Use of Glass-ionomer cement as a restorative material: a systematic review

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Abstract

Background: The clinical applications of glass ionomers cements (GICs) are varied: restoration, lining material, sealing, hyper sensibility care and temporary cavity restoration. 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. The aim of this study was to evaluate whether primary and permanent teeth can be definitively restored with glass ionomer cements, based on the PICO(S) question “What is the clinical performance in primary and permanent teeth restored with glass ionomer cements?”,

Methods: 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 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.

Results: A systematic literature search in MEDLINE/PubMed, Scopus and Web of Science databases identified 132 references potentially relevant. Twenty-four eligible articles were identified, only 13 articles were included. 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.

Conclusions: Glass ionomer cements seems to be a viable choice in both dentitions, but primary dentition presents more evidence, especially regarding the Atraumatic Restorative Treatment (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.

Systematic review registration: This study was registered on the PROSPERO (International prospective register of systematic reviews) with registration CRD42022320602.

Background

Around the world, the choice of the best restorative material for primary and permanent carious teeth, still a difficult task. 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, and, during the 1950s, this approach changed, adding greater emphasis on biocompatibility and adhesion to dental tissues (1). In addition, it has been shown that dental caries treatment is not only technical, but requires a broader approach, with the use of less

invasive techniques, biocompatibility aesthetics and lower costs of the materials, being that all these factors must be taken into account for greater clinical success and patient satisfaction (2, 3). At this context, during the 1960/1970s, the glass ionomer cements were developed, performing an acid-basic adhesion reaction with hydroxyapatite and conquering various clinical applications (2), range from temporary to definitive restoration, lining material, sealing and hyper sensibility care (4, 5, 6).

Nowadays, the GIC shows some advantages such as the fluoride release for a pro-longed period, a good adhesive strength, a low solubility and equivalent thermal expansion coefficient to tooth structure. Its main disadvantages are a lower of long-term wear and strength, beyond a moisture-sensitivity (4). So, with the past of the years, the use of GICs in clinical practice have increased, being followed by a greater number of systematic reviews regarding their performance. The potential of the ionomer to control secondary caries lesions in margins of restorations or in contact with adjacent surfaces were discussed in previous studies. Tedesco et al. (2017) demonstrated that the ART technique is a good alternative for restoring occlusoproximal cavities in primary teeth. In addition, different types of GIC had the performance previously evaluated and the survival between the ART restorations and conventional treatment were also compared by other reviews.

Aware that there are several types of glass ionomer as well as different indications due to different clinical situations, knowing how to identify the best material for each case is very important for the success and longevity of the treatment. However, there are still gaps concerning the performance of GICs and a comprehensive review is de-sirable to synthesis, compare and contrast the findings of previously systematic re-views published of this material. Therefore, the objective of this study was to evaluate, through an umbrella review, the longevity of GICs as a definitive restoration of prima-ry and permanent teeth.

Methods

This study 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 (TFN) resolved cases of conflict or doubt.

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.

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.

The defined PICO (S) question is: P (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 of clinical trials.

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

((“dental restoration” OR restoration OR “atraumatic restorative treatment (ART)” 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))

All titles and abstracts of studies found were initially evaluated by one reviewer based on the inclusion criteria: (1) to be a systematic review of clinical trials (2) to evaluate the clinical longevity of GICs in primary and permanent teeth as a restorative material. After the first evaluation, the articles that met the inclusion criteria were re-viewed 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 of GICs as a restorative material; (3) studies of dental restorative materials in teeth with enamel alterations, root caries and non-carious cervical lesions. The full papers of the included studies were read to ensure that they were about restoration of primary and permanent teeth with GICs and were not critical/narrative reviews, letters to the editor or guidelines.

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, data-bases used, search strategy, search date, number of reviewers, inclusion and exclusion criteria, language, type of restorative materials, restorative technique, follow-up peri-od, objective of the study, quality analysis and risk of bias (yes or no and which tool were

used), main results and conclusions. 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.

Results

Study selection

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 rele-vant, 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 in-formation 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 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 longevity of GICs. Finally, 13 studies were included in the following review. The study selection process is shown in Fig. 1.

Characteristics of included studies

The characteristics of the included studies are shown in Table 1 in supplementary materials. 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 pre-sent 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 longevity of 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 general, more evidence is needed to draw conclusions on which is the best material for definitive restorations in permanent and primary dentition.

Quality Analysis

AMSTAR-2 was used for the methodological quality of the included studies, as shown in Table 1. None of the articles had positive criteria in all the evaluated requi-sites 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, Ruen-grungsom 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- 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.Santamaria 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

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 2. 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.

Table 2- Results of risk of bias assessment using the ROBIS tool.

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	Low risk	Low risk	Low risk	Low risk	Unclear risk
2.Garbim et al. 2021	Low risk	Low risk	Low risk	Low risk	Low risk
3.Maia et al. 2021	Low risk	Low risk	Low risk	Low risk	Unclear risk
4.Santos et al. 2016	Low risk	Low risk	Low risk	Low risk	Low risk
5.Yengopal et al. 2009	High risk	Low risk	Low risk	Low risk	Unclear risk
6.Ruengrungsom et al. 2018	High risk	Low risk	High risk	High risk	High risk
7.Heintze et al. 2022	Unclear risk	Low risk	Low risk	High risk	Low risk
8.Tedesco et al 2018	Low risk	Low risk	Low risk	Low risk	Low risk
9.Kielbassa et al. 2016	High risk	Low risk	Low risk	Low risk	High risk
10.Studart et al. 2012	High risk	High risk	High risk	High risk	High risk
11.Amorim et al. 2018	Unclear risk	Low risk	Low risk	Low risk	Low risk
12.Raggio et al. 2012	High risk	Low risk	Low risk	High risk	Low risk
13.Mickenautsch et al. 2015	Low risk	Low risk	Low risk	High risk	High risk

Quality of evidence analysis

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 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 Fig. 2.

Discussion

This umbrella review aimed at gathering the maximum level of scientific evidence to determine if the glass ionomer cements are a good 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 and ROBIS (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 degree of recommendations of all studies included in this umbrella review was classified as Class II, which means that there is still conflicting evidence on longevity of GICs and their recommendations compared to other materials. In addition, the level of evidence of the included revisions was classified as level B, which means that the data was obtained from less robust meta-analyses and single randomized clinical trials. 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 present results emphasized that more high-quality studies evaluating the GICs longevity as restorative material are needed. 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.

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 (48). 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 (53). 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%) (52).

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 (51). Only one study reported inferior longevity of HVGICs compared to composite resins (49).

In primary dentition the ART technique can be effective because it helps in reducing the anxiety of the patients (44, 45, 53). Despite is wide application in primary dentition, two studies found that the annual failure rates (AFRs) of ART were higher in primary dentition compared to permanent in both single and multi-surface restorations (44, 48). The main reasons of failure were marginal defects, loss of the restoration, excessive wear and retention loss in both dentitions (45, 48, 49). 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 (48, 53, 54). ART seems to be a better choice in single-surface occlusal restorations (54). In general, ART techniques seem to show high survival rates after 3–6 years in both dentitions.

Glass ionomer cements have evolved during the years and several modifications have been experimented, but there is not enough scientific evidence on their effective-ness to be used in clinical situations. One modification that is being actively used in patients is RMGIC, which is being used in both primary and permanent dentitions (45, 48).

RMGICs seems to be a very good option in restoring Class I and II cavities and performed better than HVGIC and composite resins in some studies in terms of survival rates, fluoride release and biologic considerations (43, 46, 48). Other studies could not find significant differences between RMGICs compared to conventional GICs, composite resins, compomers and amalgam (45, 46, 47, 48, 54) or there's conflicting evidence on which performs better between RMGICs and composite resins. Silver-reinforced glass ionomer cement seems to have the lower survival rates and higher recurrences of secondaries caries (46).

Compomers seems to be statistically better compared to conventional GIC regard-ng median survival time (MST), surface texture, marginal discoloration, tooth decay and higher fatigue and fracture resistance, while compared to RMGICs showed no significant differences (46). While in other studies, compomer performed better than both conventional GIC and RMGIC in terms of survival rates, marginal adaptation, surface roughness and form (48, 50).

There is conflicting evidence on the best longevity between conventional GICs and composite resins. In all studies, Class II restorations showed higher failure rates com-pared to Class I restorations in both dentitions irrespective of materials or techniques. So, the survival rates seem 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 experience, type and location of the cavity. The material of choice should be evaluated as a result of these factors.

Conclusion

GIC restorations seems to have good medium/long-term longevity in both perma-nent 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.

There are gaps in the literature and various conflicting results on the 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 longevity 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.

Abbreviations

GICs- Glass-ionomer cements

ART- Atraumatic Restorative Treatment

RMGICs- resin-modified glass ionomer cements

HVGIC- high-viscosity glass ionomer cements

Declarations

Ethics approval and consent to participate

Not applicable to a systematic review.

Consent for publication

Not applicable.

Availability of data and materials

All data generated or analysed during this study are included in this published article.

Competing interests

Authors declare no competing interests.

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Authors' contributions

APanetta designed the study, collected and processed the data and drafted the manuscript.

AMoura collected and processed the data and drafted the manuscript and revised the final document.

TNovaes- collected and processed the data and drafted the manuscript.

PLopes- revised the final document.

RRio- - revised the final document.

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Figures

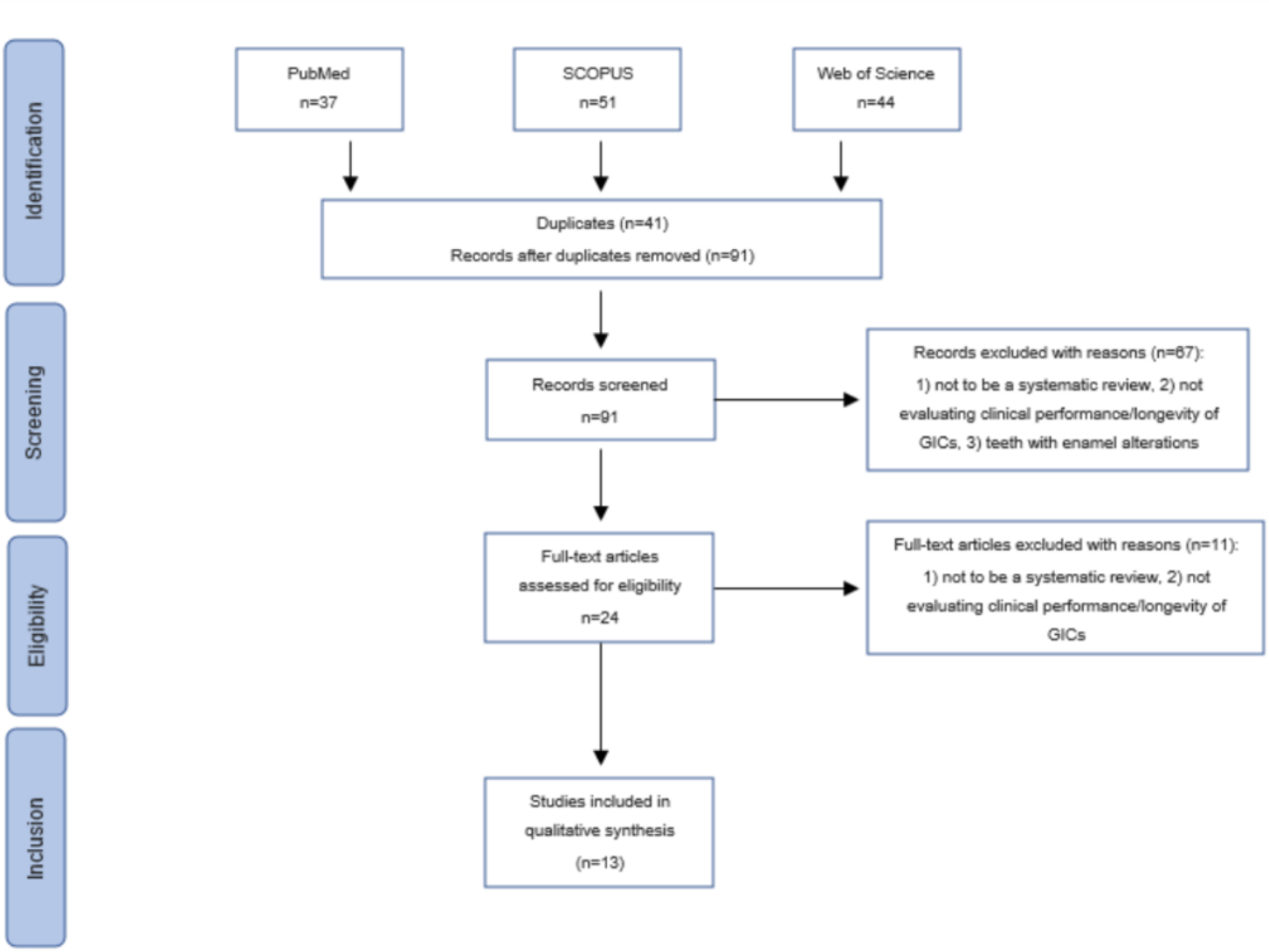

Figure 1

Overview of article selection procedure according to PRISMA guidelines.

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

Figure 2

Results of quality of evidence analysis.