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REVIEW

COMPARATIVE EVALUATION OF THE EFFICACY OF CHEMO-MECHANICAL CARIES REMOVAL AND ATRAUMATIC RESTORATIVE TREATMENT ON PAIN REACTION AMONG CHILDREN: A SYSTEMATIC REVIEW AND QUANTITATIVE SYNTHESIS

Evaluación comparativa de la eficacia de la eliminación quimiomecánica de caries y el tratamiento restaurativo atraumático dental en la reacción al dolor en niños: una revisión sistemática y síntesis cuantitativa

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ABSTRACT

Aim: The aim of the systematic review and quantitative synthesis was to assess and compare the efficacy of chemo-mechanical caries removal (CMCR) and atraumatic restorative treatment (ART) on pain reaction among children.

Material and Methods: *Scopus, PubMed, Cochrane, Science Direct, EBSCOhost, Lilacs, Web of Science*, and *Google Scholar* were searched from the earliest available year till July 15, 2024. PICO Strategy: P: Children; I: Chemo-mechanical caries removal; C: Atraumatic restorative treatment; O: Pain reaction. The review comprised only randomised controlled trials and clinical studies. The risk of bias assessment and quality of evidence were assessed using the RoB-2 Tool and GRADE Tool, respectively.

Results: Five full-text publications that met the requirements for eligibility underwent additional processing for data extraction. The overall results of the review suggest that there is no difference in the effect of CMCR and ART on pain reaction among children with a 95% CI of OR: 0.12 [0.01, 1.68]; p=0.12. However, the pooled data suggested high heterogeneity (p<0.0001; I^2=89%) among the studies.

Conclusions: The current review concludes that the effect of CMCR and ART on pain reaction among children is comparable. However, the certainty is low due to high heterogeneity among the included studies. Further studies with a combination of subjective and objective scales may help determine the true pain reaction and provide more conclusive evidence for pain reaction to CMCR and ART.

Keywords: *Dental caries; Dental atraumatic restorative treatment; Papain; Pain; Child; Systematic review.*

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RESUMEN

Objetivo: El objetivo de esta revisión sistemática y síntesis cuantitativa fue evaluar y comparar la eficacia de la eliminación quimiomecánica de caries (EQMC) y el Tratamiento restaurativo atraumático dental (TRAD) en la reacción al dolor en niños.

Materiales y métodos: Se realizaron búsquedas en *Scopus, PubMed, Cochrane, Science Direct, EBSCOhost, Lilacs, Web of Science y Google Scholar* desde el año más antiguo disponible hasta el 15 de julio de 2024. Estrategia PICO: P: Niños; I: Eliminación quimiomecánica de caries; C: Tratamiento restaurador atraumático; O: Reacción al dolor. La revisión incluyó únicamente ensayos controlados aleatorizados y estudios clínicos. La evaluación del riesgo de sesgo y la calidad de la evidencia se realizaron mediante las herramientas RoB-2 y GRADE, respectivamente.

Resultados: Cinco publicaciones de texto completo que cumplían los criterios de elegibilidad se sometieron a un procesamiento adicional para la extracción de datos. Los resultados generales de la revisión sugieren que no existe diferencia en el efecto de la EQMC y la TRAD sobre la reacción al dolor en niños, con un intervalo de confianza del 95% para la OR: 0,12 [0,01, 1,68]; p=0,12. Sin embargo, los datos combinados mostraron una alta heterogeneidad (p<0,0001; I^2=89%) entre los estudios.

Conclusión: La presente revisión concluye que el efecto de la EQMC y la TRAD sobre la reacción al dolor en niños es comparable. No obstante, la certeza es baja debido a la alta heterogeneidad entre los estudios incluidos. Futuros estudios que combinen escalas subjetivas y objetivas podrían ayudar a determinar la verdadera reacción al dolor y proporcionar evidencia más concluyente sobre la reacción al dolor con la EQMC y la TRAD.

Palabras clave: *Caries dental; Tratamiento restaurativo atraumático dental; Papaína; Dolor; Niño; Revisión sistemática.*

INTRODUCTION

Globally, dental caries is the most prevalent pediatric disease.[1] The World Health Organization (WHO) estimates that dental caries affect 60–90% of school-age children, mostly in underdeveloped nations.[2] While rotary devices can remove caries relatively quickly, there is a risk of damaging tooth structure and overheating the pulp or nerves, which can result in excruciating pain.[3] While local anesthetics may lessen pain, young children may become more fearful of needles and less cooperative during restorative treatments due to the noise and vibration of rotary devices.[4]

The two most important factors in pediatric dentistry are dental treatment-related anxiety and discomfort.[5] Anxiety and pain are strongly associated with more intrusive restorative dental treatments for children, according to a systematic study that concentrated on patient-reported outcomes.[6] Patients delay seeking care because of the fear associated with rotary devices.[7]

Dental caries can be managed using various techniques, such as chemo-mechanical removal and atraumatic restorative treatment (ART). The ability to remove only the caries-infected tissue while leaving the caries-affected tissue intact is a common characteristic of these techniques.[8] In ART,

hand instruments are used to remove soft and demineralized carious tissue, which is then conditioned and restored using an adhesive substance.[9] Because ART doesn't require rotary instruments, rubber dams, or local anesthetics, it produces less pain.[9] As a result, it's regarded as a patient-friendly procedure. Even though ART is considered to be a non-traumatic therapy, a systematic review found no evidence that it lowers patient anxiety when compared to traditional treatments.[10]

Due to the simplicity of the removal of carious tissue, chemo-mechanical caries removal (CMCR) has been proposed as a substitute to reduce patient concern.[11] This method, when combined with hand instruments, allows for the minimally invasive removal of contaminated carious tissue by dissolving it with a chemical agent.[12] One of the main benefits of CMCR is that it only removes the infected layer of dentin, preserving more dental tissue and preventing pulpal tissue irritation. It can be used on uncooperative children and patients who are physically disabled or who have infectious diseases.[13]

In recent years, minimally invasive dentistry (MID) has become central to modern pediatric dental care, focusing on conserving tooth structure and ensuring a more comfortable experience for children. Despite this positive shift, there is still limited analytical evidence[14-17] directly comparing how various minimally invasive techniques—such as CMCR and ART—affect children's perception of pain during treatment. Gaining clearer insights into this aspect can help clinicians choose techniques that not only preserve teeth but also make dental visits less stressful for young patients. Hence, the aim of this systematic review is to assess and compare the efficacy of CMCR and ART on pain reaction among children.

MATERIALS AND METHODS

The systematic review procedure was conducted by the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines.[18]

Study registration

The protocol and study details have been registered in PROSPERO. (Registration number: CRD42024565077).

Focused question

Is there a difference in the effect of CMCR and ART on pain reaction among children?

PICO analysis

Population: Children

Intervention: Chemo-mechanical caries removal

Comparator: Atraumatic restorative treatment

Outcome: Pain reaction

Search strategy

To locate relevant papers, a thorough search was conducted across databases like *PubMed, Cochrane, Scopus, Lilacs, Science Direct, Web of Science, EBSCOhost*, and *Google Scholar* (first 100 hits screened) from the earliest date available until July 15, 2024. A manual search of scholarly journals, conference proceedings, unpublished articles, and cross-references was done to find further publications. The search strategies for the above-mentioned databases have been summarized in Table 1.

Inclusion criteria

- Studies on children (with no restriction on gender)
- Study design: Randomized controlled trials and clinical studies
- Studies comparing the pain reaction of CMCR and atraumatic restorative treatment

Exclusion criteria

- Articles using any other minimally invasive technique as a comparator
- Outcome not assessing pain reaction.
- Articles on CMCR without a control group.
- Cross-sectional studies, longitudinal studies, cohort studies, case-control studies, *in-vitro* studies, animal studies, reviews.

Screening and selection

The reviewers (SM and RM) examined the study titles separately. Duplication resulted in the omission of articles from different databases. If the search terms appeared in the article title, it was considered eligible for abstract reading. If the abstracts supported the aim of the study, the papers were considered for full-text reading. Their eligibility was assessed after the full-text data were obtained. If the articles satisfied the eligibility requirements, they were processed further for data extraction (Figure 1). The reference lists of the full-text papers were manually searched to locate additional research. Discussions were used to settle disagreements.

Data extraction

The following information was gathered and put into an Excel spreadsheet (MS Excel 2020) by two reviewers: author details, study year, study location, study design, participant demographics, pain assessment scale, in-tervention, outcome, and inference of the included studies. Publications written in other languages were translated into English using Google Translate.[19] When full-text publications were unavailable, the pertinent authors were contacted to obtain the mis-sing text or other information. To maintain consistency, both reviewers (SM and RM) first carried out a calibration exercise on a subset of studies. Any differences in their screening or data extraction were discussed and resolved by consensus, and the criteria were refined to ensure uniform application throughout the review.

Risk of bias assessment

The Cochrane risk-of-bias tool for randomized trials Version 2 (RoB 2) was used to evaluate the risk of bias for randomized controlled trials.[20] Random sequence generation, allocation concealment, participant and personnel blinding, outcome assessment blinding, insufficient outcome data, selective reporting, and other biases were the criteria utilized to evaluate the bias. There were three categories for overall bias risk: low, high, and uncertain.

The risk of bias in clinical comparative studies was evaluated using the ROBINS-I (Risk of Bias In Non-randomised Studies - of Interventions Tool).[21] The following criteria were applied to evaluate the bias: confounding bias, participant selection bias, intervention classification bias, deviation from intended interventions bias, missing data bias, outcome measurement bias, and reported result selection bias. There were four categories for overall bias risk: low, moderate, serious, and critical.

Quality of evidence

The strength of evidence in the included studies was evaluated using the GRADE (Grading of Recommendations, Assessment, Development, and Evaluations) tool.[22] This framework classifies evidence into four levels—very low, low, moderate, and high.

Each study was carefully assessed across the key GRADE domains, including risk of bias, consistency of results, indirectness, imprecision, and potential publication bias, to determine its overall quality.

Data analysis

After entering the obtained data in the data extraction table for the qualitative synthesis, the meta-analysis was conducted for the quantitative synthesis. The difference in outcome between the chemo-mechanical and ART groups was evaluated using a random-effect model. To estimate the odds ratio (OR) at a 95% confidence interval (CI), the total number of events in each group with positive pain scores was used. The heterogeneity in the findings of the included studies was evaluated using the I^2 statistic and Chi-square tests. For statistical significance, heterogeneity was defined as a *p*-value less than 0.1. Review Manager version 5.4.1 was used to conduct the statistical analysis.

RESULTS

Search and selection results

Using *PubMed, Scopus, EBSCOhost, Web of Science, Science Direct, Lilacs, Cochrane databases, Google Scholar*, and manual searching, 664 articles were found. 650 titles were assessed once the search was cleared of duplicates. After reading the titles, 15 articles were selected. Following the evaluation of the abstract, ten articles were removed. Five[23-27] full-text publications were processed for data extraction. The characteristics of the included studies have been presented in Table 2.

Table 1

Search strategies for the various databases used in this study

Database	Search string
PubMed	((chemo mechanical caries removal OR papain) AND dental atraumatic restorative treatment) AND (pain OR pain measurement OR pain perception OR patient comfort) AND (child OR primary molar)
Cochrane Library	("chemo mechanical caries removal" OR "papain") AND "dental atraumatic restorative treatment" AND ("pain" OR "pain measurement" OR "pain perception" R "patient comfort") AND ("child" OR "primary molar")
Scopus	(TITLE-ABS-KEY("chemo mechanical caries removal" OR "papain") AND TITLE-ABS-KEY ("dental atraumatic restorative treatment") AND (TITLE-ABS-KEY("pain") OR TITLE-ABS-KEY ("pain measurement") OR TITLE-ABS-KEY("pain perception") OR TITLE-ABS-KEY ("patient comfort")) AND (TITLE-ABS-KEY("child") OR TITLE-ABS-KEY("primary molar")))
Lilacs	((chemo mechanical caries removal OR papain) AND dental atraumatic restorative treatment) AND (pain OR pain measurement OR pain perception OR patient comfort) AND (child OR primary molar)
ScienceDirect	("chemo mechanical caries removal" OR "papain") AND "dental atraumatic restorative treatment" AND ("pain" OR "pain measurement" OR "pain perception" OR "patient comfort") AND ("child" OR "primary molar")
Web of Science	("chemo mechanical caries removal" OR "papain") AND ("dental atraumatic restorative treatment") AND ("pain" OR "pain measurement" OR "pain perception") OR patient comfort")) AND ("child" OR "primary molar"))
EBSCO Host	((chemo mechanical caries removal OR papain) AND dental atraumatic restorative treatment) AND (pain OR pain measurement OR pain perception OR patient comfort) AND (child OR primary molar)
Google Scholar	"chemo mechanical caries removal" OR "papain" AND "dental atraumatic restorative treatment" AND ("pain" OR "pain measurement" OR "pain perception" OR "patient comfort") AND ("child" OR "primary molar")

Table 2

Characteristics of included studies

Author, Year of study	Place of study	Type of study	Participant description (Sample size, age, gender)	Pain assessment scale	Intervention	Outcome	Inference
Satie *et al*,[22] (2011)	Brazil	Split-mouth, randomized controlled trial	Total participants=8 children. Age=3-6 years	Wong-Baker Faces Pain Rating Scale (WBS)	Group 1= 8 primary molars ART Group 2=8 primary molars Chemo-mechanical caries removal The cavities were restored with GIC	Chemo-mechanical group No pain=100% ART No pain=100%	No difference in pain perception between the groups
Khalek *et al*,[23] (2017)	Egypt	Parallel-arm, randomized controlled trial	Total participants =50 children Age=4-8 years	Sound, Eye, and Motor (SEM) scale	Group 1=25 participants Chemo-mechanical caries removal Group 2=25 participants ART The cavities were restored with chemically cured GIC	Chemo-mechanical group Median S score=1 (comfort) Median E score=1 (comfort) Median M score=1 (comfort) Adjusted mean SEM score=3.6 Mean time for caries removal=5.8 min ART Median S score=3 (moderately painful) Median E score=2 (mild discomfort) Median M score=3 (moderately painful) Adjusted mean SEM score=7.8 *p*-value=0.001 Mean time for caries removal=4.8 min	Chemo-mechanical caries removal is associated with minimal is pain compared to ART However, the working time for chemo -mechanical caries removal is more
Pascareli-Carlos *et al*,[24] (2021)	Brazil	Parallel-arm, randomized controlled trial	Total participants=40 children Age=4-9 years	Wong-Baker Faces Pain Rating Scale (WBS)	Group 1=20 participants Chemo-mechanical caries removal Group 2=20 participants ART The cavities were restored with GIC	Chemo-mechanical and ART group No pain=55% Mild pain=40% Moderate pain=5% Working time for chemo-mechanical removal 8.4 min Working time for ART 9.2 min	No statistical difference in pain perception beween the groups. No statistical difference in the working time between the groups
Gupta *et al*,[25] (2022)	India	Split-mouth clinical comparative study	Total participants=40 children Age=4-10 years	Wong-Baker Faces Pain Rating Scale	Group 1= 40 primary molars Chemo-mechanical removal Group 2=40 primary molars ART The cavities were restored with GIC	Chemo-mechanical group Score 0=59.5% Score 2=30% Score 4=7.5% ART Score 0=70% Score 2=12.5% Score 4=12.5% *p-value*=0.147 Mild discomfort in ART group	No statistically significant between the groups

Author, Year of study	Place of study	Type of study	Participant description (Sample size, age, gender)	Pain assessment scale	Intervention	Outcome	Inference
Ghanem *et al*,[26] (2023)	Egypt	Randomized controlled trial	Total participants=50 children Age=5-8 years	Sound, Eye, and Motor (SEM) scale	Group 1= 25 participants Chemo-mechanical caries removal Group 2=25 participants ART The cavities were restored with resin modified GIC	Chemo-mechanical group SEM score 1 =100% SEM score 2=0% ART SEM score 1=60% SEM score 2=40% *p*-value<0.001 Children showed more co-operative behavior (*p*=0.002) Working time for chemo-mechanical removal 9.5 min Working time for ART 5.7 min	Chemo-mechanical caries removal is associated with minimal pain compared to ART However, the working time for chemo-mechanical caries removal is more

Table 3

Risk of bias assessment in non-RCT using the RoB-I Tool

Study	Domain	Gupta *et al*
Gupta *et al*,[25] (2022)	Bias due to confounding	No
	Bias in selection of participants	No
	Bias in classification of interventions	No
	Bias due to deviation from intended interventions	No
	Bias due to missing data	No
	Bias in measurement of outcomes	No
	Bias in the selection of reported result	No
	Judgement	Low

Table 4

Quality of evidence as assessed by the GRADE Tool

Certainty assessment							№ of patients		Effect		
No. of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	CMCR	ART	Relative 95% CI)	Absolute (95% CI)	Quality of the Evidence (GRADE)
5	Randomised and non-randomised trials	Serious	Not serious	Serious	Not serious	None	25/118 (21.2%)	56/118 (47.5%)	OR 0.12 (0.01 to 1.68)	377 per 1000 (from 466 fewer to 128 more)	⊕⊕⊗⊕ High

Figure 1

PRISMA flowchart: Selection process for the studies included

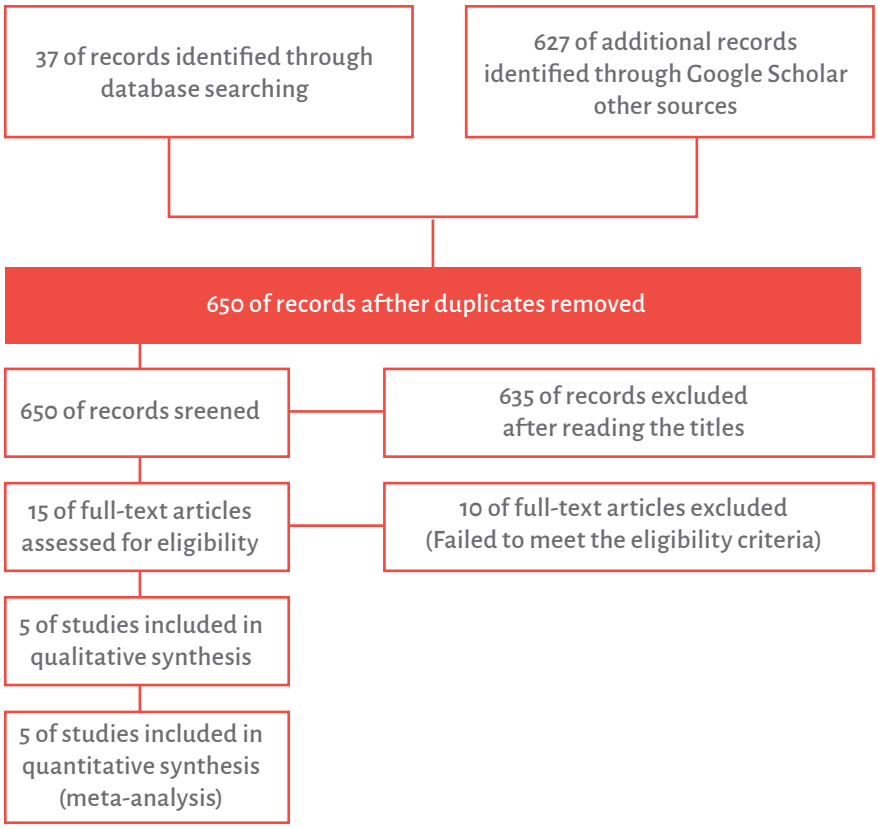


Figure 2

Quality of evidence as assessed by the GRADE Tool

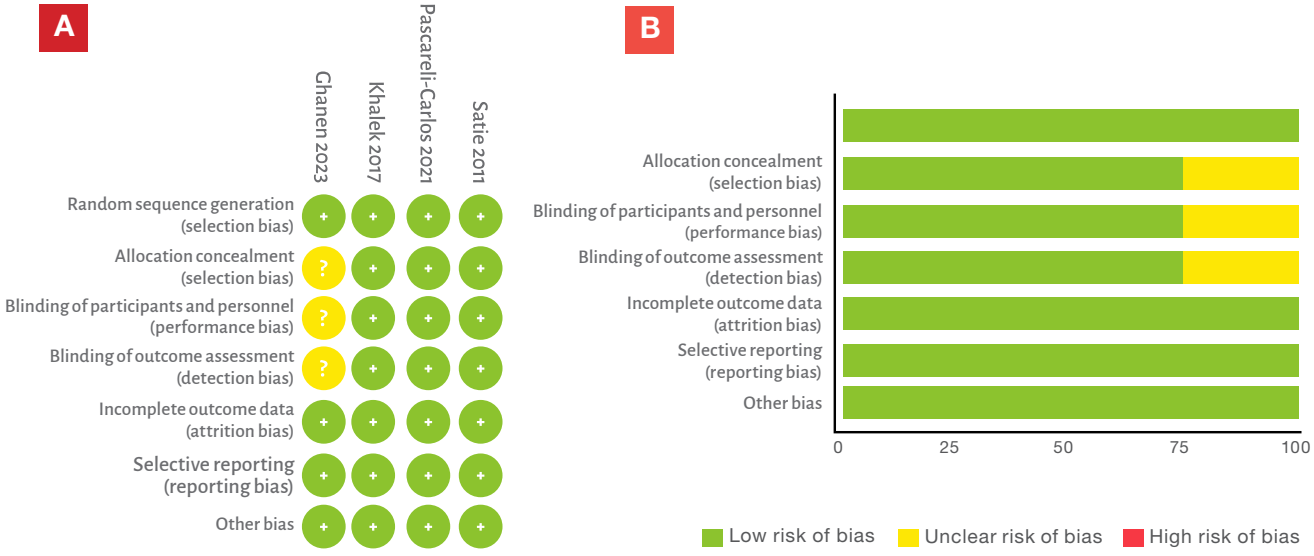
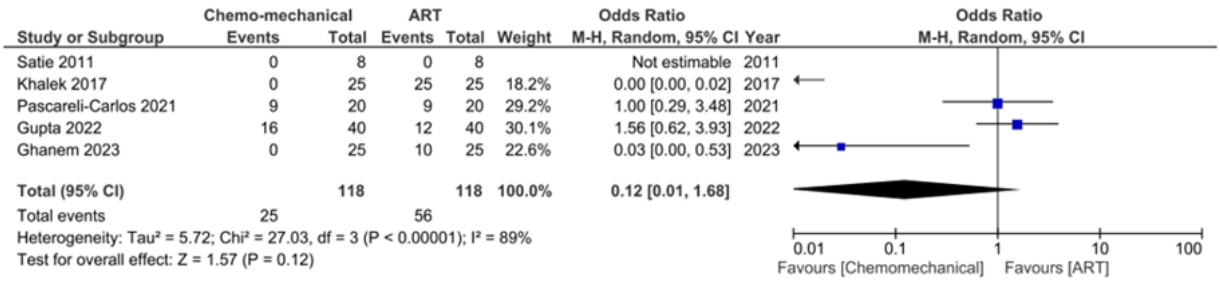


Figure 3

Quantitative analysis$p$=0.12; I2=89%

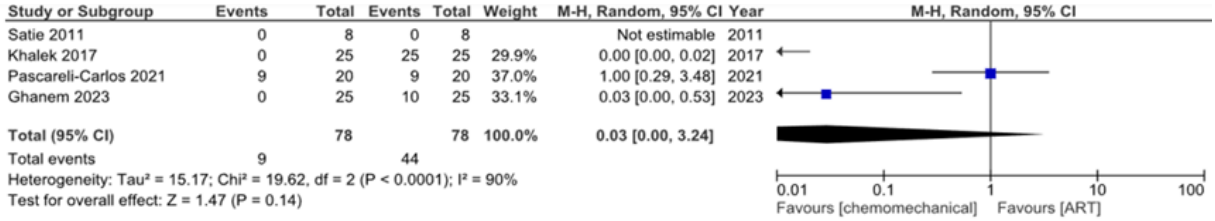


Forest plot depicting high heterogeneity with a 95% CI of OR: 0.12 [0.01, 1.68]; p=0.12; I^2=89%

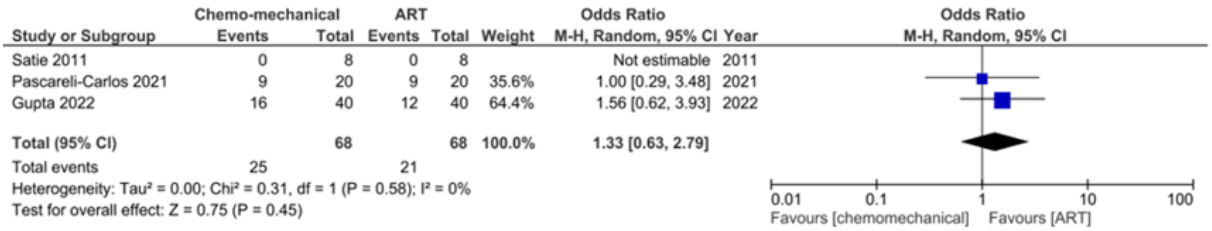
Figure 4

Sub-group analysis

A



B



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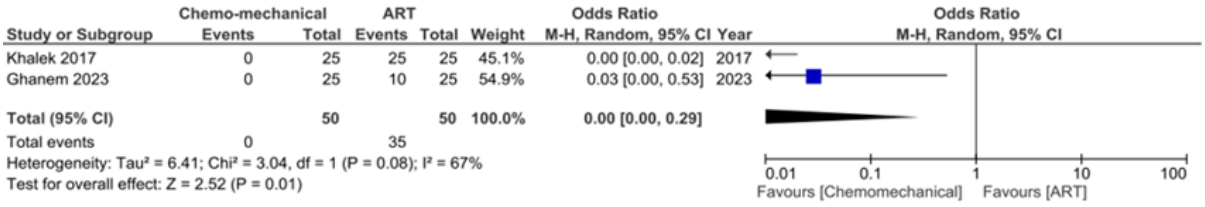

A: Based on RCTs with a 95% CI of OR: 0.03 [0.00, 3.24]; p=0.14; I^2=90% **B:** Based on WBS with a 95% CI of OR: 1.33 [0.63, 2.79]; p=0.45; I^2=0%. **C:** Based on SEM scale with a 95% of OR: 0.00 [0.00,0.29]; p=0.08; I^2=67%.

Characteristics of included studies

Four studies[23-25,27] were randomised controlled trials whereas, one was a clinical comparative study.[26] A split-mouth design was used in two studies[23,26] while a parallel design was used in three studies.[24,25,27] Individuals (aged between 4 and 10 years) were included in the study. The sample size of the included studies ranged from 8 to 50.

Place of study

Two studies were conducted in Brazil,[23,25] two in Egypt,[24,27] and one in India.[26]

Clinical indices

The Sound, Eye, and Motor (SEM) scale was used in two studies[24,27] whereas, the Wong-Baker Faces Pain Rating Scale (WBS) was used in three studies.[23,25,27]

Intervention

In all the studies,[23-27] papain was used as the CMCR agent for 1-3 mins (based on the manufacturer's instructions) and ART was performed using hand instruments. Both the intervention and control groups were restored using GIC.

In the study conducted by Khalek *et al.*,[23] and Ghanem *et al.*,[27] the SEM scale was used by the assessors to gauge the child's response to cavity preparation and caries removal after seeing videos of caries removal sessions. The WBS was given to patients right after the treatment procedure in the study conducted by Pascareli-Carlos *et al.*,[25] The best-fitting illustration for the patient's perceived pain was asked to be pointed at. In the study conducted by Satie *et al.*,[23] the WBS was used to measure how a child reacted to pain during the treatment.

In the study conducted by Gupta *et al.*,[26] WBS was presented to the patients immediately after the treatment and the patients were asked to select a face that best represented their level of pain.

Study outcomes

CMCR was associated with minimal pain compared to ART in two studies.[24,27] In the study conducted by Khalek *et al.*,[24] the adjusted mean SEM score for CMCR was 3.6 whereas for ART was 7.8. In the study conducted by Ghanem *et al.*,[27] 100% of the participants had a SEM score of 1 (comfort) for CMCR whereas, for ART it was 60%. No statistically significant difference was found between CMCR and ART in three studies.[23,25,26]

The working time for CMCR and ART was assessed in three studies. The working time for CMCR was 5.8, 8.4, and 9.5 mins whereas for ART it was 4.8, 9.2, and 5.7 min in the studies conducted by Khalek *et al.*,[24] Pascareli-Carlos *et al.*,[25] and Ghanem *et al.*[27]

Risk of bias assessment

In RCTs, three studies[24,25,27] were rated as low risk of bias whereas, one[23] was rated as unclear risk of bias. The study was rated as unclear risk of bias because details regarding allocation concealment, blinding of participants and personnel, and blinding of the outcome assessment were not mentioned. The risk of bias summary has been illustrated in Figure 2A. Random sequence generation, incomplete outcome data, reporting bias, and other bias exhibited a low risk of bias of 100%. Allocation concealment, blinding of participants and personnel, and blinding of outcome assessment exhibited a low risk of bias of 75%. The risk of bias graph has been illustrated in Figure 2B. For the clinical comparative study, the overall risk of bias was low, (Table 3).

Quality of evidence

The evidence's quality was determined to be "high," indicating that the true effect is close to the estimate of the effect. (Table 4).

Synthesis of result

A high statistical heterogeneity was found between the studies; Test for heterogeneity: $p<0.00001$; $I^2=89\%$ (Figure 3).

Sub-group analysis

A subgroup analysis of RCTs showed that there was no significant difference in pain scores between CMCR and ART (OR: 0.03 [95% CI: 0.00–3.24]; $p = 0.14$). However, the findings within this subgroup were highly inconsistent, as indicated by the high heterogeneity ($I^2 = 90\%$, $p < 0.0001$), suggesting substantial variation among the included studies (Figure 4A).

When pain was measured using the Wong–Baker Faces Pain Scale (WBS), the results were more consistent, again showing no significant difference between CMCR and ART (OR: 1.33 [95% CI: 0.63–2.79]; $p = 0.45$). In this subgroup, heterogeneity was low ($I^2 = 0\%$, $p = 0.58$), indicating that the studies were largely in agreement (Figure 4B).

In contrast, studies that used the Sound, Eye, and Motor (SEM) scale found that CMCR was associated with significantly lower pain compared to ART (OR: 0.00 [95% CI: 0.00–0.29]). Although these results favored CMCR, moderate heterogeneity was observed ($I^2 = 67\%$, $p = 0.08$), suggesting some variation in the study outcomes (Figure 4C).

DISCUSSION

Dental caries is a prevalent disease that affects people of all ages. A biological and less intrusive method has become more important in the management of carious lesions. Therefore, eliminating infected dentin without sacrificing healthy dentin—which can remineralize— has been the ultimate objective of conservative restorative dentistry.

In this review, two studies[24,27] suggested that CMCR was associated with minimal pain compared to ART, whereas three studies[23,25,26] suggested that no statistically significant difference was found between the two groups. A quantitative synthesis of the included studies revealed a high heterogeneity between the studies thus making it difficult to make a conclusion ($p<0.00001$; $I^2=89\%$). A sub-group analysis of RCTs suggested no difference in the scores between CMCR and ART with high heterogeneity ($p<0.0001$; $I^2=90\%$). A sub-group analysis of patients whose pain score was recorded using the WBS also suggested that there is no difference in the scores between CMCR and ART with no heterogeneity ($p=0.58$; $I^2=0\%$). However, this finding should be interpreted with caution, as it is drawn from only three studies, which limits how confidently the results can be generalized. A sub-group analysis of patients whose pain score was recorded using the SEM scale suggested that CMCR was associated with minimal pain compared to ART with moderate heterogeneity ($p=0.08$; $I^2=67\%$).

Since 1975, several CMCR agents have been produced. They fall into one of two broad categories: agents based on enzymes or agents based on sodium hypochlorite (NaClO).[28] All the studies in this review used papain as the CMCR agent. Papain is an enzyme-based agent that is considered an effective chemical debriding agent. It is a cysteine protease obtained from green papaya (*Carica papaya*) fruits and latex.[29] It is believed to function by breaking down partially degraded collagen molecules and assisting in the removal and disintegration of the fibrin mantle produced by the carious process without damaging the intact collagen fibrils.[28] This leads to a softening of the diseased dentin, which can be removed

with non-cutting instruments and without anesthesia.

Dorri *et al.*,[30] found that children reported less pain with ART compared to traditional cavity preparation. Deng *et al.*,[31] similarly showed that papain-based CMCR techniques caused less discomfort than conventional methods. In addition, da Silva *et al.*,[32] reported that using CMCR together with ART reduced pain even more effectively than ART alone. Despite these insights, no systematic review has directly compared CMCR and ART in terms of pain reduction. This makes the present review the first to specifically explore this comparison.

The working time of CMCR was found to be higher than that of ART. This could be explained by the fact that the study's lesions were accessible with hand instruments and ART; in contrast, caries was removed chemo-mechanically by using the CMCR agent multiple times. However, according to a systematic study by Hamama et al, CMCR had a higher excavation time than rotary instruments but somewhat less than ART (mean working time for CMCR, rotary instruments, ART= 6.36, 2.99, and 6.98 min respectively).[29] The difference in the findings of the current systematic review and the aforementioned systematic review could be due to variation in the age of the individuals, types of lesions, and accessibility.

Based on the pain assessment scales used, it was observed that while studies using the WBS supported neither treatment, those utilizing the SEM scale concluded that CMCR is superior to ART in producing the least amount of pain. Pain is a subjective experience. The WBS evaluates a child's perception of pain. The inherent dread and apprehension associated with the operation or dentist appointment may make this scale erroneous or untrustworthy. The SEM scale obscures the confounding variables connected to the child's sense of pain and suffering by concentrating on the auditory, visual, and motor alterations as noted by the dentist.[33] Hence, the nature of the scale used to assess the pain reaction plays a significant role in deciding the outcome of the intervention.

Limitations

This review has a few important limitations to consider. First, only a small number of studies directly compared CMCR and ART. Subgroup analysis using WBS showed no heterogeneity. However, it was based on just three studies, which limits how confidently the results can be interpreted. Second, considerable heterogeneity was seen in the other subgroup analyses, possibly because of differences in participant age and operator experience. Third, the way minimally invasive techniques were carried out varied across studies, and the lack of a consistent method for measuring pain may have influenced the findings.

Finally, many of the included studies had relatively small sample sizes and showed an unclear risk of bias, particularly in blinding and outcome assessment. Moreover, formal assessment of publication bias could not be performed due to the small number of included studies.

Future recommendations

Studies using a combination of both subjective and objective pain assessment scales may be helpful in determining the true pain reaction and provide more conclusive evidence of pain perception for a particular intervention. This would further substantiate the efficacy of CMCR and ART in terms of pain reaction. A finger pulse oximeter,[34] which measures heart rate and oxygen saturation during dental operations, can be used to evaluate physiological factors. Fu-

ture studies are required to evaluate the effectiveness of these two minimally invasive restorative methods in real-world settings, particularly those with limited resources. These studies should also focus on children with special needs, children who struggle with behavior management, and children who have had unfavorable dental treatment experiences.

Large-scale multi-center trials need to be conducted in the future to get more valid results. Furthermore, the chemo-mechanical method of caries removal is not cost-effective in under-developed and developing countries due to the addition of the cost of chemical agents. Therefore, further studies need to be conducted to evaluate the feasibility and cost-effectiveness of the CMCR method.

CONCLUSIONS

The current review concludes that there is no difference in the effect of chemo-mechanical caries removal and atraumatic restorative treatment on pain reaction among children. However, the certainty is low due to high heterogeneity among the included studies. Further studies with a combination of subjective and objective scales may help determine the true pain reaction and provide more conclusive evidence for pain reaction to chemo-mechanical caries removal and atraumatic restorative treatment.

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