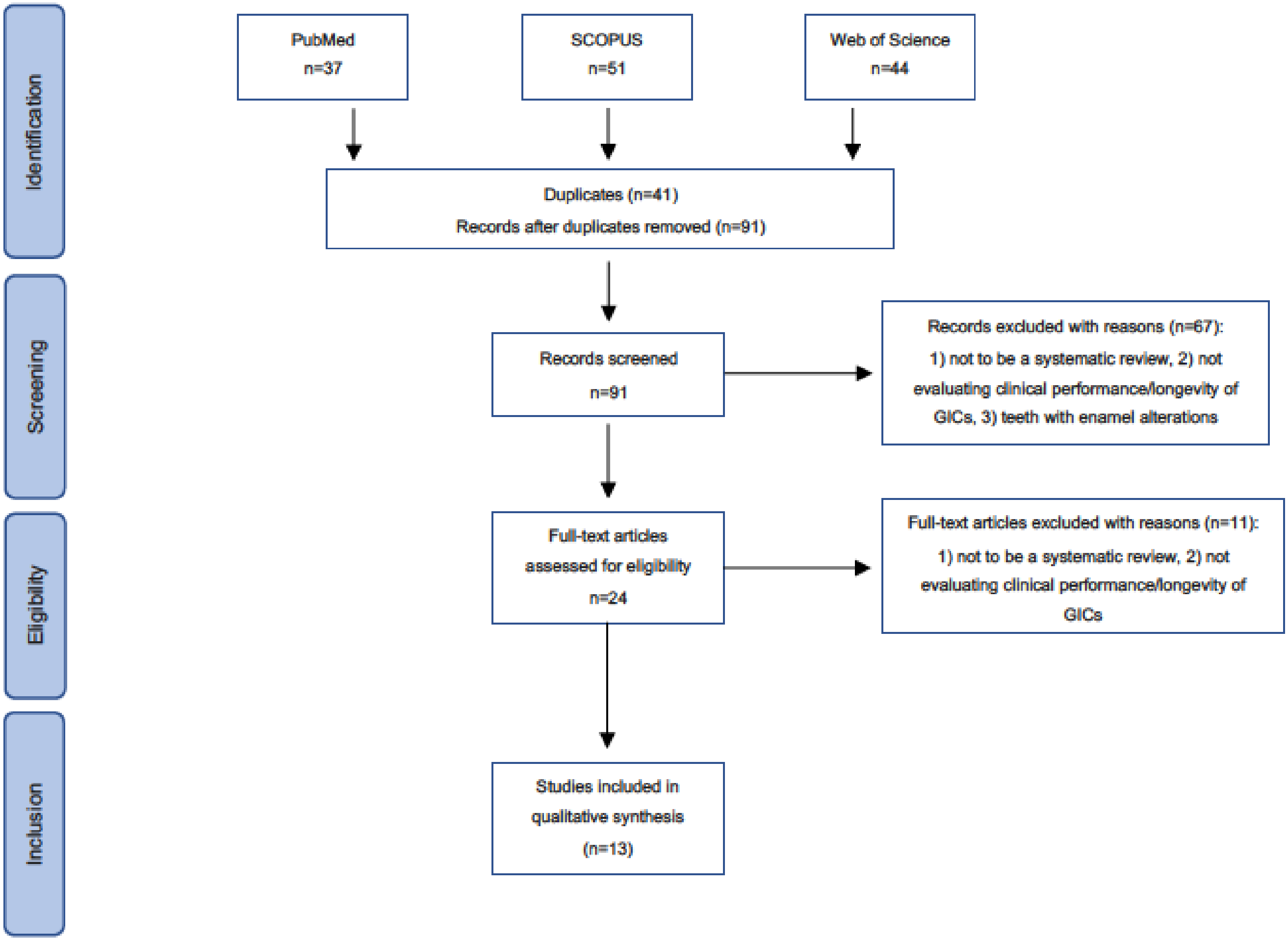

Figure 1. Flowchart of the inclusion criteria process

3.2 CHARACTERISTICS OF INCLUDED STUDIES

The characteristics of the included studies are shown in Table 1. Only 6 studies presented a PICO question and 7 mentioned a protocol registration. Two studies did not report a search strategy. All the studies presented inclusion and exclusion criteria. The follow-up periods ranged from 6 months to 6 years. Regarding quality analysis and risk of bias, only 6 studies presented both and 2 did not present neither of them. Two studies presented quality analysis but not risk of bias and other 2 the opposite. Four studies included results in other languages besides English. The included studies aimed at evaluating the clinical performance of glass-ionomer cements (GICs) used as a definitive restorative material in both primary and permanent dentition. Different types of GICs were evaluated in the included studies: resin-modified glass ionomer cements (RMGICs), compomers, low and high viscosity glass ionomer cements. Some studies compared amalgam and composite resins to GICs in terms of longevity/clinical performance. In general, more evidence is needed to draw conclusions on which is the best material for definitive restorations in permanent and primary dentition.

3.3 QUALITY ANALYSIS

AMSTAR-2 was used for the methodological quality of the included studies, as shown in Table 2. None of the articles had positive criteria in all the evaluated requisites and none of the articles had a priori design. Most of the studies (Santamaria et al. 2020, Garbim et al. 2021, Maia et al. 2021, Santos et al. 2016, Yengopal et al. 2009, Ruengrungsom et al. 2018, Heintze et al. 2022, Tedesco et al. 2018, Amorim et al. 2018, Raggio et al. 2012, Mickenautsch et al. 2015) defined a search strategy (positive criteria) and excluded grey literature (Santamaria et al. 2020, Yengopal et al. 2009, Ruengrungsom et al. 2018, Heintze et al. 2022, Tedesco et al. 2018, Kielbassa et al. 2016, Studart et al. 2012, Amorim et al. 2018, Raggio et al. 2012). In all the studies, inclusion and exclusion criteria were described, receiving a positive value. Four studies (Ruengrungsom et al. 2018, Heintze et al. 2022, Studart et al. 2012, Mickenautsch et al. 2015) did not use tools for quality analysis, being negatively evaluated. Two studies

(Studart et al. 2012, Mickenautsch et al. 2015) did not use any risk of bias tool. Two studies (Amorim et al. 2018, Mickenautsch et al. 2015) have some conflict of interest, however more related to teaching the use of GIC in different strategies.

Table 1. Characteristics of the included studies

TITLE	YEAR	AUTHOR	PICO	PROTOCOL REGISTRATION	INCLUDED STUDIES	META-ANALYSIS	DATABASES	SEARCH STRATEGY	SEARCH DATE	DUPLICATE ELIMINATION	INCLUDED LANGUAGES	NUMBER OF REVIEWERS
How to Intervene in the Caries Process: Dentin Caries in Primary Teeth	27 August 2020	Ruth M. Santamaria et al.	Yes	No	18	No	MEDLINE/PubMed	Yes	March 1, 2019	Not specified	English, Spanish	6
Atraumatic restorative treatment restorations performed in different settings: systematic review and meta-analysis	18 August 2021	Jonathan R. Barbim et al.	Yes	Yes	38	Yes	PubMed/MEDLINE, Scopus, Web of Science, Open Grey	Yes	April-20	Yes	English, no restrictions	3
Survival of atraumatic restorative treatment restorations in the elderly patients: a systematic review	6 December 2021	Thais S. Mata et al.	Yes	Yes	7	No	PubMed/MEDLINE, Scopus, LILACS, SciELO, Embase, Web of Science, OpenGrey, OpenThesis	Yes	August 2020	Yes	English, Portuguese, no restrictions	2
Survival of Adhesive Restorations for Primary Molars: A Systematic Review and Meta-analysis of Clinical Trials	1 September 2016	Ana P. Santos et al.	Yes	Yes	11	Yes	Cochrane Oral Health Group's Trials Register, PubMed/MEDLINE, Web of Science, Cochrane Library, LILACS, Clinical Trials - U.S. National Institute of Health, National Institute for Health and Clinical Excellence	Yes	Up to November 2015	Yes	English, no restrictions	6
Dental fillings for the treatment of caries in the primary dentition	15-Apr-09	V. Yengopal et al.	No	Yes	3	No	The Cochrane Oral Health Group's Trials Register, CENTRAL, MEDLINE, EMBASE, SIGLE	Yes	January 2009	Yes	English, no restrictions	2
Comparison of ART and conventional techniques on clinical performance of glass-ionomer cement restorations in load bearing areas of permanent and primary dentitions: A systematic review	November 2018	C. Ruengrungsom et al.	No	No	67	No	PubMed	Yes	29 March 2018	Not specified	English	Not specified
Clinical efficacy of resin-based direct posterior restorations and glass-ionomer restorations – An updated meta-analysis of clinical outcome parameters	24 February 2022	Siegward D. Heintze et al.	Yes	No	62	Yes	PubMed, SCOPUS	Yes	January 2020	Not specified	English	2
Scientific evidence for the management of dentin caries lesions in pediatric dentistry: A systematic review and network meta-analysis	21 November 2018	Tamara K. Tedesco et al.	Yes	Yes	15	Yes	MEDLINE/PubMed, Web of Science, Scopus	Yes	December 2017	Yes	English, no restrictions	3
Systematic review on highly-viscous glass-ionomer cement/resin coating restorations (Part I): Do they merge Minamata Convention and minimum intervention dentistry?	20 October 2016	Andrej M. Kielbassa et al.	Yes	No	7	No	PubMed, Cochrane Library, EBSCO, EMBASE, SCOPUS	No	June 2016	Yes	English	5
Atraumatic Restorative Treatment in permanent molars: a systematic review	January/March 2012	L. Studart et al.	No	No	28	No	PubMed/MEDLINE, LILACS	No	April 2001 - December 2010	Not specified	English, Portuguese, Spanish	3
Survival percentages of atraumatic restorative treatment (ART) restorations and sealants in posterior teeth: an updated systematic review and meta-analysis	19 September 2018	R. G. de Amorim	No	Yes	48	Yes	PubMed, EMBASE, LILACS, BBO, CNKI, VIP	Yes	Not specified	Not specified	English, Dutch, Spanish, Portuguese, Chinese	6
Is Atraumatic restorative treatment an option for restoring occlusoproximal caries lesions in primary teeth? A systematic review and meta-analysis	28 November 2012	Daniela P. Raggio et al.	No	No	3	Yes	PubMed	Yes	Up to February 2012	Not specified	English	3
Failure Rate of Direct High-Viscosity Glass-Ionomer Versus Hybrid Resin Composite Restorations in Posterior Permanent Teeth - a Systematic Review	22 December 2015	S. Mickenautsch et al.	Yes	Yes	6	No	PubMed/Medline, CENTRAL (Cochrane Library), Directory of Open Access Journals (DOAJ), Biomed Central, IndMed, Sabinet, OpenSIGLE, GoogleScholar	Yes	Until December 2, 2013	Yes	English	2

Continuation of Table 1.

AUTHOR	INCLUSION CRITERIA	EXCLUSION CRITERIA	MATERIAL TYPE	TREATMENT TYPE	FOLLOW-UP	OBJECTIVE OF THE STUDY	QUALITY ANALYSIS	RISK OF BIAS	TOOLS/DATA ANALYSIS	OUTCOME	CONCLUSIONS
Ruth M. Santamaría et al.	Yes	Yes	Preformed metal crowns, amalgam, composite resin, glass ionomer cement, and compomer	Restorative	At least 12 months after intervention	To evaluate the treatment and material used in primary dentition to effectively treat dentin carious lesions	Yes	Yes	PRISMA statement, Cochrane risk of bias tool, Mendeley software, ORCA/EFCD consensus workshop	The studies included compare different dentin carious lesions techniques and approaches, such as selective carious tissue removal, no carious tissue removal, atraumatic restorative treatment (ART), ultraconservative treatment (UCT), no treatment of carious lesions. Also, results compared the performance of different restorative dental materials.	Due to insufficient evidence and limited quality, conclusion could not be drawn. But in general, there isn't just an ideal single treatment that must be taken into considerations when managing dentin carious lesions in primary teeth.
Jonathan R. Garbim et al.	Yes	Yes	High viscosity glass ionomer	Restorative	12 or 36 months	To evaluate the atraumatic restorative treatment (ART) longevity in primary and permanent dentition.	Yes	Yes	PRISMA guidelines 2020, RoB 2.0 tool - Cochrane Handbook for Systematic Reviews of Interventions, ROBINS-I tools, Begg's Test, Rstudio, ART evaluation criteria, United States Public Health Service (USPHS), Gemert-Schriks criteria	Different brands of glass ionomer cements were compared regarding ART longevity in primary and permanent dentition, in occlusal and multi-surface restorations.	ART restorations seems to have a long-term survivability, making it a reliable treatment in both primary and permanent dentition.
Thaís S. Maia et al.	Yes	Yes	Glass ionomer	Restorative	6 months - 5 years	To evaluate the atraumatic restorative treatment (ART) longevity in elderly patients.	Yes	Yes	Joanna Briggs Institute's Critical Appraisal Tool, PRISMA guidelines	Conventional and resin modified glass ionomer cements (RMGIC) were compared in terms of ART survivability, evaluating wear, marginal defects and need for replacement.	Despite would be ideal to conduct more studies with longer follow-ups, ART showed positive results in terms of longevity in elderly patients.
Ana P. Santos et al.	Yes	Yes	Composite resin (CR), conventional glass ionomer cement (GIC), resin-modified glass ionomer (RMGIC), silver reinforced glass ionomer cement, and compomer	Restorative	18, 24, 36 months	To evaluate the longevity and clinical performance of different adhesive restorative materials in primary molars.	Yes	Yes	PRISMA guidelines, Reference Manager 12.05.0, modified version of the Jadad scale (0-8 points), Comprehensive Meta-Analysis Program (Biostat, Englewood, N.J., USA), United States Public Health Service (U.S.PHS)	Results compared how five different restorative materials performed in Classes I and II in 5-10 years old patients in different settings, with different types of isolations.	More randomized controlled trials are needed, but from this study all materials performed well when used for restorations in primary molars, excepting the silver-reinforced glass ionomer cement, whose survival rate was the worse. Glass ionomer cements didn't show less survival rates compared to resin-based materials.
V. Vangopal et al.	Yes	Yes	Resin-modified glass ionomer, amalgam, compomer	Restorative	Minimum 6 months	To compare the outcomes of different dental materials used in restorations of carious lesions in primary dentition.	Yes	Yes	Cochrane Collaboration statistical guidelines, Cochrane Highly Sensitive Search Strategy (CHSSS), Cochrane Handbook for Systematic Reviews of Interventions 5.0.1, Chi2 test for heterogeneity, Ryge criteria	Resin-modified glass ionomer cement compared to amalgam in class II restorations. The clinical success was evaluated taking into considerations surface texture, marginal integrity, axial contour, wear, restoration placement, secondary caries, restoration fracture and staining.	Due to the absence of scientific evidence, is not possible to recommend a specific material. The 5 trials did not show any significant differences regarding the outcomes.
C. Ruengrungsom et al.	Yes	Yes	Glass ionomer cements	Restorative	≥ 1 year	To observe the clinical performance of glass ionomer cements in Classes I and II restorations using the ART techniques.	No	Yes	ROBINS-I, PRISMA flow diagram	Comparison of single/multi-surface restorations in load bearing areas in permanent and primary teeth performed with conventional GIC technique vs ART technique and reasons for failure.	The conventional GIC technique showed better results compared to the ART technique and it is preferred in primary dentition (lower annual failure rates). In general, multi-surface restorations showed greater failure rates compared to single-surface restorations. The main causes of failures were fracture and dislodgment. RMGIC conventional technique showed promising results in restoring proximal cavities.
Siegward D. Heintze et al.	Yes	Yes	Resin composite, compomer or GICs restorations (high viscous glass ionomer and resin-modified glass ionomer)	Restorative	≥ 2 years	To evaluate the longevity of Class I and II restorations performed with resin-based materials and glass ionomer.	No	Yes	Ryge criteria, Cochrane Collaboration's tool	In the analysis, materials were divided in microhybrid, nanohybrid and hybrid regarding composite filler and bulk fill materials, GICs and compomers were treated as a separated category. The conditioning and adhesive systems were: etch&rinse 2 and 3 steps, self-etch 2 and 1 steps, enamel etch + enamel bonding and no etching/adhesive systems (polyacrid acid and GICs). Curing time ranged from 10-60 seconds. Follow-up periods 2-8 years.	Resin showed better results in terms of longevity compared to compomers and GICs due to fracture and excessive wear.
Tamara K. Tedesco et al.	Yes	Yes	Low and high viscosity Glass Ionomer Cement, resin-modified glass ionomer cement (RMGIC) resin composite, amalgam	Restorative	≥ 1 year	To observe the success rate and effectiveness of dentin carious lesion treatments in primary dentition.	Yes	Yes	Cochrane Handbook for Systematic Reviews of Interventions, ROBINS-I, PRISMA-NMA extension, GRADE tool, I2 test, R package "stats" version 3.15.5	Comparison between conventional restorative treatment (CRT), atraumatic restorative treatment (ART), non-restorative caries treatment (NRCT) and ultraconservative caries treatment (UCT) in occlusal/occluso-proximal surfaces in primary dentition.	The success of the treatment depends on the depth of progression of the caries and the surfaces involved. Without information about the depth of progression of the carious lesions, the CRT technique with compomer showed the best results followed by the ART technique. The Hall technique (stainless-steel crowns) performed best in occluso-proximal surfaces. Application of 38% silver diamine fluoride (SDF) twice per year showed great increase in caries reduction. In the end, it's not possible to recommend the best treatment option due to few studies with high risk of bias.
Andrei M. Kielbassa et al.	Yes	Yes	High viscosity glass ionomer cement/resin coating	Restorative	6 months-6 years	To evaluate the clinical performance of high viscosity glass ionomer cements/resin coating (hvGIC/RC) in class I and II.	Yes	Yes	Oxford quality scoring system, PRISMA guidelines, US Public Health Service (USPHS) criteria	Resilience, wear, durability, abrasion resistance, chipping, color match and marginal adaptation were taken into consideration when assessing the clinical performance of hvGIC/RC in classes I and II restorations.	Short-medium term, hvGIC/RC systems showed promising results in terms of abrasion resistance, retention rates and clinical fracture toughness with high survival rates in both classes I and II restorations, although less longevity was showed in classes II compared to classes I.
L. Ducker et al.	Yes	Yes	Resin-modified glass ionomer cements, low and high viscosity glass ionomer cements, amalgam	Restorative	≥ 6 months	To evaluate clinical performance of ART technique in permanent molars.	No	No	Not specified	Different ART restorative materials and methods in single and multi-surface cavities in permanent molars were compared.	ART showed high survival rates in single (5 years) and multi-surface (3 years) restorations. Longevity in multi-surface restorations was lower compared to single surface. However more studies are required to draw conclusions.
R. G. de Amorim	Yes	Yes	Low and high viscosity glass ionomer cements	Restorative	≥ 1 year	To assess ART restorations and sealants survival rates and carious preventive effects in permanent and primary posterior teeth.	Yes	Yes	PRISMA statement, I2 values, Cochrane Research Group	The survival rates of single-surface ART restorations in permanent posterior teeth were 87.1% over 5 years and 77% for multi-surface over 5 years. In primary dentition for single-surface restorations the survival rate was 94.3% and for multi-surface was 65.4% over 3 years. The mean annual dentine carious lesions failures rates were 0.9% over 3 years and 1.0% over 5 years.	Both dentine carious lesions preventive effect and survival rates over 2-5 years of ART restorations in primary and permanent dentitions were relatively high, in exception of restorations in primary posterior teeth over 3 years period, which showed lower survival rates. In general, multi-surface restorations present lower survival rates compared to single-surface.
Daniela P. Raggio et al.	Yes	Yes	High viscosity glass ionomer cement	Restorative	≥ 6 months	To evaluate if ART is a viable option for occluso-proximal restorations in primary dentition.	Yes	No	Comprehensive Meta Analysis 2.2.064, US Public Health Service (USPHS) criteria	ART with high viscosity glass ionomer cements and conventional restorative techniques with amalgam or composite resin were compared, resulting in 48.7-88.0% survival rates in ART restorations and 42.0-100% in conventional.	ART and conventional restorations techniques showed similar success rates and are a viable option for occluso-proximal restorations in primary molars. More studies on factors such as pulp damage and caries lesion progression are needed.
S. Mickenautsch et al.	Yes	Yes	High viscosity glass-ionomers, hybrid resin composites	Restorative	≥ 1 year	To evaluate the success rates/longevity of high viscosity glass ionomer cements compared to hybrid composite resins in single/multi-surface restorations in permanent posterior teeth.	No	No	Australian New Zealand Clinical Trials Registry, Clinical Trials US, EU Clinical Trials Register, meta-Register of Controlled Trials (mRCT), South African National Clinical Trials Register, WHO Clinical Trials, IADR abstracts, International Poster Journal of Dentistry and Oral Medicine, Rev Man 4.2, Berger VW. Selection bias and covariate imbalances in randomized clinical trials. Chichester, UK: John Wiley & Sons, Ltd 2005, ITC software, I2 test, Cochrane's Q-test	The statistical comparison between hvGIC and HRC in classes I and II restorations in permanent posterior teeth after 24-60 months showed no differences.	No final judgement can be made due to poor scientific evidence on this comparison. More studies are needed to draw conclusions.

Table 2. Criteria adopted for the analysis of the methodological quality of the studies and their respective responses.

Criteria / Author/Year	Was an 'a priori' design provided?	Was there duplicate study selection and data extraction?	Was a comprehensive literature search performed?	Was the status of publication (i.e. grey literature) used as an inclusion criterion?	Was a list of studies (included and excluded) provided?	Were the characteristics of the included studies provided?	Was the scientific quality of the included studies assessed and documented?	Was the scientific quality of the included studies used appropriately in formulating conclusions?	Were the methods used to combine the findings of studies appropriate?	Was the likelihood of publication bias assessed?	Was the conflict of interest stated?
1.Santamaría et al. 2020	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No
2.Garbim et al. 2021	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
3.Maia et al. 2021	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
4.Santos et al. 2016	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No
5.Yengopal et al. 2009	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No
6.Ruengrungsom et al. 2018	No	No	Yes	No	Yes	Yes	No	Yes	No	Yes	No
7.Heintze et al. 2022	No	No	Yes	No	Yes	Yes	No	Yes	No	Yes	No
8.Tedesco et al 2018	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No
9.Kielbassa et al. 2016	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	No
10.Studart et al. 2012	No	No	No	No	Yes	Yes	No	Yes	No	No	No
11.Amorim et al. 2018	No	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
12.Raggio et al. 2012	No	No	Yes	No	Yes	Yes	Yes	Yes	No	No	No
13.Mickenautsch et al. 2015	No	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	Yes

3.4 RISK OF BIAS ASSESSMENT

The criteria considered for the analysis of the risk of bias of the included studies was evaluated through the ROBIS tool and the results of this analysis are described in Table 3. Two studies (Garbim et al 2021, Santos et al. 2016) presented very low risk of bias, meanwhile 3 studies (Santamaria et al. 2020, Maia et al. 2021, Amorim et al. 2018) showed positive results in all criteria, except for one criteria of unclear risk. One study (Studart et al. 2012) showed a very high risk of bias, with negative results in all criteria. Five studies (Yengopal et al. 2009, Heintze et al. 2022, Kielbassa et al. 2016, Raggio et al. 2012, Mickenautsch et al. 2015) showed 3 positive results out of five and can be considered as low risk of bias. Ruengrungsom et al. 2018 showed high risk of bias.

Criteria / Author/year	Phase 2				Phase 3
	1. Study eligibility criteria	2. Identification and selection of studies	3. Data collection and study appraisal	4. Synthesis and findings	Risk of bias in the review
1.Santamaría et al. 2020	☺	☺	☺	☺	?
2.Garbim et al. 2021	☺	☺	☺	☺	☺
3.Maia et al. 2021	☺	☺	☺	☺	?
4.Santos et al. 2016	☺	☺	☺	☺	☺
5.Yengopal et al. 2009	☹	☺	☺	☺	?
6.Ruengrungsom et al. 2018	☹	☺	☹	☹	☹
7.Heintze et al. 2022	?	☺	☺	☹	☺
8.Tedesco et al 2018	☺	☺	☺	☺	☺
9.Kielbassa et al. 2016	☹	☺	☺	☺	☹
10.Studart et al. 2012	☹	☹	☹	☹	☹
11.Amorim et al. 2018	?	☺	☺	☺	☺
12.Raggio et al. 2012	☹	☺	☺	☹	☺
13.Mickenautsch et al. 2015	☺	☺	☺	☹	☹

Table 3. Results of risk of bias assessment using the ROBIS tool.

3.5 QUALITY OF EVIDENCE ANALYSIS

The GRADE tool was used to determine the quality of evidence of the included studies. The degree of recommendations is classified as Class II, which means that there is still conflicting evidence on clinical performance/longevity of GICs and their recommendations compared to other materials. The level of evidence is classified as level B, which means that the data was obtained from less robust meta-analyses and single randomized clinical trials. Results are shown in Table 4.

Recommendations	Degree of recommendation	Level of evidence
Clinical performance/longevity of GICs	II	B
Recommend material	II	B

Table 4. Results of quality of evidence analysis.

Table caption

Class I: Conditions on which there is conclusive evidence, or, in case of missing, general agreement that the procedure is safe and useful/effective;

Class II: Conditions on which there is conflicting evidence and/or divergence of opinions about the safety and usefulness/efficacy of the procedure;

Class IIa: Weight or evidence/opinion in favour of the procedure. Majority approves;

Class IIb: Safety and utility/efficacy less well established, with no predominance of opinions in favour;

Class III: Conditions on which there is evidence and/or consensus that the procedure is not useful/effective and, in some cases, may be harmful.

Evidence levels:

Level A: Data obtained from multiple large, concordant randomized trials and/or robust meta-analysis of randomized clinical trials;

Level B: Data obtained from a less robust meta-analysis, from a single randomized trial or from non-randomized (observational) studies;

Level C: Data obtained from consensual opinions of experts.

4. DISCUSSION

This umbrella review aimed at gathering the maximum level of scientific evidence to determine if the glass ionomer cements are a viable and reliable option to restore permanent and primary teeth in a definitive way. Since the quality of the literature is very important in this type of review, three tools were used to assess the quality and risk of bias of the included studies: AMSTAR-2, ROBIS and GRADE (results can be found in the previous pages). Methodological quality, risk of bias and quality of evidence were important to evaluate because this review aimed at collecting the highest quality studies on this subject, in order to formulate proper conclusions.

The studies that were classified as "high quality" showed robust methodology, an organized selection of the studies and elaboration of the findings. On the other hand, low quality studies were lacking in methodology such as quality analysis, risk of bias and study eligibility criteria, or were not very clear about the findings, making them not reliable to advise any material.

The results of the search strategy were organized in a flowchart (Figure 1), with the various steps of the process (identification, screening, eligibility, inclusion). The number of dental restorative materials introduced into the market in the last years has grown rapidly. Choosing which material to use for a dental restoration is important and really depends on the clinical case. It is important to understand if glass ionomer cements have enough scientific evidence to make them a safe choice for definitive restorations of primary and permanent teeth and comparing their clinical performance to other dental materials.

Glass ionomer cements have evolved during the years and several modifications have been experimented, but there is not enough scientific evidence on their effectiveness to be used in clinical situations. One modification that is being actively used in patients is resin-modified glass ionomer cement (RMGIC), which is being used in both primary and permanent dentition.

In permanent dentition conventional-HVGIC restorations showed high survival rates (2-6 years) in terms of surface texture, marginal discolouration and adaptation, and anatomic form[50]. Another study reported high survival rates regarding ART/HVGIC approach in posterior permanent teeth over the first 5 years in single-surface restorations, while it was not possible to conclude for multi-surface restorations[55]. While ART techniques showed a wide range of survival rates (29.6-100%) over 4 months-6 years follow up period regarding single occlusal restorations and 6 months-2 years in multi-surface restorations (30.6-100%)[54].

High-viscosity glass ionomer cements with a resin coating (HVGIC/RC) seems to have similar results compared to conventional GICs and composite resin up to 5 years in Class I and II restorations in terms of fracture toughness, retention rates and abrasion resistance[53]. While another study reported inferior longevity of HVGICs compared to composite resins[51].

In primary dentition can be effective the atraumatic restorative treatment (ART) technique because it helps in reducing the anxiety of the patients[46,47,55]. Despite is wide application in primary dentition, two studies found that the annual failure rates (AFRs) of ART techniques were higher in primary dentition compared to permanent in both single and multi-surface restorations[46,50]. The main reasons of failure were marginal defects, loss of the restoration, excessive wear and retention loss in both dentitions[47,50,51]. There is conflicting evidence regarding the conventional-GIC compared to ART-GIC restoration techniques, since different studies showed different results: better results with conventional techniques and no significant differences, respectively[50,55,56]. ART seems to be a better choice in single-surface occlusal restorations[56]. In general, ART techniques seem to show high survival rates after 3-6 years in both dentitions. Also, GICs appear to be a good material to restore root caries because showed fewer biological complications compared to other materials[47,50].

RMGICs seems to be a very good option in restoring Class I and II cavities and performed better than high-viscosity glass ionomer cements (HVGIC) and composite resins in some studies in terms of survival rates, fluoride release and biologic considerations[45,48,50]. Other studies could not find significant differences between RMGICs compared to conventional GICs, composite resins, compomers and amalgam[47,48,49,50,56] or there's conflicting evidence on which performs better between RMGICs and composite resins.

Silver-reinforced glass ionomer cement (SRGIC) seems to have the lower survival rates and higher recurrences of secondaries caries[48].

Compomers seems to be statistically better compared to conventional GIC regarding median survival time (MST), surface texture, marginal discoloration, tooth decay and higher fatigue and fracture resistance, while compared to RMGICs showed no significant differences[48]. While in other studies, compomer performed better than both conventional GIC and RMGIC in terms of survival rates, marginal adaptation, surface roughness and form[50,52].

There is conflicting evidence on the best performance between conventional GICs and composite resins. In all the studies, Class II restorations showed higher failure rates compared to Class I restorations in both dentitions irrespective of materials or techniques and survival rates seems to be highly influenced by the type of cavity and the experience of the operator. Most of the evidence is aimed at primary dentition.

The choice of the "best material" really depends on the situation, since every clinical case is unique, with many different variables to be considered, for example setting, permanent or primary dentition, operator, type and location of the cavity. The material of choice should be evaluated as a result of these factors.

5. CONCLUSIONS

There are gaps in the literature and various conflicting results on the performance/longevity of these materials.

More long-term studies are needed to evaluate if GICs are a good choice for longer periods of time (>6 years).

Due to the lack of studies comparing the performance of different dental restorative materials, it is not possible to conclude if GICs performs better or worse compared to other materials. More high-quality studies are needed.

GIC restorations seems to have good medium/long-term longevity in both permanent and primary dentition. The techniques, type of GIC, type of cavity and experience of the operator highly influence the clinical performance. However, many of these studies presented high risk of bias and low quality.

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