Systematic Review
Geriatric Dentistry

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Survival of atraumatic restorative treatment restorations in the elderly patients: a systematic review

Abstract: This study aimed to assess the survival of glass ionomer cement (GIC) restorations performed using the atraumatic restorative treatment (ART) in elderly patients. The systematic review protocol was registered in the PROSPERO database. The records were searched until August 2020 in eight electronic bibliographic databases, and included randomized and non-randomized clinical trials and observational studies, with no restrictions on the language or year of publication. Study selection and data extraction were performed independently by two reviewers. Data were extracted, summarized, collected for qualitative analysis, and evaluated for individual risk of bias using the Joanna Briggs Institute's Critical Appraisal Tool. The literature search retrieved 5,186 records; however, only seven studies fulfilled the eligibility criteria and were included. The studies were published between 2002 and 2019. A total of 1,239 restorations were investigated at intervals of 6, 12, 24, and 60 months of follow-up. Some studies had a low risk of bias, while others had moderate and high risk of bias. In general, GIC restorations placed using ART were considered satisfactory. The 6-month, 12-month, and 24-month survival rates ranged from 81.3% to 97.2%, 72.2% to 94%, and 63% to 87%, respectively; additionally, the survival rate for the longest follow-up period (60 months) was 85%. Given the best evidence-based information regarding caries removal, we highlight the need to provide a conservative and effective technique for use in elderly patients. ART is a promising and viable alternative that guarantees the survival of restorations in elderly patients.

Keywords: Dental Atraumatic Restorative Treatment; Aged; Geriatric Dentistry; Glass Ionomer Cements; Root Caries.

Introduction

Overall, life expectancy increased worldwide by 5.5 years between 2000 and 2016, from 66.5 to 72 years of age.[1] It is estimated that the number of people aged ≥60 years will reach 2 billion by the year 2050, representing a projection of about one fifth of the world population.[2] In light of these demographic changes, there has been an increase in the incidence of diseases that are characteristic of aging in the society.[3]

Although a significant reduction in edentulism among the elderly has been observed—that is, natural teeth are retained for longer periods, oral

diseases are common in this population.[4] Despite the decreasing rates among adults, dental caries remains a significant problem for the elderly.[5] The common predisposing risk factors for oral diseases in the elderly include barriers to adequate oral hygiene, decreased salivary flow,[6] gingival recession leading to increased exposed surfaces requiring supportive therapy, and problems related to motor coordination.[7]

While these factors influence the development of dental caries, both the dental professional and the clinical decision-making process play a significant role in treating this disease.[8] The concept of minimally invasive dentistry includes recommendations for preventive strategies against the etiological factors of caries, as well as strategies for the treatment and control of the disease to slow down the destructive restorative cycle.[9,10] Among the treatment options for dental caries, conventional treatment (CT) consisting of caries removal using rotary burs with an electric device is considered the gold standard.[11] Such a treatment requires anesthesia in most cases. However, this treatment may cause discomfort, pain, dentine sensitivity, vibrations and pressure by rotary devices, noise, and increase the temperature of the dentin near the pulp.[12] In such a scenario, the atraumatic restorative treatment (ART) emerges as a viable alternative.[13]

In ART, the decayed tissue is removed by excavating the infected, necrotic, and superficial dentin, leaving a layer of affected dentin over the pulp.[13] The technique is characterized by the use of hand instruments under relative isolation, absence of anesthesia, and subsequent restoration with glass ionomer cement (GIC).[14] This technique has demonstrated promising results in the deciduous dentition,[15] with advantages such as removal of minimal remaining dental structure, preservation of vitality, and prevention of lesion progression.[16,17] ART has also been shown as a viable alternative for the elderly as it is a conservative procedure for caries removal, is less invasive, and can be performed without the need for anesthesia.[13] Thus, implementing this less invasive approach results in low levels of pain, discomfort, and anxiety; good predictability; low costs; and good patient acceptance.[18,19] However, studies have been inconclusive on whether ART should be considered as an adequate alternative to replace CT, which is considered the gold-standard therapy for dental caries for the elderly. Accordingly, the present review aimed to systematically investigate the survival rate of restorations placed using ART in elderly patients.

Methodology

Study registration

This systematic review was reported according to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement,[20] and was performed according to the the Joanna Briggs Institute Manual.[21] The systematic review protocol was registered *a priori* in the PROSPERO (*[CRD42019138170]*) (https://www.crd.york.ac.uk/prospero/https://www.crd.york.ac.uk/prospero/). The only deviation from the original registered protocol was that in the last version of the review, we decided to include not only randomized controlled trials (as stated in the first version of the protocol), but also other types of studies, such as non-randomized experimental (quasi-experimental) and prospective longitudinal clinical studies.

Research question and eligibility criteria

The present systematic review was designed to answer the following question: "What is the survival rate of restorations after ART for dental caries in elderly patients?"

The inclusion criteria were randomized or non-randomized clinical trials and observational studies (cross-sectional and longitudinal, retrospective or prospective), which evaluated ART with the outcome of survival rate of restorations (%) performed with GIC in elderly patients. There was no restriction on the type of ionomer cement used (conventional or resin-modified GIC). According to the World Health Organization, the elderly population consists of individuals aged ≥ 60 years for middle- and low-income countries and ≥65 years for high-income countries.[2]

Studies involving older adults with systemic impairments were excluded. Studies not related to the objective, review articles, letters to the editor/editorials, personal opinions, books/book chapters,

textbooks, conference abstracts, and patents were also excluded. There were no restrictions on the language or year of publication.

Sources of information, search, and study selection

The search was performed until August 2020, with search alerts using a self-updating tool in the following databases: PubMed (including MedLine), Scopus, LILACS, SciELO, Embase, and Web of Science. The OpenGrey and OpenThesis databases were used to partially capture the "gray literature." The Medical Subject Headings (MeSH), Health Sciences Descriptors (DeCS), and Embase Subject Headings (Emtree) resources were used to select search descriptors. In addition, synonyms and free terms were used to enhance the search. Several combinations of the Boolean operators "AND" and "OR" were used to enhance the research strategy (Table 1). The search terms were adapted to each database. Additionally, a manual search was performed through a systematic analysis of the references of the eligible studies. The results obtained from the primary databases were initially exported to EndNote Web™ (Clarivate ™, Analytics, Philadelphia, USA), excluding duplicates. Subsequently, they were exported to Microsoft Word (Microsoft ™, Ltd, Washington, USA). The details of eligible "gray literature" were added to this list, and the remaining duplicates were removed manually.

Before selecting the studies, a calibration exercise was performed, in which the reviewers discussed the eligibility criteria and applied them to a sample of 20% of the studies retrieved to determine the inter-examiner agreement (kappa > 0.81). Subsequently, exclusions were performed by titles (first phase), by abstracts (second phase), and upon reading the full articles (third phase). All the phases were independently evaluated by two evaluators (TSM and TDL), and in case of doubt or disagreement, a third evaluator (LRP) was consulted to make a final decision. If an article could not be found online, other libraries were contacted to retrieve the articles. In case of studies published in languages other than English or Portuguese, the full text was translated.

Data collection

Before data extraction, a calibration exercise was performed with both reviewers (TSM and TDL) to ensure consistency among reviewers. Information was extracted jointly from an eligible study. Any disagreement between the reviewers was resolved through discussions, and when both reviewers disagreed, a third reviewer (LRP) was consulted to make a final decision.

The following information was extracted from the articles: identification of the study (author, year, country, and research location), sample characteristics (number of patients in each study and distribution by sex, average age, and type of cavity), characteristics of sample collection and processing (assessment time and evaluation method of restorations), main results (mean number of teeth present, clinical performances of the ART restorations and failures), and the type of study. In case of incomplete or insufficient information, the corresponding author was contacted via e-mail.

Risk of individual bias of the studies

The Joanna Briggs Institute's Critical Appraisal Tools for use in Systematic Reviews[21,22] were used to assess the risk of bias and the individual quality of the selected studies. A specific tool was used for the study design. Two authors [TSM and TDL] assessed each domain independently regarding their potential risk of bias, as recommended by the PRISMA statement.[20]

Each study was categorized according to the percentage of positive answers to the questions corresponding to the assessment tool. The risk of bias was considered ***High*** when the study obtained < 49% of "yes" answers, ***Moderate*** when the study obtained 50–69% of "yes" answers, and ***Low*** when the study reached > 70% of "yes" answers.

Summary measures and syntheses of results

Initially, a meta-analysis was planned for cases in which the data from the eligible studies were homogeneous. However, due to methodological and observational differences between the included studies, the review authors concluded that conducting a meta-analysis would not be appropriate owing to significant heterogeneity. Accordingly, a descriptive analysis of the findings of the studies was undertaken to identify the core themes related to the aims of this review.

Table 1. Strategies for database search.

Database	Search Strategy (August 2020)
PubMed http://www.ncbi.nlm.nih.gov/pubmed	((“Dental Atraumatic Restorative Treatment” OR “Atraumatic Restorative Treatment” OR “Restorative Treatment” OR “Caries Removal” OR “Partial Caries Removal” OR “Chemomechanical Caries Removal” OR “Chemico-mechanical” OR “Minimal Intervention Dentistry” OR “Minimally Invasive Treatment” OR “Stepwise-excavation” OR “Stepwise Removal” OR “Stepwise Technique” OR “Selective Caries Removal” OR “Excavation” OR “Selective Excavation”) AND (“Older Adults” OR “Frail Elderly” OR “Frail Elder” OR “Functionally Impaired Elderly” OR “Frail Older Adults” OR “Gerodontology” OR “Geriatrics” OR “Elderly” OR “Elderly Adults” OR “Dental Care For Elderly” OR “Aged”) AND (“Longevity” OR “Survival Rate” OR “Dental Restoration Failure” OR “Survival” OR “Restoration Failure” OR “Clinical Performance”))
Scopus http://www.scopus.com	(((“Dental Atraumatic Restorative Treatment” OR “Atraumatic Restorative Treatment” OR “Restorative Treatment” OR “Caries Removal” OR “Partial Caries Removal” OR “Chemomechanical Caries Removal” OR “Chemico-mechanical”) AND (“Older Adults” OR “Frail Elderly” OR “Frail Elder” OR “Functionally Impaired Elderly” OR “Frail Older Adults”)))
	(((“Minimal Intervention Dentistry” OR “Minimally Invasive Treatment” OR “Stepwise-excavation” OR “Stepwise Removal” OR “Stepwise Technique” OR “Selective Caries Removal” OR “Excavation” OR “Selective Excavation”) AND (“Gerodontology” OR “Geriatrics” OR “Elderly” OR “Elderly Adults” OR “Dental Care For Elderly” OR “Aged”)))
	(((“Dental Atraumatic Restorative Treatment” OR “Atraumatic Restorative Treatment” OR “Restorative Treatment” OR “Caries Removal”) AND (“Older Adults” OR “Frail Elderly” OR “Elderly” OR “Aged”) AND (“Longevity” OR “Survival” OR “Restoration Failure” OR “Clinical Performance”)))
LILACS http://lilacs.bvsalud.org/	(tw:((“Dental Atraumatic Restorative Treatment” OR “Atraumatic Restorative Treatment”) AND (“Older Adults” OR “Frail Elderly”)))
	(tw:((“Restorative Treatment” OR “Caries Removal”) AND (“Frail Elder” OR “Functionally Impaired Elderly”)))
	(tw:((“Partial Caries Removal” OR “Chemomechanical Caries Removal”) AND (“Frail Older Adults” OR “Gerodontology”)))
	(tw:((“Chemico-mechanical” OR “Minimal Intervention Dentistry”) AND (“Frail Older Adults” OR “Gerodontology”)))
	(tw:((“Stepwise Removal” OR “Stepwise Technique”) AND (“Elderly Adults” OR “Dental Care For Elderly”)))
	(tw:((“Selective Caries Removal” OR “Excavation” OR “Selective Excavation”) AND (“Aged” OR “Elderly”)))
	(tw:(((“Dental Atraumatic Restorative Treatment” OR “Minimally Invasive Treatment”) AND (“Geriatrics” OR “Elderly”))))
	(tw:((“Dental Atraumatic Restorative Treatment” OR “Atraumatic Restorative Treatment”) AND (“Longevity” OR “Survival Rate” OR “Survival” OR “Restoration Failure”)))
SciELO http://www.scielo.org/	Dental Atraumatic Restorative Treatment AND Older Adults
	Atraumatic Restorative Treatment AND Frail Elderly
	Atraumatic Restorative Treatment AND Elderly
	Restorative Treatment AND Frail Elder
	Caries Removal AND Functionally Impaired Elderly
	Partial Caries Removal AND Frail Older Adults
	Chemomechanical Caries Removal AND Gerodontology
	Chemico-mechanical AND Geriatrics
	Minimal Intervention Dentistry AND Elderly
	Minimally Invasive Treatment AND Elderly Adults
	Stepwise-excavation AND Dental Care For Elderly
	Stepwise Removal AND Aged
	Stepwise Technique AND Elderly
	Selective Caries Removal AND Geriatrics
	Excavation AND Gerodontology
	Selective Excavation AND Elderly Adults
	Chemomechanical Caries Removal AND Elderly
	Stepwise Technique AND Older Adults
	Chemomechanical Caries Removal AND Geriatrics
	Dental Atraumatic Restorative Treatment AND Survival Rate
	Atraumatic Restorative Treatment AND Clinical Performance

Continue

Continuation

Database	Search Strategy (August 2020)
Embase http://www.embase.com	('dental atraumatic restorative treatment'/exp OR 'dental atraumatic restorative treatment' OR 'atraumatic restorative treatment'/exp OR 'atraumatic restorative treatment' OR 'restorative treatment' OR 'caries removal' OR 'partial caries removal' OR 'chemomechanical caries removal' OR 'chemico-mechanical' OR 'minimal intervention dentistry' OR 'minimally invasive treatment'/exp OR 'minimally invasive treatment' OR 'stepwise-excavation' OR 'stepwise removal' OR 'stepwise technique' OR 'selective caries removal' OR 'excavation' OR 'selective excavation') AND ('older adults'/exp OR 'older adults' OR 'frail elderly'/exp OR 'frail elderly' OR 'frail elder' OR 'functionally impaired elderly' OR 'frail older adults' OR 'gerodontology' OR 'geriatrics'/exp OR 'geriatrics' OR 'elderly'/exp OR 'elderly' OR 'elderly adults' OR 'dental care for elderly' OR 'aged'/exp OR 'aged') AND ('longevity'/exp OR 'longevity' OR 'survival rate'/exp OR 'survival rate' OR 'dental restoration failure'/exp OR 'dental restoration failure' OR 'survival'/exp OR 'survival' OR 'restoration failure' OR 'clinical performance')
Web Of Science http://apps.webofknowledge.com/	(((("Dental Atraumatic Restorative Treatment" OR "Atraumatic Restorative Treatment" OR "Restorative Treatment" OR "Caries Removal" OR "Partial Caries Removal" OR "Chemomechanical Caries Removal" OR "Chemico-mechanical" OR "Minimal Intervention Dentistry" OR "Minimally Invasive Treatment" OR "Stepwise-excavation" OR "Stepwise Removal" OR "Stepwise Technique" OR "Selective Caries Removal" OR "Excavation" OR "Selective Excavation") AND ("Older Adults" OR "Frail Elderly" OR "Frail Elder" OR "Functionally Impaired Elderly" OR "Frail Older Adults" OR "Gerodontology" OR "Geriatrics" OR "Elderly" OR "Elderly Adults" OR "Dental Care For Elderly" OR "Aged") AND ("Longevity" OR "Survival Rate" OR "Dental Restoration Failure" OR "Survival" OR "Restoration Failure" OR "Clinical Performance")))
OpenGrey http://www.opengrey.eu/	(("Dental Atraumatic Restorative Treatment" OR "Atraumatic Restorative Treatment" OR "Minimal Intervention Dentistry" OR "Selective Caries Removal") AND ("Older Adults" OR "Elderly") AND ("Longevity" OR "Clinical Performance"))
OpenThesis http://www.openthesis.org/	((Dental Atraumatic Restorative Treatment OR Atraumatic Restorative Treatment OR Partial Caries Removal OR Minimal Intervention Dentistry) AND (Older Adults OR Elderly) AND (Longevity OR Survival Rate OR Clinical Performance))

Results

Study selection

During the first phase of study selection, 5,186 results, including the "grey literature," (Figure) were obtained from eight electronic databases. After removing the repeated/duplicate results, 4,675 articles remained for the analysis of titles and abstracts. After a detailed analysis, only 15 studies were eligible for full-text analysis. The references of the 15 potentially eligible studies were carefully evaluated, and no additional articles were selected. Of the 15 studies, eight studies did not fulfil the inclusion criteria and were eliminated. The reasons for exclusion were studies that included patients aged < 60 years,[23-25] studies without results of restoration survival rates,[26] comments,[27,28] and reviews.[29,30] Thus, seven studies were selected for qualitative analysis. Figure displays the process of search, identification, inclusion, and exclusion of articles.

Characteristics of eligible studies

One quasi-experimental study,[7] one cohort study,[31] and five randomized clinical trials[11,19,32,33,34] were included. The studies were published between 2002 and 2019 and were carried out in Finland,[31] China,[11] Ireland,[7,19,32] Spain,[33] and Colombia.[34] The follow-up periods in the selected studies ranged from 6 months to 5 years, with 12 months of follow-up being the most common. Definitive restorations were performed using different types of GICs. While five studies[9,11,19,31,32] used conventional GIC, two studies[33,34] used resin-modified GIC. The presence of marginal defects, wear, and need for replacement or repair were assessed and used to classify whether a restoration was acceptable (present and satisfactory restoration or with slight marginal defect) or unacceptable (present with major defect or major wear, and not present)—in other words, whether the restoration was successful or unsuccessful.

Other sources of information regarding the demographic and clinical characteristics of the population are presented in Table 2. The average age of the sample ranged from 73.0 to 81.5 years. All studies were approved by the Ethics Committee of their respective institutions or hospitals, and informed consent was obtained prior to the start of the study. One study[31] evaluated the survival of ART without a comparator, five studies[7,11,19,32,34] compared the survival of restorations made using ART with those made using CT. Additionally, a study[33] compared the survival of

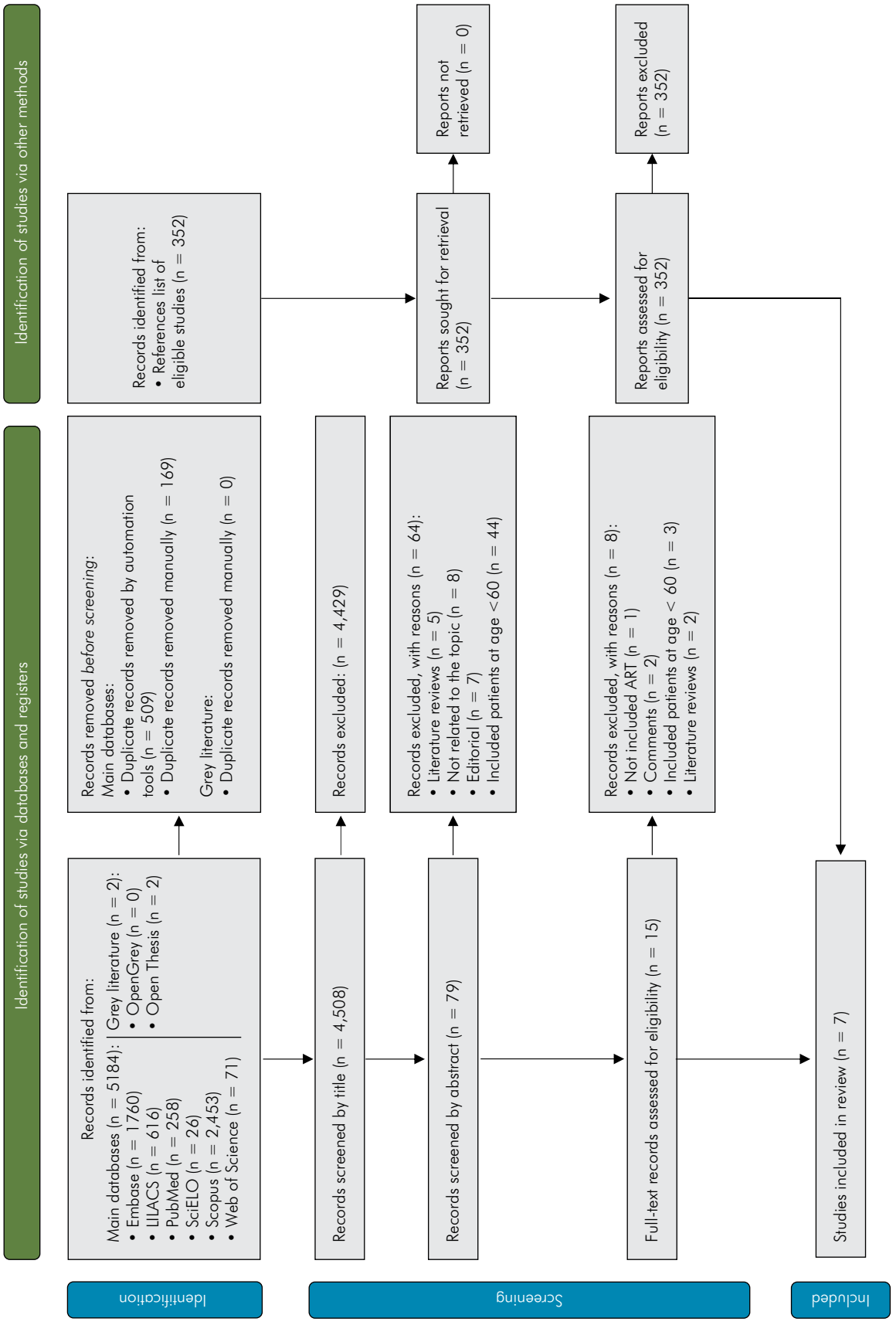

Figure. PRISMA flow diagram outlining the study selection process.

restorations made using ART with those made using ART and Carisolv chemicomechanical removal. Three studies[31,32,33] did not report calibration among dentists who performed the restorative procedures.

Two studies[7,32] had the same registration number for their randomized controlled clinical trials. Although they were registered under the same protocol number, new patients were added to the initial sample of a previous study.[32] Thus, it was presumed that there was duplication of data, although one of them had a longer follow-up. To resolve the doubts that arose in these two studies,[7,32] contact was attempted by sending an email to the collaborators of those studies. However, as there was no response after two attempts, it was decided to classify the study by da Mata *et al*. (2019)[7] as quasi-experimental.

The mean number of teeth present in elderly patients ranged between 11.8–17. For studies that mentioned the DMF-T (decayed, missing, and filled teeth index) at baseline, the score varied between 21.8 and 28.5. Generally, restorations involved one surface, two surfaces, or even three surfaces, as in the studies by Lo et al., 2006[11] and Mata et al., 2019.[7] The assessment of the integrity of restorations was carried out using the ART assessment criteria, which evaluate the condition of the restoration as a whole and the presence of slight or major defects. As these defects widen, they can lead to a partial or total loss of the restoration, which were the main reasons for failure in all studies.

Risk of individual bias of the studies

Table 3 shows detailed information on the risk of bias of the studies included in the qualitative analysis of randomized clinical trials, quasi-experimental, and cohort studies.

Table 2. Summary of the main characteristics of the eligible studies included on qualitative analysis.

Author, year	Country	Research location	Sample: (n)	Participants (Male, Female)	Average age (years)	Type of cavity	Restoration evaluation time	Restoration assessment criterion	Type of study
Honkala e Honkala, 2002[31]	Finland	Residential and nursing homes in Helsinki	ART: (33)	21	74.5±*	Coronal caries	12 months	ART Criteria	Cohort
Lo et al., 2006[11]	China	Residential and nursing homes in Hong Kong	ART: (78) Control: (84)	103 (72,31)	78.6±*	Root caries	6 and 12 months	ART Criteria and USPHS Criteria	Randomized controlled
Mata et al., 2014[19]	Ireland	Day-care hospital and in a community centre to Cork University Dental School and Hospital	ART: (128) Control: (132)	82 (42,40)	73±6.7	Coronal or root caries	12 months	ART Criteria	Randomized controlled
Gil-Montoya et al., 2014[33]	Spain	University of Granada (Spain)	ART: (33) ART + Carisolv: (33)	28 (14,14)	81.5±6.9	Root caries	6, 12 and 24 months	ART Criteria	Randomized controlled
Mata et al., 2015[32]	Ireland	Cork University Dental Hospital and St Finbarr's Geriatric Day Hospital in Cork	ART: (142) Control: (158)	99 (53,46)	73.2±6.8	Coronal or root caries	6, 12 and 24 months	ART Criteria	Randomized controlled
Gonzalez and Zuluaga, 2016[34]	Colombia	Nursing homes in Bogotá	ART: (73) Control: (101)	75 (35,39)	74.9±*	Root caries	6 months	ART Criteria	Randomized controlled
Mata et al., 2019[7]	Ireland	University Dental Hospital and St Finbarr's Geriatric Day Hospital in Cork	ART: (142) Control: (158)	99 (53,46)	73.2±6.8	Coronal or root caries	6, 12, 24 and 60 months	ART Criteria	Quasi-experimental (non-randomized)

*Standard deviation not mentioned.

Table 3. Risk of bias assessed by the Joanna Briggs Institute Critical Appraisal Tools for Cohort studies,[35] Randomized Clinical Trials,[36] and Quasi-experimental studies.[36]

Authors	Q.1	Q.2	Q.3	Q.4	Q.5	Q.6	Q.7	Q.8	Q.9	Q.10	Q.11	Q.12	Q.13	% yes
Cohort study														
Honkala e Honkala, (2002)[31]	-	U	√	-	-	√	√	√	-	-	√			45,4
Randomized clinical trials														
Lo *et al.*, (2006)[11]	√	U	√	N/A	N/A	√	√	√	-	√	U	√	√	72.7
Mata *et al.*, (2014)[19]	√	√	√	N/A	N/A	√	√	√	-	√	U	U	√	72.7
Gil-Montoya *et al.*, (2014)[33]	√	U	√	U	N/A	U	√	√	-	√	U	√	√	58.3
Mata *et al.*, (2015)[32]	√	√	√	N/A	N/A	√	√	√	-	√	U	√	√	81.8
Gonzalez and Zuluaga (2015)[34]	√	√	√	N/A	N/A	√	√	√	-	√	U	√	√	81.8
Quasi-experimental study														
Mata *et al.*, (2019)[7]	√	√	√	√	N/A	U	√	√	√					71.4

√ - yes; -- - No; U- Unclear; N/A – Not applicable. Risk of domains for cohort studies – Q.1) "Were the two groups similar and recruited from the same population?" Q.2) "Were the exposures measured similarly to assign people to both exposed and unexposed groups?" Q.3) Was the exposure measured in a valid and reliable way?" Q.4) "Were confounding factors identified?" Q.5) "Were strategies to deal with confounding factors stated?" Q.6) "Were the groups/participants free of the outcome at the start of the study (or at the moment of exposure)?" Q.7) "Were the outcomes measured in a valid and reliable way?" Q.8) "Was the follow up time reported and sufficient to be long enough for outcomes to occur?" Q.9) "Was follow up complete, and if not, were the reasons to loss to follow up described and explored?" Q.10) "Were strategies to address incomplete follow up utilized?"; Q.11) "Was appropriate statistical analysis used?". Risk of bias domains for randomized clinical trials – Q.1) "Was true randomization used for assignment of participants to treatment groups?"; Q.2) "Was allocation to groups concealed?" Q.3) "Were treatment groups similar at the baseline?" Q.4) "Were participants blind to treatment assignment?" Q.5) "Were those delivering treatment blind to treatment assignment?" Q.6) "Were outcomes assessors blind to treatment assignment?" Q.7) "Were treatment groups treated identically other than the intervention of interest?" Q.8) "Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed?" Q.9) "Were participants analyzed in the groups to which they were randomized?" Q.10) "Were outcomes measured in the same way for treatment groups?" Q.11) "Were outcomes measured in a reliable way?" Q.12) "Was appropriate statistical analysis used?" Q.13) "Was the trial design appropriate for the topic, and any deviations from the standard RCT design accounted for in the conduct and analysis?". Risk of bias domains for Quasi-experimental studies – Q.1) "Is it clear in the study what is the 'cause' and what is the 'effect' (i.e. there is no confusion about which variable comes first)?" Q.2) "Were the participants included in any comparisons similar?" Q.3) "Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?" Q.4) "Was there a control group?" Q.5) "Were there multiple measurements of the outcome both pre and post the intervention/exposure?" Q.6) "Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analyzed?" Q.7) "Were the outcomes of participants included in any comparisons measured in the same way?" Q.8) "Were outcomes measured in a reliable way?" Q.9) "Was appropriate statistical analysis used?".

The cohort study[31] had a high risk of bias. Question 1 was considered as "No" because it did not describe the comparison, although a larger number of patients were cited without reporting precisely on how this was done. Question 2 was considered as "Unclear," because the comparator had not been described; therefore, it was not possible to know if the exposure was similar. Questions 4 and 5 were considered as "No," because the confounding factors were not identified and measured. Questions 9 and 10 were considered as "No" because the reasons for loss to follow-up were not described and were not taken into account in the analysis.[35]

Four clinical trials[11,19,32,34] had a low risk of bias, and one study[33] had a moderate risk of bias. Question 2 was considered as "Unclear" for two studies[7,11] because neither explained precisely how the sample was sequentially allocated. Questions 4 and 5 were considered as "Not applicable" because it was not possible to blind the participants as well as those who were administering the treatments. One of the studies[33] was considered as "Unclear" with regard to question 4 because it was a double-blind study that did not specify which individuals were blinded, similar to question 6. Question 11 was also considered as "Unclear" for all studies, except one,[7] because the studies did not provide further details on the reliability of the examiners' measurement. Question 12 was considered as "Unclear" in one study[19] because it did not inform the statistical test.[36]

Finally, the quasi-experimental study[7] had a low risk of bias. Question 5 was considered as "Not applicable" because it was not possible to apply the evaluation criteria before carrying out the procedure. Question 6 was considered as "Unclear," because it was not reported whether the analysis of the impact

of the individuals' loss of follow-up on the results was performed.[36]

Synthesis of results

All included studies evaluated the survival time of GIC restorations after ART, and a short variation in the survival was observed. The observed global sample comprised 1,239 restorations, without taking into consideration the follow-up periods. A total of 84 restorations were analyzed for failures in the included studies, ranging from 0 to 14.

In general, as the follow-up time increased, the survival rate decreased. Of the seven studies included, five studies[7,11,32,33,34] assessed the 6-month survival rate of the restorations, this being considered as the baseline, which ranged from 81.3% to 97.2% survival. Six studies[7,11,19,31,32,33] evaluated the survival at 12 months, and the survival rate ranged between 72.2% and 94%. Three studies[7,32,33] evaluated survival at 24 months and found that the rate ranged from 63% to 87%.

Only one study[7] evaluated the survival of restorations after 60 months, with a survival rate of 85% of 82 restorations evaluated in the ART group. GIC restorations had a higher survival rate at 12 months when made with conventional cement, except in the study by Gonzalez and Zuluaga,[34] whose evaluation period was different from the others. This inference was made by comparing the survival rates of conventional and resin-modified cements, even though studies evaluated different numbers of restorations. The details regarding the survival of the restorations in each study are shown in Table 4.

The dropout rate was mentioned in all studies, except one.[7] Other outcomes common to two or more studies are presented in Table 5. Only one study[19] reported the average time, cost, and effectiveness of the restorative procedure. The average procedure time was 13 min for ART and 18 min for CT. For costs, a "professional's stipend" represented the greatest component of the total cost, approximately 87% in ART and 72% in conventional restorations. Another aspect evaluated by da Mata et al.[7] was patients' preferred treatment. The majority (64.5%) said that they preferred to receive dental treatment with the use of anesthesia. Regarding the use of rotary instruments, 71.1% of the patients stated that they preferred a non-drilling restorative treatment.

Table 4. Summary of the main results of the studies included in the qualitative analysis.

Authors	Mean number of teeth present in patients	Intervals (months)	Sample ART (n)	Sample CT (n)	Clinical performance of the ART restorations (survival) (%/n)	Clinical performance of the CT restorations (survival) (%/n)	Failure ART restorations (n)	Failure CT restorations (n)
Honkala e Honkala, 2002[31]	17	12	33	-	79 (15)	-	4	-
Lo et al., 2006[11]	12.8	6	64	68	90.6 (58)	95.5 (65)	6	3
		12	59	63	86.4 (51)	92.1 (58)	8	5
Mata et al., 2014[19]	+	12	124	128	91.1 (113)	97.7 (125)	+	+
Gil-Montoya et al., 2014[33]	11.6	6	37	44*	97.2 (36)	95.4 (42)*	0	2*
		12	36	42*	72.2 (26)	73.8 (31)*	10	10*
		24	26	26*	63 (19)	62 (22)*	3	4*
Mata et al., 2015[32]	ART: 16 CT: 15	6	118	124	91.5 (108)	92.7 (115)	4	2
		12	127	141	87.4 (111)	89.3 (126)	8	4
		24	96	121	77 (74)	80.1 (97)	14	11
Gonzalez and Zuluaga, 2016[34]	8.4	6	64	84	81.3 (52)	92.9 (78)	12	6
Mata et al., 2019[7]	15.8	0–6	129	151	97	99	4	2
		6–12	125	149	94	97	4	2
		12–24	119	140	87	92	6	7
		24–60	82	111	85	79	1	5

n: number of restorations evaluated; +: not mentioned by the author; -: no control group; *related to ART + Carisolv group, not conventional removal.

Table 5. Other outcomes of included studies.

Authors	Dropout rate	DMFT score at baseline (decayed, missing and filled teeth)	Assessment of the integrity of restorations		Mean number of teeth present	Surface involved on restorations	Ionomer cement type for ART	Main reasons for restoration failure
			ART	CT				
Honkala e Honkala, 2002[31]	42 restorations	21.8 2 slight marginal defects 3 unacceptable with marginal defect 1 totally lost	13 present being good	-	17	One or multiple surfaces	Conventional	Partly or completely missing
Lo et al., 2006[11]	+/- 30 restorations	+ 12 with slight defect 4 major defect or wear	39 present and sound 16 with slight defect 1 major defect or wear	42 present and sound	12.8 3 multiples 159 single-surface		Conventional	Gross marginal defect and loss of retention
Mata et al., 2014[19]	8 restorations	+	+	+	+	229.5 single surface	Conventional	Partly or completely missing
Gil-Montoya et al., 2014[33]	11 restorations	+	+	*	11.6	Single surface	Resin-modified glass ionomer	Marginal defect >0.5
Mata et al., 2015[32]	+	ART 25.74 CT 28.54	74 in good condition 6 with slight marginal defect 2 with slight wear 13 partly or completely missing One secondary caries	97 in good condition 13 with acceptable marginal defect 11 partly or completely missing	ART 15 CT 16	220.9 single surface	Conventional	Partly or completely missing
Gonzalez and Zuluaga, 2016[34]	11 patients	+ 6 with slight marginal defect 2 mild 13 partial or total missing 17 secondary caries	74 in good condition 13 with acceptable marginal defect 11 partial or total missing One secondary caries	97 in good condition	+ 68 single surface 54 single surface 15 two surfaces 9 two surface 1 three surfaces 1 four surfaces	ART CT	Resin-modified glass ionomer	Partly or completely missing and secondary caries
Mata et al., 2019[7]	20 restorations	27.2	+	+	15.8	255.6 single surface	Conventional	+

+: not mentioned by the author; -:did not have a control group; * related to ART + Carisolv group, not conventional removal.

Discussion

This study aimed to assess the survival rate of restorations placed using ART in elderly patients. Based on the results from a low to high risk of bias studies, we observed a satisfactory survival rate for GIC restorations of coronal or root caries lesions in the elderly, with rates ranging between 72% and 94% after 12 months.

ART is a relatively simple technique that renders local anesthesia typically unnecessary,[37] generally reducing anxiety to levels that enable patients to cooperate better during clinical procedures.[38,39] Moreover, it is possible to perform the procedure in areas that do not have electricity, as it does not require a dental clinic, an office, or portable conventional dental equipment. In addition, this technique can also be used in the hospital setting, for instance, among patients who require intensive care. For these reasons, ART has been the focus of scientific research.[40,41] Nevertheless, the implementation of ART faces difficulties worldwide.[40] The results found in this systematic review were satisfactory; however, the considerable variation between the eligible studies made a meta-analysis unviable.

Aging is often associated with systemic diseases and decreased body dexterity, particularly among the oldest and most frail individuals.[7] Elderly patients who are restricted at home or living in institutions and/or patients with dementia, arthritis, or neuropathies show more difficulty in maintaining oral hygiene correctly, even when they have caregivers at their disposal.[6] The majority of elderly patients frequently use medications and a diet that can potentially decrease the salivary flow and increase the prevalence of caries. For these patients, conventional dental treatment for caries removal may not be acceptable or accessible, with minimally invasive treatments being the alternative. These patients can be managed with ART, as it can be performed in these situations.[12,13]

One factor that could explain our findings might be related to the restorative material of choice. Glass ionomer shows lower adhesion when compared to other adhesive materials, such as composite resin.[42] Although there are studies showing its satisfactory clinical longevity,[43] glass ionomer does not appear to be ideal for use in load-bearing areas or restorations involving multiple surfaces.[44] In addition, this review did not consider all aspects of the restorative procedure, as there was a lack of information about the conditions under which the restorations were performed. An example of this would be what precautions were taken to avoid contamination, an essential measure to ensure adhesion and longevity.

Two types of GIC were used in eligible studies. This difference can also contribute to the variations found because the physical performance and properties are material dependent.[45] Conventional GIC used in most of the included studies,[7,11,19,31,32] consists of a fluoroaluminosilicate glass powder, usually a calcium or strontium salt, that is mixed with a liquid of polyalkenoic acids for setting via an acid-base reaction. This cement has specific properties, such as fluoride release and biocompatibility, in addition to being a self-adhesive material that bonds to tooth hard tissues through chemical bonding.[46] On the other hand, the resin-modified GIC, used in two eligible studies,[33,34] contains monomers and photoinitiators and was created to solve some of the problems of conventional GICs, such as sensitivity to moisture and low mechanical properties during the initial 24 h after placement. These characteristics confer advantages and disadvantages for each cement, contributing to the indications in each clinical situation. However, it was difficult to make a direct comparison between the material used and the results obtained in the included studies. In addition to the difference between the types of cement, there was also a difference in the sample size of these longitudinal evaluations.

It is known that the success and longevity of a dental restoration depend on the sealing of the cavity walls as well as the retention on the tooth surface.[47] The location in which the ART was performed differed among the eligible studies; it was either in the coronal portion or in the root. One-third of the older adult population is observed to have root caries[48] due to higher plaque accumulation, difficulty in controlling and cleaning the plaque, and consequent periodontal problems, such as gingival recession.[5] In this context, the GIC appears to be a good material for restoring root caries as, when well-adapted, GIC restorations show less marginal leakage without compromising the periodontal health. In addition, it seems that GIC restorations may have additional positive effects on the subgingival biofilm composition when compared with other materials.[49,50] The main difference attributed to the restorations placed on the coronal surface is their submission to occlusal loading from chewing, which

may increase the risk of wear and fracture.[44] In contrast, in root lesions, the evaluation of the apical extent of the root caries lesion is necessary to achieve clinical access and moisture control.[47] It is difficult to assume that the location of the lesion directly influences the failure rate of the restoration, since it is necessary to take into account the conditions of the restorative procedure.

Clinical studies have shown statistically similar clinical performances between GIC restorations made using ART and composite resin restorations made by the conventional caries removal technique, when evaluated using the ART and the modified United States Public Health Service (USPHS) criteria, respectively. Survival rates > 90% for both techniques after 1, 2, and up to 5 years of follow-up agree with the results found in the present systematic review, which suggest that GIC can be considered as a viable option for restoring permanent teeth.[51-54]

To assess the clinical performance of restorations, a score-based clinical examination is commonly used in some ART clinical studies.[55,56] This is an appropriate approach as it codifies restorations according to previously established criteria, such as the presence or absence of parameters, including marginal defects, dental caries, or wear. A qualitative analysis of the results revealed that the main reasons for failure of ART were the presence of marginal defects and partial or complete loss of restoration. These failures are probably inherent in ART and are related to the material, and to obtaining a seal by pressing the glass ionomer against the cavity, which generates a rough surface.

After an extensive and thorough literature search, we were able to find only a small number of eligible studies on the survival of ART restorations in elderly individuals. Thus, it is possible to assume that most dentists have serious limitations to the use of ART, and the traditional principles of total caries removal using rotary instrumentation is their first treatment choice.[57] One plausible reason is the lack of knowledge of this evidence in clinicians and dental schools that should be spreading this approach.[41] However, restorations made using ART show satisfactory clinical performance and survival provided they are well indicated and performed correctly, especially in elderly patients.

Limitations and methodological considerations

This study had some limitations. Few studies met the eligibility criteria, and three[7,19,32] of the seven included studies were conducted by the same research group. In addition, the certainty of evidence was compromised due to inconsistent eligible studies. At this point, it should be noted that of these three studies, one was classified as quasi-experimental, although the authors claim that it was a randomized controlled study. This contradiction was identified because this study had the same number of participants as in the 2015 study.[32] Thus, we assumed that randomization was performed for this study,[32] and the study from 2019[7] was just a follow-up using the same patients from a previous study.[32] Moreover, we could not perform an analysis to assess the publication bias due to the small number of studies; however, a broad search strategy has been carefully conducted and applied in different databases to capture potentially eligible studies and minimize this limitation.

The authors acknowledge that some studies included in this review have shown limited methodological design with the absence of details on the restorative procedure (moisture condition, manipulation of cement, aspect of smoothness, and polishing of the restoration, among others). We believe that these aspects decrease the conclusiveness of the presented findings. Based on the present systematic review, studies with longer follow-up periods should be encouraged to improve the certainty of evidence. ART seems to be a viable alternative for caries treatment among the elderly.

Conclusion

ART shows promising results for the survival of restorations in elderly patients. As a clinical outcome, the present study provides relevant and essential information that could serve as a basis for choosing treatment options for caries removal in elderly patients. However, studies with a longer follow-up period and

robust methodology are required to further elucidate this evidence.

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