Submitted: 29 June, 2024 Accepted: 20 August, 2024 Published: 03 March, 2025 DOI:10.22514/jocpd.2024.145

SYSTEMATIC REVIEW

Journal of Clinical Pediatric Dentistry

Application of magic distraction therapy for the alleviation of dental fear and anxiety in children younger than 12 years: a systematic review and meta-analysis of randomized controlled trials

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Abstract

Background: Dental fear and anxiety (DFA) in children leads to increased pain sensitivity and challenging behaviors that complicate treatment. Employing magic as a distraction therapy utilizes children's imagination and curiosity to mitigate these effects, yet its systematic evaluation is lacking. This study aimed to evaluate the effect of magic distraction therapy (MDT) in reducing DFA in children and identify the determinants of its efficacy. **Methods**: This study adhered to the 2020 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and was registered in the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY202420074). We searched Embase, MEDLINE, Scopus, the Cochrane Central Register of Controlled Clinical Trials, and the Cumulative Index to Nursing and Allied Health Literature (CINAHL) for randomized controlled trials (RCTs) involving children under 12 years receiving dental treatment with MDT. Studies that combined multiple distraction methods or used hypnosis were excluded. The meta-analysis analyzed the data using a random effects model, with subgroup analysis and meta-regression. The methodological quality of the studies was assessed using the revised Cochrane risk-of-bias tool for randomized trials (RoB 2). **Results**: The analysis included four RCTs involving a total of 180 children aged 2 to 11 years. Overall, 25.0% of the included studies had a low risk of bias, 75.0% had some risk of bias, and none had a high risk of bias. Magic significantly reduced dental anxiety (Hedges' $g = -1.236$, 95% confidence interval (CI): -1.798 to -0.673, $p < 0.001$), particularly during treatments involving local anesthesia ($p = 0.006$), performed concurrently during treatment ($p = 0.008$), and in younger children (coefficient = -0.2077 per year, $p < 0.001$). **Conclusions**: This study supports MDT as an effective approach for reducing DFA in children, highlighting the importance of timing, anesthesia and patient age in optimizing anxiety reduction strategies. **Clinical Trial Registration**: INPLASY202420074.

Keywords

Attention; Behavior therapy; Dental anxiety; Magic; Pediatric dentistry

1. Introduction

Dental fear and anxiety (DFA) is a prevalent psychological condition in children posing significant challenges in pediatric dentistry. DFA encompasses both dental fear, an immediate emotional response to specific stimuli such as dental procedures, and dental anxiety, a more generalized feeling of unease not directly linked to specific dental stimuli [1, 2]. This form of psychological distress can escalate pain sensitivity [3, 4], resulting in resistance and uncooperative behavior during dental treatment. Such reactions hinder treatment quality and adversely affect the patient's oral health and quality of life in the long term [5, 6]. Understanding and addressing DFA is crucial for enhancing treatment outcomes and patient well-being.

To address this issue, various behavioral guidance techniques have been widely applied to alleviate DFA in children [7]. In particular, distraction has been recognized for its effectiveness in mitigating anxiety without contraindications in pediatric patients [8]. Distraction diverts attention from dental procedures and diminishes DFA [9], thereby enhancing treatment outcomes. Studies have shown that both active distraction, such as through virtual reality [10, 11] or playing mobile games [12], and passive distraction, such as through

watching audio-visual videos [13, 14] or listening to audio [14, 15] significantly reduced DFA levels in children and facilitated a therapeutic process. This reduction in DFA facilitates smoother dental procedures and also contributes to a positive dental experience. These strategies show potential in pediatric dentistry for improving patient comfort and engagement.

Magic, as an art of illusion, captivates audiences by challenging cognitive expectations, and its cognitive effects can offer substantial benefits in distraction therapy. It capitalizes on children's magical beliefs [16, 17], and their developing executive attention as they grow older [18]. Magic tricks create cognitive conflict and enhance curiosity [19, 20]. The intense focus required to experience magic tricks redirects attention from dental treatments, significantly lowering DFA. Furthermore, magic facilitates social interaction, strengthening the rapport between children and dentists [21, 22], fosters a cooperative treatment atmosphere [23–25], and enhances treatment compliance and success rates [26, 27].

Research on dental treatments has explored magic as a distraction therapy to alleviate DFA among young patients, with several randomized controlled trials (RCTs) affirming its effectiveness. One study revealed magic reduced time spent in the dental chair and enhanced cooperation during procedures like X-ray examinations [28]. In addition, magic significantly reduced DFA in children after treatment [29, 30], even when local anesthesia was administered [31, 32]. Thus, magic distraction therapy (MDT) can be a viable adjunctive to traditional methods such as "tell-show-do" (TSD). MDT includes the Magic Thumb Light trick, Magic Coloring Book trick, and Item Prediction trick, with varying effects depending on the child's age [31].

The use of magic as distraction therapy in pediatric dentistry is an innovative approach to reducing DFA in children. Although several RCTs have explored its effectiveness, a comprehensive synthesis or analysis of these studies [29–32] has been lacking. There has been insufficient understanding of the factors that influence the success of magic as a distraction therapy. This study aimed to fill this gap by conducting a systematic review and meta-analysis to evaluate the overall impact of MDT on DFA in children. Additionally, it sought to identify determinants of its efficacy, such as the mode of distraction, the presence of local anesthesia, and the characteristics of the pediatric participants. By addressing these specific objectives, this research provides evidence-based recommendations to enhance clinical practices for managing DFA in children, thereby highlighting its novelty and purpose.

2. Materials and methods

2.1 Search strategy

This study was conducted following the 2020 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [33] (**Supplementary Table 1**) and was registered in the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY202420074). Two investigators (KTL and MJC) performed a detailed search across multiple databases including Embase, MEDLINE, Scopus, the Cochrane Collaboration Central Register of Controlled Clinical Trials and the Cumulative Index to Nursing and Allied Health Literature (CINAHL), without language restrictions. The search covered records from the earliest date of data entry in the databases up to 22 February 2024 (**Supplementary Table 2**). Potential studies were identified after a rigorous review process which included a manual bibliography check of the selected articles to identify additional relevant studies and exclude those without full texts. Initially, two researchers screened the titles and abstracts, followed by full-text assessments of potentially relevant articles. Any disagreements were resolved by a third investigator (WLW).

2.2 Inclusion and exclusion criteria

This systematic review and meta-analysis, framed by the PICO model, aimed to answer the research question: "Does magic used as a distraction therapy reduce DFA in children under 12 years compared to standard of care or other techniques?". It focused on children under 12 years as the population (P), with magic used as distraction therapy (I) compared against the standard of care or other techniques (C), and anxiety scores as the outcome (O), defined as anxiety scores measured using any validated survey instrument designed to assess DFA in children. Given that previous studies have mainly observed significant effects in younger children and have shown that the impact of magic tricks may be age-related [31], we specifically included studies of children under 12 years. This ensured the precision and relevance of the meta-analysis. Inclusion criteria encompassed RCTs on children under 12 years receiving dental treatment with magic as the distraction. Studies were excluded if they combined other distraction forms, used hypnosis, had overlap with previous trial samples, or had only been published as conference abstracts or posters.

2.3 Search outcomes

This study assessed the effectiveness of MDT in reducing DFA in children. When a single trial employed various scales, the two investigators (KTL and MJC) deliberated to reach a consensus on the principal indicator for inclusion in the meta-analysis. In cases of disagreement, a third investigator (WLW) was consulted to resolve the discrepancies.

2.4 Methodological quality appraisal

We used the revised Cochrane risk-of-bias tool for randomized trials (RoB 2) to assess the methodological quality of the included RCTs [34]. The RoB 2 evaluates bias in five domains: (1) bias arising from the randomization process, (2) bias due to deviations from intended interventions, (3) bias due to missing outcome data, (4) bias in the measurement of the outcome, and (5) bias in the selection of the reported result. Each domain is rated as "low risk", "some concerns" or "high risk". An overall risk of bias judgment was made for each study based on these domain-level ratings. The evaluation was independently conducted by two researchers (KTL and MJC), who then discussed their findings to reach a consensus on ratings. In instances of disagreement, a third researcher (WLW) was consulted for mediation to ensure consistency in

the assessment and resolve any discrepancies.

2.5 Data extraction

Two investigators (KTL and MJC) independently extracted data from studies, noting publication details, participant demographics, MDT types, intervention mode, dental treatment type (whether local anesthesia was used), and outcome measurements. Whenever information was missing, efforts were made to contact authors for the necessary data. The process followed the guidelines outlined in the Cochrane Handbook [35] to ensure scientific rigor in synthesizing the effects of MDT across various conditions. For studies with multiple interventions, a consensus was reached to identify the most relevant arm for inclusion in the meta-analysis.

2.6 Statistical analysis

This meta-analysis, acknowledging variability in age groups and intervention methods, employed a random-effects model for data analysis [36] using the Comprehensive Meta-Analysis software (version 4, Biostat, Englewood, NJ, USA). Statistical significance was set at a p-value < 0.05. The primary outcome, which was the change in anxiety scores among children, was quantitatively analyzed using Hedges' g (with 95% confidence interval (CI)) to measure effect size. Values of 0.2, 0.5 and 0.8 indicated small, medium and large effects, respectively [37]. Heterogeneity was assessed using I^2 and Cochran's Q statistics, with I^2 values of 25%, 50% and 75% corresponding to low, moderate, and high levels of heterogeneity among studies, respectively [38]. Subgroup analyses focused on the mode of intervention, whether local anesthesia was used, and participant characteristics. On the other hand, meta-regression explored the effect of age on DFA reduction. Sensitivity analysis was conducted using a leave-one-out approach to test the robustness of result. This was performed by sequentially excluding each study [35]. Publication bias was assessed using funnel plots and the Begg and Mazumdar rank correlation method. These are suitable for smaller datasets for statistically assessing bias and determining the significance through Kendall's tau correlation coefficient [35].

3. Results

3.1 Study characteristics

This systematic review adhering to the PRISMA guidelines, included a total of four RCTs [29–32] with the results depicted in a flow diagram (Fig. 1). The included RCTs involved a total of 180 children aged 2 to 11 years, recruited for their high anxiety scores [29, 32] or uncooperative behavior [30, 31]. The intervention in all the included studies was the Magic Thumb Light trick, where the magician makes light magically appear and disappear in their hands. In the two dual-arm studies, the control groups consisted of traditional non-pharmacological behavioral management techniques [32] and audiovisual cartoons [30]. In the three-arm study [29], the TSD arm was chosen as the control group over mobile dental game distraction techniques, as TSD is widely considered a fundamental, straightforward and parent-friendly behavioral management technique [39]. In the four-arm study [31], the thumb light trick was selected from three magic interventions (thumb light trick, book trick and item trick) to maintain consistency with the magic used in the other included analyses. Additionally, data from two age groups, 2 to 7 years and 7 to 11 years, were combined to standardize the age range of the included studies. Based on the timing of the magic relative to the dental treatment, the mode of MDT was categorized as either pre-post [29] or concurrent [30–32]. Among the dental treatments administered, two studies used local anesthesia [31, 32], while the remaining studies did not. Procedures such as ultrasonic scaling [29] and single-tooth glass ionomer cement restorations [30] were used in studies that did not involve local anesthesia. Table 1 summarizes the details of the trials retrieved, and **Supplementary Table 3** details the excluded studies and the specific reasons for their exclusion.

3.2 Methodological quality of the included studies

Regarding the overall methodological quality of the included studies, 25.0% of the evaluated studies were found to have a low risk of bias, while 75.0% were found to have some risk of bias. None of the studies were found to have a high risk of bias (Fig. 2). In the detailed assessment, three studies were rated as having some risk of bias in the randomization process. Of these three studies, one provided only a brief statement of random assignment without further details [31], making it uncertain how the randomization was implemented. This lack of detailed description raised concerns about potential selection bias. Another study lacked detailed information about allocation concealment [30]. Without proper allocation concealment, there was a risk that the allocation process may have been manipulated, leading to an imbalance in baseline characteristics between groups, potentially affecting the internal validity of the study. The third study did not provide comprehensive data on baseline characteristics [32]. Baseline data are crucial for assessing the comparability of groups at the start of the trial. Without this information, it was difficult to determine whether the randomization process successfully produced balanced groups, which could have influenced the study outcomes. Fig. 3 summarizes the details of the risk of bias assessment.

3.3 Synthesis of results

The included studies assessed DFA using various standardized tools. These tools included subjective scales used by the children, such as the Chotta Bheem-Chutki Scale [29], Venham's Picture Test [30], Facial Anxiety Scale [31], and Raghavendra, Madhuri, Sujata Pictorial Scale [32]. Objective scales used by the researchers included the Modified Venham's Clinical Ratings of Anxiety and Cooperative Behavior Scale [30] and Venham's Anxiety and Behavior Rating Scale [32]. Additionally, vital signs, such as pulse rate [30, 32] and oxygen saturation [30] were used. To ensure consistency, only the subjective scales used by the children were selected for inclusion in the meta-analysis, following discussion and consensus among the researchers.

The meta-analysis demonstrated that employing the magic

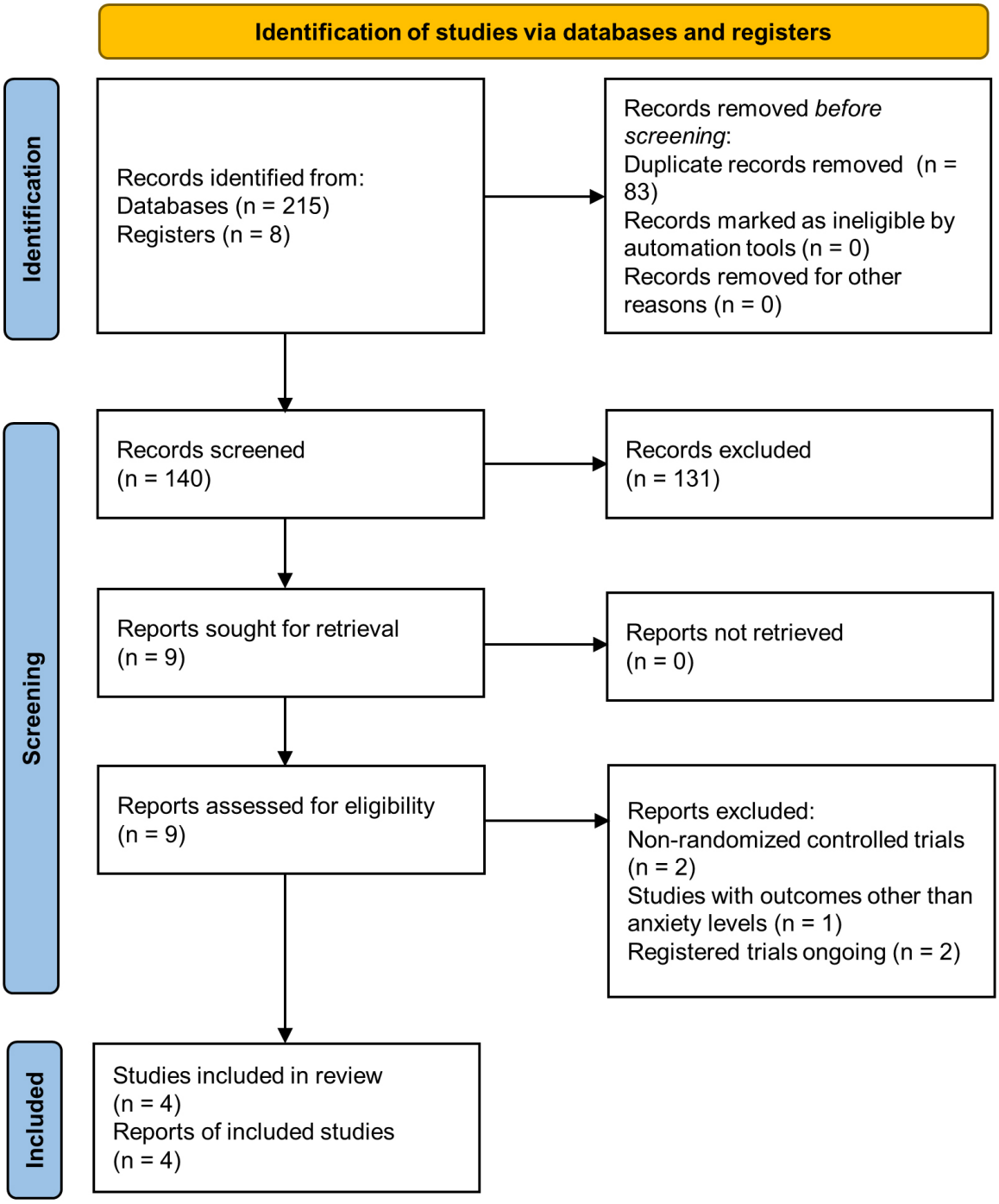

FIGURE 1. PRISMA 2020 flowchart for the current systematic review and meta-analysis.

trick as a distraction therapy significantly reduced DFA in children (Hedges' $g = -1.236$, 95% CI = −1.798 to −0.673, $p < 0.001$) (Fig. 4). Although moderate to high heterogeneity was observed (Q-value = 8.759, df(Q) = 3, $p = 0.033$, $I^2 = 65.7\%$), a leave-one-out sensitivity analysis maintained the statistical significance of MDT in alleviating DFA. The pooled effect estimate remained statistically significant even after sequentially excluding each included study (Fig. 5).

Based on its timing relative to the dental treatment, MDT was first categorized either as pre-post [29] or concurrent [30–32] intervention mode. Subgroup analysis revealed that the concurrent intervention mode significantly reduced DFA in children (Hedges' $g = -1.519$, 95% CI = −1.891 to −1.147, $p < 0.001$; Q-value = 1.677, df(Q) = 2, $p = 0.432$, $I^2 = 0\%$). In contrast, the pre-post intervention mode did not significantly reduce the DFA in children (Hedges' $g = -0.538$, 95% CI = −1.157 to 0.081, $p = 0.088$; Q-value < 0.001, df(Q) = 0, $p = 1.000$, $I^2 = 0\%$). Further comparative analysis demonstrated the superior efficacy of the concurrent over the pre-post intervention mode in mitigating DFA in children ($p = 0.008$). These results highlighted the importance of intervention timing (Fig. 6).

This study also categorized the included trials into two subgroups: those that used local anesthesia [31, 32] and those that did not [29, 30]. Subgroup analysis revealed that MDT significantly alleviated DFA in children during dental treat-

TABLE 1. Summary of magic distraction therapy in the retrieved randomized controlled trials.

First author, year	Study population	Sample size (female/male)	Age distribution	Magic distraction therapy tricks	Mode of Intervention	Type of Dental Treatment	Local Anesthesia	Selected assessment tool
Asokan, 2020 [29]	Children with high anxiety scores	Magic = 20 (NA) Game = 20 (NA) TSD = 20[1] (NA)	4–5	Magic Thumb Light trick	Pre-post	Ultrasonic scaling	No	Chotta Bheem-Chutki scale
Konde, 2020 [31]	Children with strong-willed behavior	Light = 60[2] (NA) Book = 60 (NA) Item = 60 (NA) Control = 60[2] (NA)	2–13[2]	Magic Thumb Light trick, Magic Coloring Book trick, or Item Prediction trick	Concurrent	NA	Yes	Facial anxiety scale
Thosar, 2022 [30]	Children with uncooperative behavior	Magic = 15 (NA) Cartoon = 15 (NA)	4–11	Magic Thumb Light trick	Concurrent	Single-tooth glass ionomer cement restorations	No	Venham's picture test
Kothari, 2023 [32]	Children with high anxiety scores	Magic = 15 (NA) Control = 15 (NA) Total = 30 (15/15)	4–6	Magic Thumb Light trick	Concurrent	NA	Yes	Raghavendra, Madhuri, Sujata Pictorial Scale

Abbreviations: NA, not available; TSD, tell-show-do.

[1] *The TSD arm was chosen as the control group over mobile dental game distraction techniques.*

[2] *The age range of participants included in the meta-analysis was 2 to 11 years. This analysis included 40 participants in both the Magic Thumb Light and control groups.*

ments, regardless of whether local anesthesia was used (with local anesthesia: Hedges' $g = -1.659$, 95% CI = −2.088 to −1.231, $p < 0.001$; Q-value = 0.003, df(Q) = 1, $p = 0.959$, $I^2 = 0\%$; without local anesthesia: Hedges' $g = -0.762$, 95% CI = −1.239 to −0.285, $p = 0.002$; Q-value = 1.237, df(Q) = 1, $p = 0.266$, $I^2 = 19.1\%$). Moreover, the comparative analysis showed that during dental treatments, the use of local anesthesia significantly enhanced the reduction of DFA in children compared to when local anesthesia was not used ($p = 0.006$) (Fig. 7).

In this meta-analysis, the included studies primarily involved children with high anxiety scores [29, 32] or uncooperative behavior [30, 31]. Subgroup analysis revealed that MDT significantly ameliorated DFA in children with both high anxiety scores (Hedges' $g = -1.054$, 95% CI = −1.916 to −0.193, $p = 0.016$; Q-value = 4.757, df(Q) = 1, $p = 0.029$, $I^2 = 79.0\%$) and uncooperative behavior (Hedges' $g = -1.402$, 95% CI = −2.228 to −0.576, $p = 0.001$; Q-value = 1.493, df(Q) = 1, $p = 0.222$, $I^2 = 33.0\%$). However, a direct comparison between these two subgroups found no significant difference in the effectiveness of MDT in reducing DFA ($p = 0.568$) (Fig. 8).

To investigate whether the age of the children who received MDT influenced the reduction of DFA, a meta-regression analysis was conducted. The results showed a significant correlation between the midpoint of the age range of the included children and the improvement of DFA (coefficient = −0.2077 per year of age, $p < 0.001$) (Fig. 9).

In the funnel plot analysis, the symmetrical distribution of

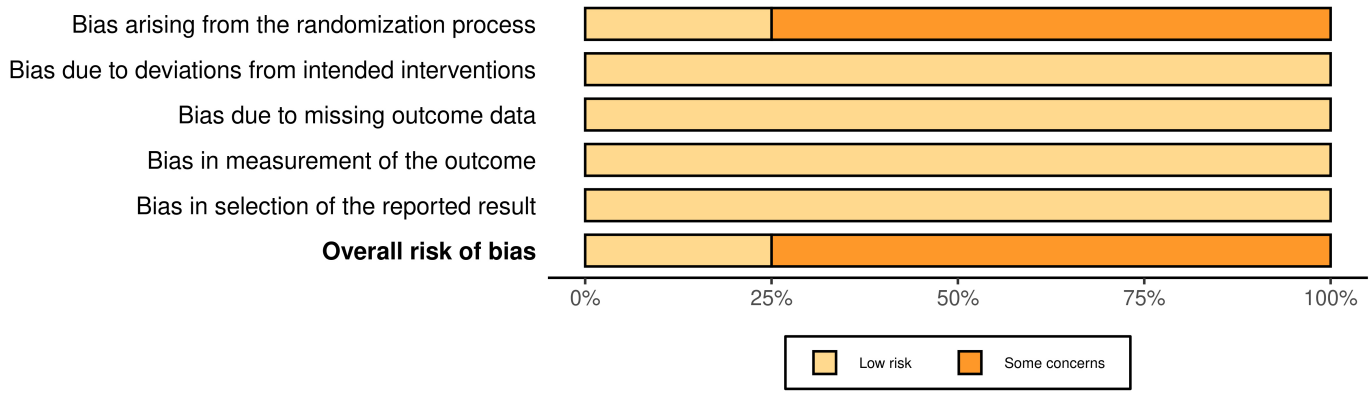

FIGURE 2. Summary of assessment of the risk of bias for the studies included in the current meta-analysis, utilizing the revised Cochrane risk-of-bias tool for randomized trials (RoB 2). Among the evaluated studies, 25.0% were identified as having a low risk of bias, and 75.0% were identified as having some risk of bias. No studies were identified as having a high risk of bias.

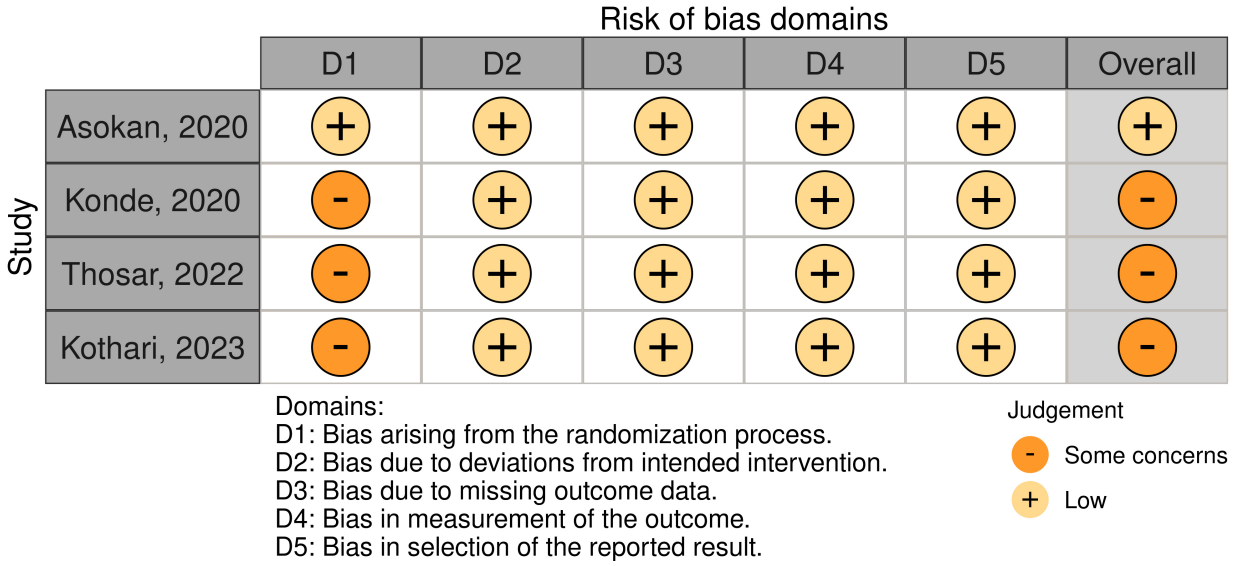

FIGURE 3. Detailed assessment of the risk of bias for studies included in the meta-analysis, utilizing the revised Cochrane risk-of-bias tool for randomized trials (RoB 2). Asokan, 2020 [29]; Konde, 2020 [31]; Thosar, 2022 [30]; Kothari, 2023 [32].

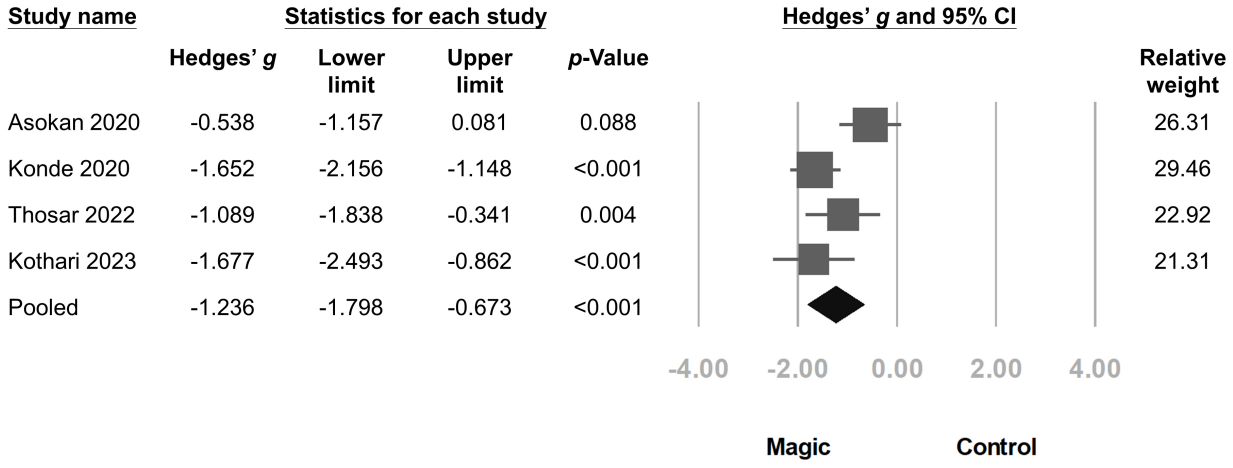

FIGURE 4. Forest plot comparing the impact of magic distraction therapy on dental fear and anxiety in children against the control group. The results indicated that magic distraction therapy effectively reduced dental fear and anxiety ($p < 0.001$). CI, confidence interval. Asokan, 2020 [29]; Konde, 2020 [31]; Thosar, 2022 [30]; Kothari, 2023 [32].

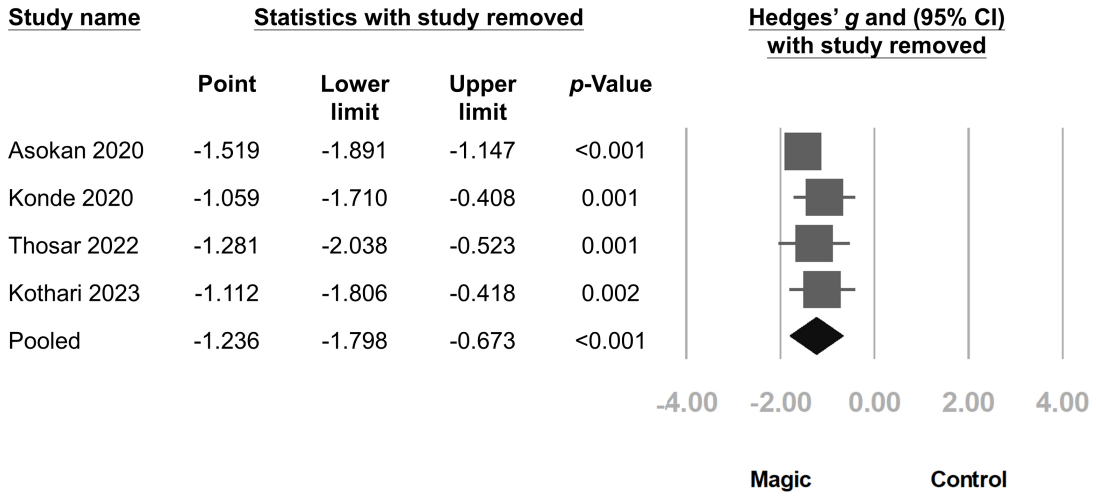

FIGURE 5. Results from the leave-one-out sensitivity analysis. Exclusion of any single trial from the analysis did not lead to significant changes in the primary outcomes. All analyses consistently demonstrated a significant statistical effect of magic distraction therapy in reducing dental fear and anxiety in children. CI, confidence interval. Asokan, 2020 [29]; Konde, 2020 [31]; Thosar, 2022 [30]; Kothari, 2023 [32].

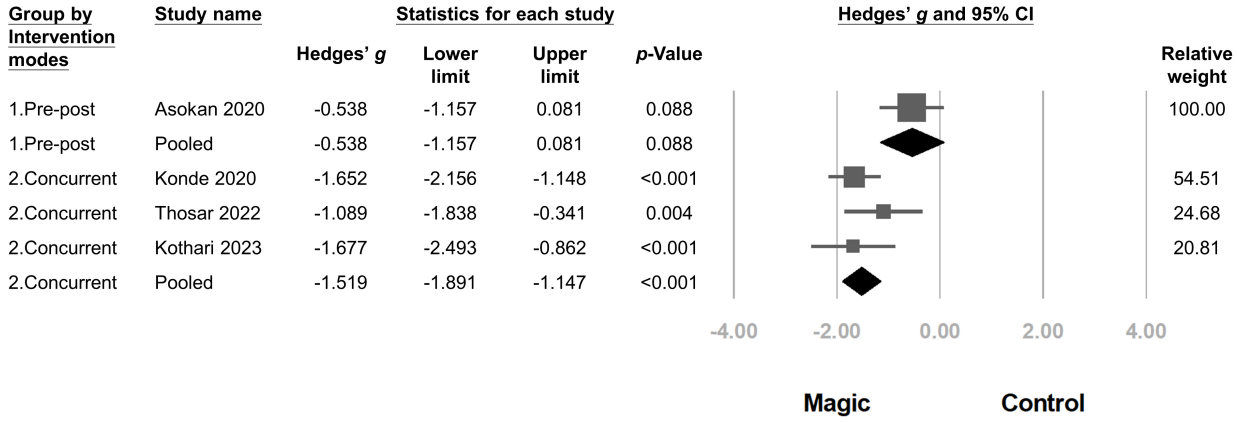

FIGURE 6. Subgroup analysis comparing the efficacy of magic distraction therapy based on its timing relative to dental treatment, categorizing it into pre-post and concurrent intervention modes. The concurrent intervention mode significantly reduced dental fear and anxiety in children ($p < 0.001$) whereas the pre-post intervention mode did not achieve statistical significance ($p = 0.088$). This suggests a significant impact of intervention modes on the efficacy. CI, confidence interval. Asokan, 2020 [29]; Konde, 2020 [31]; Thosar, 2022 [30]; Kothari, 2023 [32].

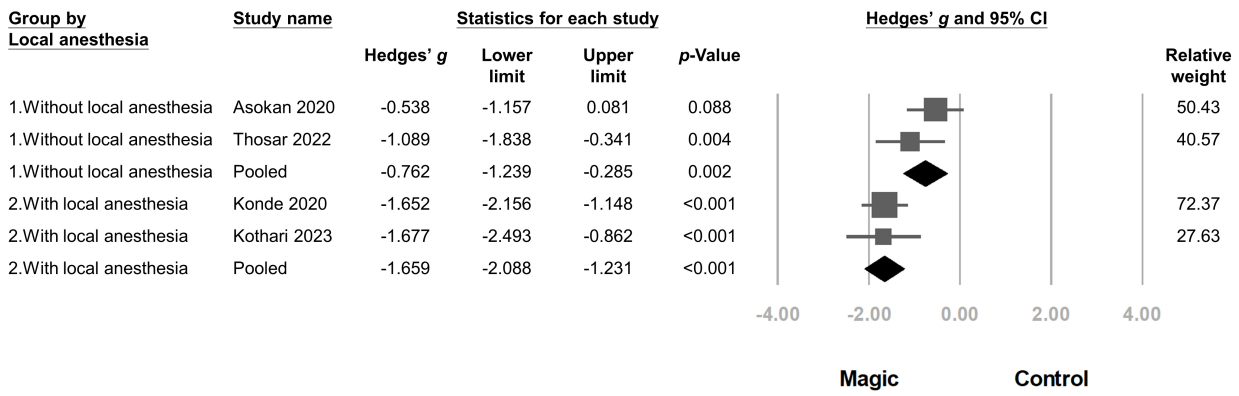

FIGURE 7. Subgroup analysis comparing the efficacy of magic distraction therapy based on whether of local anesthesia was used during dental treatments. Both conditions demonstrated significant reductions in DFA (with local anesthesia, $p < 0.001$; without local anesthesia, $p = 0.002$). However, a greater effect size was observed when local anesthesia was used ($p = 0.006$). This suggests enhanced efficacy of the therapy when used in the presence of local anesthesia. CI, confidence interval. Asokan, 2020 [29]; Konde, 2020 [31]; Thosar, 2022 [30]; Kothari, 2023 [32].

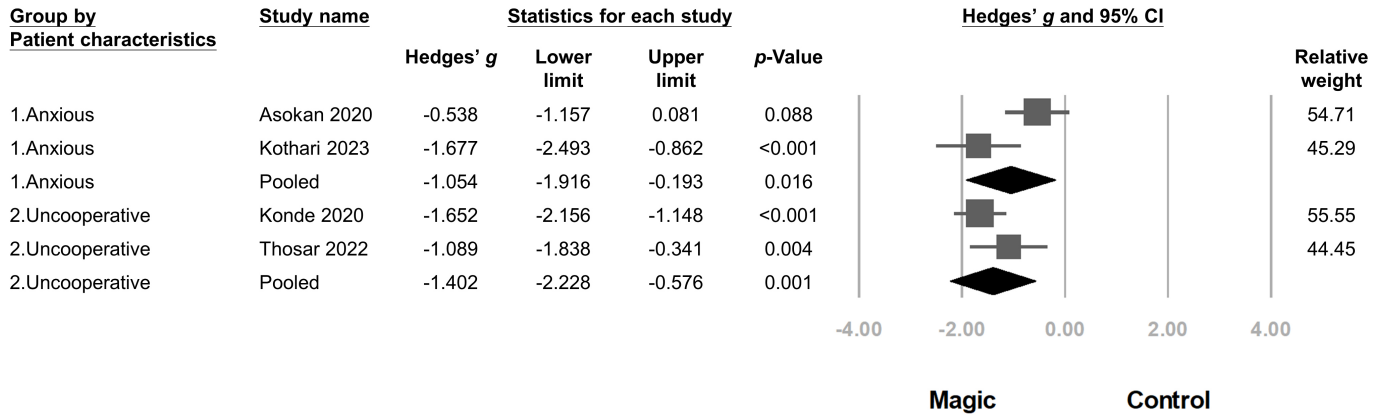

FIGURE 8. Subgroup analysis comparing the efficacy of magic distraction therapy in children with high anxiety scores and uncooperative behavior. Significant improvements in dental fear and anxiety were observed in both subgroups ($p = 0.016$ and $p = 0.001$, respectively), with a larger effect size observed for uncooperative behavior than for high anxiety scores. However, there was a considerable overlap in the 95% CIs. This indicates the broad applicability and effectiveness across different behavioral characteristics. CI, confidence interval. Asokan, 2020 [29]; Konde, 2020 [31]; Thosar, 2022 [30]; Kothari, 2023 [32].

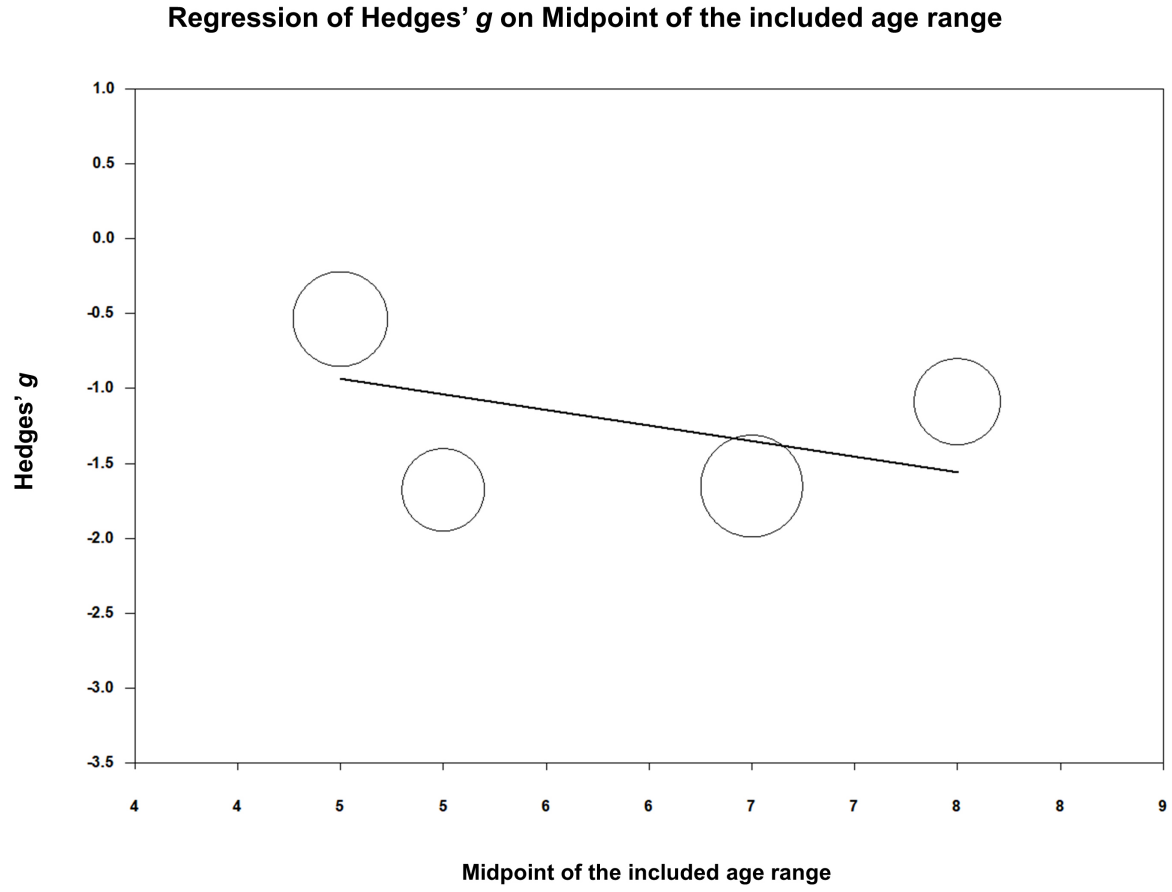

FIGURE 9. Meta-regression of effect size (Hedges' *g*) on the midpoint of the age range of the included children (years of age). The analysis yielded a coefficient of −0.2077 ($p < 0.001$).

effect sizes across the four studies indicated no significant publication bias (**Supplementary Fig. 1**). Additionally, the Begg and Mazumdar rank correlation with continuity adjustment revealed no evidence of statistically significant publication bias (Kendall's $S = 0$, $p = 1.0000$). Nonetheless, it is important to acknowledge that due to the smaller sample size, the statistical power of these results may be limited.

4. Discussion

This is the first systematic review and meta-analysis to assess the efficacy of MDT in reducing DFA in children undergoing dental treatment. Previous literature [19] has qualitatively highlighted the efficacy of MDT in alleviating DFA in children. However, as of writing, quantitative integration and analysis on the efficacy of MDT are still lacking. To ad-

dress this gap, this study quantified the effects of MDT on DFA in children. Despite the moderate to high heterogeneity observed across the studies, analysis of the data from four RCTs revealed significant reductions in DFA levels. Further sensitivity analyses confirmed the effectiveness of the therapy. Additionally, subgroup analyses showed that the concurrent intervention mode was more effective in reducing DFA than the pre-post intervention mode. The therapy was effective in reducing DFA during dental treatments regardless of whether local anesthesia was used, but it was particularly more effective during procedures requiring anesthesia. The therapy resulted in similar benefits to patients who had high levels of anxiety or uncooperative behaviors. Notably, meta-regression analysis showed that younger children benefited more from the therapy compared to older ones.

Recent literature further supports the use of magic in healthcare, demonstrating its efficacy across various dimensions of health. Magic interventions have demonstrated significant benefits in distraction therapy, humor therapy, and psychotherapy. For instance, magic has been used as a distraction therapy to reduce anxiety and pain, as well as to improve cooperation in pediatric patients during dental and other medical procedures (*e.g.*, venipuncture) [19]. Additionally, humor therapy programs like Open Heart Magic [40] and MagicAid [41] have shown that magic can alleviate anxiety and enhance patient engagement through humor and interactive performances [19]. These findings underscore the broader applicability and potential of magic-based interventions in healthcare, reinforcing the observed benefits of MDT in reducing DFA in pediatric dental settings.

The novelty of this study lies not only in providing the first quantitative synthesis of the efficacy of MDT in pediatric dental settings but also in its in-depth examination of factors influencing its effectiveness. These findings emphasize the potential of magic as a novel distraction technique that can be integrated into dental practice to improve patient comfort and compliance, particularly in younger children.

In this systematic review and meta-analysis, heterogeneity was observed across study outcomes. However, the subgroup analyses, which focused on the intervention mode of MDT and the use of local anesthesia in dental treatments, significantly reduced this heterogeneity. These findings suggest that these subgroups account for much of the observed variability and provide a clearer interpretation of the results. It also highlights the importance of considering clinical contexts and intervention specifics when assessing the efficacy of MDT.

In the first subgroup analysis, the concurrent intervention mode significantly alleviated DFA in children compared to the pre-post intervention mode. MDT was effective because experiencing the impossible during a magic show enhances curiosity and attention, thus diverting attention from dental treatment [19]. According to the protocol by Asokan *et al.* [29], the Magic Thumb Light trick was first performed for 3 to 5 minutes. After the performance, the children were asked if they were ready to undergo dental treatment. However, this approach was ineffective in sufficiently diverting the children's attention, as their focus reverted to the dental treatment when questioned about their readiness to undergo the dental procedure. In contrast, the concurrent intervention mode successfully diverted the children's attention, as the magic performance and dental treatment occurred almost simultaneously, thus effectively reducing their DFA levels.

While the pre-post intervention mode showed limited direct impact on DFA, its use in humor therapy programs like the Open Heart Magic [40] and the MagicAid [41] has proven effective in reducing pediatric inpatient anxiety. This approach emphasizes the active participation in children which fosters interactions with medical staff and empowers children through learning magic. Consequently, this leads to diminished anxiety levels [40, 41]. These findings are supported by studies demonstrating that active distraction techniques are more effective in alleviating DFA than passive distraction techniques [42]. By increasing children's active involvement, the effects of magic interventions can be significantly enhanced; however, further research is needed to provide stronger evidence.

The second subgroup analysis showed that MDT effectively lowered DFA in children whether local anesthesia was used. The greater DFA reduction observed in procedures involving local anesthesia may be attributed to the high anxiety levels at the beginning of the procedure [43, 44]. This suggests that magic therapy could be especially beneficial before invasive treatments. Although direct evidence linking distraction techniques to higher efficiency in dental practice is limited, using these interventions for patients requiring local anesthesia could improve clinical outcomes, and may be a viable strategy in busy dental settings.

The third subgroup analysis showed that MDT comparably reduced DFA in children with either high anxiety or uncooperative behavior, demonstrating its broad applicability. Nonetheless, there was an overlap between these two subgroups. Among the studies involving children with high anxiety scores, one excluded extremely non-compliant children [32], while another did not provide such information [29]. Furthermore, among the studies that included children exhibiting uncooperative behavior, baseline anxiety scores varied despite the inclusion criteria being limited to uncooperative behavior [30, 31]. Therefore, caution is needed when interpreting the universal effect of MDT on children with different characteristics. Future research should consider studying these two groups separately, (*e.g.*, the impact of the therapy on children with uncooperative behavior, but without high anxiety scores) to better understand various factors influencing children with uncooperative behavior.

In terms of other patient characteristics, this study identified age as a significant factor influencing the effectiveness of MDT in reducing DFA. The analysis demonstrated that younger children benefited more from MDT, highlighting the importance of tailoring intervention to age differences. A study by Konde *et al.* [31], similarly demonstrated age-specific effects of different magic tricks, with the Magic Thumb Light trick being more effective in younger children. These results underscore the importance of considering the cognitive and emotional development of pediatric patients when designing distraction techniques. Future studies should focus on tailoring distraction techniques to the age and developmental stage of pediatric patients to maximize efficacy.

The four studies included in this meta-analysis were highly homogeneous in terms of subjects, interventions, and outcome

measures. All studies focused on children with DFA within a consistent age range, specifically involving younger children at critical developmental stages. Each study investigated the effectiveness of a magic-themed distraction technique, specifically the Magic Thumb Light trick, to reduce DFA during dental treatment. Furthermore, standardized anxiety scales were utilized, ensuring consistency in outcome measures. This uniformity supports the appropriateness of combining these studies for a meta-analysis, with sensitivity analyses to reinforce the robustness of the findings. Based on the results of this study, the use of visually explicit MDT, such as the Magic Thumb Light trick, could be applied in clinical dental practice to effectively reduce DFA in children younger than 12 years.

Despite the high degree of consistency among subjects from India across the four studies, these results may not be easily extrapolated to other cultures. Culture can impact DFA in several ways. For example, culture may influence the expression of DFA in children [45], the pathways through which DFA manifests [46], the dentist's preferences for managing DFA [47], and the effectiveness of interventions aimed at reducing DFA [48]. Additionally, a study by Peretz and Gluck from Israel showed that MDT increased cooperation during dental examinations in strong-willed children [28]. Experts from various cultures have also suggested that MDT can effectively reduce anxiety, build rapport, create a comfortable atmosphere, reduce pain perception, and increase compliance and success in dental procedures [21–27]. These findings suggest that MDT may be appropriate across different cultural backgrounds, but more research is needed to explore its applicability and effectiveness in diverse cultural contexts.

Overall, employing magic as a distraction therapy is a viable option for managing DFA in children. Specifically, the Magic Thumb Light trick has been shown effective in reducing DFA in children. This trick only requires a prosthetic thumb with a small, easily concealed LED light, and executing it requires minimal training. In this trick, the magician makes the light appear and disappear at will, capturing the child's curiosity and imagination. The instructions for performing the Magic Thumb Light trick are provided in **Supplementary material 1**. The use of MDT offers three key advantages, summarized by the mnemonic ACE: Attractive, Cheap, and Easy. MDT is attractive because it captures the children's attention and stimulates their curiosity through its novelty and charm. It is cheap because it requires minimal investment in props, making it highly cost-effective. Lastly, it is easy to learn like the other basic magic tricks, enabling dental practitioners to quickly master and perform these tricks with minimal training.

Therefore, the feasibility of using magic tricks in dental practice is promising. These tricks can be seamlessly integrated into the clinical workflow without significant disruption. They can be used in the waiting room to reassure anxious children or as a continuous distraction during treatment. However, given the complexity and length of some dental treatments, magic may need to be complemented with other behavioral interventions to maintain quality and comfort during dental procedures.

This study has several limitations. First, although the included studies were all RCTs, most had some risk of bias. This bias arose from issues during the randomization process, such as the lack of detailed reporting of the randomization and allocation concealment processes, and the lack of comprehensive baseline characteristics data of the subjects. These issues may have weakened the strength of the evidence, underscoring the importance of rigorous randomization design and reporting standards in future RCTs to improve the reliability and generalizability of findings in this area. Second, the inclusion of only four studies in this meta-analysis may have affected the generalizability of the findings and introduced potential biases. A small sample size may not adequately represent the broader population, restricting the applicability of the results to different settings and demographics. Additionally, fewer studies reduce the statistical power and can accentuate potential sources of bias, such as selection bias and undetected publication bias. A limited sample size may also obscure the detection of heterogeneity between studies, which is critical for understanding variability in findings. Future research should include a larger number of studies to provide more robust and reliable conclusions. Lastly, all included studies were conducted in India, where cultural and other factors can influence DFA, thus the extrapolation of these results to other cultures requires further validation.

5. Conclusions

MDT significantly reduces DFA in children during dental treatments. It is particularly effective when used concurrently with dental procedures, especially those involving local anesthesia. Furthermore, younger children exhibited greater reductions in anxiety, underscoring the importance of age considerations. These results affirm the effectiveness of MDT in reducing DFA in children under 12 years, supporting its integration into pediatric dental practices to enhance patient comfort and compliance. Future research should focus on expanding the cultural diversity of study populations and exploring MDTs for different age groups, as well as refining the implementation of MDT across various clinical settings.

ABBREVIATIONS

CI, confidence interval; DFA, dental fear and anxiety; MDT, magic distraction therapy; RCTs, randomized controlled trials; TSD, tell-show-do; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; CINAHL, Cumulative Index to Nursing and Allied Health Literature; RoB 2, revised Cochrane risk-of-bias tool for randomized trials.

AVAILABILITY OF DATA AND MATERIALS

Data are available upon request.

AUTHOR CONTRIBUTIONS

KTL and WLW—designed the research study and wrote the manuscript. KTL and MJC—performed the research and analyzed the data. YFY and YCY—provided help and advice on supervision, reviewing and editing the manuscript. All authors contributed to editorial changes in the manuscript. All authors

read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

As a meta-analysis, this study was exempted from ethics board approval of the National Cheng Kung University Hospital.

ACKNOWLEDGMENT

We would like to express our gratitude to Ching-Ju Fang for providing methodological guidance, and Robert John Lamis for proofreading and editing the manuscript. We also acknowledge the support from the Clinical Research Center at National Cheng Kung University Hospital.

FUNDING

This work was supported by the National Health Research Institute (NHRI-13A1-CG–CO–04-2225-1).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.jocpd.com/files/article/1854083310552006656/attachment/Supplementary%20material.docx.

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How to cite this article: Kuan-Ting Lee, Ming-Jui Chung, Yu-Fen Yen, Yi-Ching Yang, Wei-Li Wang. Application of magic distraction therapy for the alleviation of dental fear and anxiety in children younger than 12 years: a systematic review and meta-analysis of randomized controlled trials. Journal of Clinical Pediatric Dentistry. 2025; 49(2): 26-37. doi: 10.22514/jocpd.2024.145.