Systematic review and meta-analysis

Comparison of Heat Generation Between Manual Metal Strips and Motor Stripping Discs for Interproximal Reduction: A Systematic Review and Meta-Analysis

Prachworrakit Kaewsirirat* Chaiyapol Chaweewannakorn** Nita Viwattanatipa***
Nuntinee Nanthavanich Saengfai****

Abstract

Background: Interproximal reduction (IPR) is a widely used orthodontic procedure that reduces the mesiodistal thickness of teeth to alleviate crowding and achieve optimal occlusion. It involves contouring tooth surfaces using manual or motor instruments. Despite being commonly used, there are concerns about the potential thermal impact on dental pulp caused by friction during the procedure. **Objective:** To conduct a systematic review and meta-analysis comparing the temperature changes, measured in degrees Celsius, between manual metal strips and motor stripping discs during IPR in a non-clinical setting. **Materials and methods:** A comprehensive literature search was conducted using four databases: Embase, PubMed, Scopus, and Google Scholar. The risk of bias in the identified studies was assessed using the QUIN tool. Meta-analysis and subgroup analysis were performed, while publication bias was evaluated using Egger's test. A sensitivity analysis was also conducted. **Results:** Four in vitro studies met the inclusion criteria, showing a low to moderate risk of bias. The meta-analysis, which included data from 354 tooth surfaces, found that motor stripping discs generated higher temperatures than manual metal strips, with a mean difference of 2.57°C (95 % confidence interval = −3.89, −1.26). A subgroup analysis of premolar teeth showed similar results. Sensitivity analysis confirmed the robustness of the findings. **Conclusion:** Both manual and motor IPR methods generate mild heat. Clinicians should be aware of overheating risks and employ intermittent stripping with water coolants to reduce temperature increases. The predominance of in vitro studies highlights the need for more clinical trials to enhance generalizability.

Keywords: Heat, Interproximal reduction, Metal strip, Stripping disc, Temperature

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Corresponding author: Nuntinee Nanthavanich Saengfai
E-mail: nuntinee.nan@mahidol.ac.th

* Postgraduate Student, Faculty of Dentistry, Mahidol University, Bangkok, Thailand
** Lecturer, Faculty of Dentistry, Mahidol University, Bangkok, Thailand
*** Clinical Professor, Faculty of Dentistry, Mahidol University, Bangkok, Thailand
**** Assistant Professor, Faculty of Dentistry, Mahidol University, Bangkok, Thailand

Introduction

Interproximal reduction (IPR) is a dental technique used to reduce the mesiodistal thickness of teeth, applicable to both the labial and buccal segments. IPR is also referred to using other terms, including interproximal enamel reduction, reproximation, slenderization, and stripping.[1,2] Ballard initially introduced the stripping technique on the proximal surfaces of the lower anterior teeth to address tooth size discrepancies.[3] The IPR concept originates from Begg's research on aboriginal groups, where natural occlusal and interproximal wear patterns, influenced by non-refined abrasive diets, allowed sufficient space for third molars to erupt without dental crowding.[4] IPR can be utilized with fixed appliance therapy or as part of removable appliance therapy, such as clear aligners.[2] It is typically indicated for resolving mild to moderate crowding to create 3–4 mm of space, potentially avoiding the need for tooth extraction[5]; correcting Bolton tooth size discrepancies to achieve normal overjet, overbite, and proper occlusion[6]; and enhancing dental aesthetics by reshaping individual teeth.[7] It can also improve long-term stability by reshaping contact points.[8]

IPR can be conducted using manual or mechanical methods.[1] Introduced by Hudson, using handheld abrasive strips is time-consuming and hardly applicable to posterior teeth.[9] Hand-operated strips are typically used for minor enamel removal cases or as introductory or finishing stripping procedures.[1] Due to limitations in interproximal access, performing IPR with manual instruments is recommended during the initial phase of treatment when crowding has not been sufficiently alleviated. After the teeth are reasonably aligned, clinicians usually perform IPR with motor instruments, as they can be parallelized to the long axis of the tooth.[10] Motor stripping discs, or the recently developed segment discs, have gained popularity due to less hand fatigue and time consumption. Disc guards, fitting over the handpiece or contra-angle mounted stripping discs, can be employed to shield adjacent tissues.[1]

IPR offers several advantages. Studies have shown that IPR does not increase the risk of tooth decay on treated surfaces; in fact, the occurrence of cavities was comparable between IPR-treated and untreated surfaces.[11] IPR also does not cause periodontal changes or dental sensitivity when used cautiously. The spaces created by IPR can shorten the duration of orthodontic treatment, especially in non-extraction cases, compared to procedures involving dental extractions.[12] However, the friction from removing the tooth structure during dental procedure generates heat that is transferred to the dentine-pulp complex. Heat transferred to the pulp can induce various histopathological changes, potentially resulting in irreversible injury. The thermal behavior of teeth involves a process of heat conduction coupled with physiological processes such as dentinal fluid flow and pulpal blood flow. The injury mechanisms encompass protoplasm coagulation, expansion of liquid within dentinal tubules, increased outflow from the tubules, vascular injuries, and tissue necrosis.

The significance of temperature differences between manual and motor IPR techniques lies in their potential to affect the health of dental pulp. Elevated temperatures during dental procedures can lead to irreversible pulpitis, a condition where the dental pulp becomes inflamed and can result in pain and the need for further dental treatment.[13] Zach and Cohen demonstrated that increasing pulp temperatures by 5.50°C and 11.10°C in Macaca Rhesus monkeys resulted in irreversible pulpitis in 15 % and 60 % of cases, respectively.[14] Therefore, even slight differences in temperature elevation between techniques could have significant clinical implications.

Despite knowing the threshold temperature increase that can cause pulpitis, it is essential to determine whether the temperature changes induced by different IPR techniques remain within safe limits. The typical method for assessing heat generation involves continuous monitoring of temperature using thermocouples such as J-type or K-type, which are considered reliable without significantly affecting temperature measurements in dental settings or materials.[13]

Many studies have compared the temperature changes in the pulp chamber resulting from various IPR techniques, including both manual and motor techniques. These studies consistently found that all IPR techniques increase pulpal temperature; however, the results and methodologies of each study differ. Since IPR is a common procedure in dental practice, understanding the temperature changes is crucial for dental pulp health. To our knowledge, no published systematic review and meta-analysis has compared heat generation between manual and motor IPR techniques. Therefore, this study examines the temperature differences when performing IPR with motor stripping discs and manual metal strips. By conducting a systematic review and meta-analysis, this study aims to provide a comprehensive and unbiased synthesis of the available evidence, offering clearer insights into the thermal impacts of these techniques and guidance for clinical practice.

Objective

This study aimed to systematically review the temperature differences, measured in degrees Celsius, when performing IPR with manual metal strips and motor stripping discs in a non-clinical setting. It also aimed to compare these temperature differences between motor stripping discs and manual metal strips through meta-analysis.

Material and methods

Registration and literature search

This systematic review and meta-analysis was registered in the PROSPERO database (CRD42024531664). Four electronic databases were searched to identify relevant articles: Embase, PubMed, Scopus, and Google Scholar. The search terms combined subject terms and free terms. No language restrictions were applied. Studies in languages other than English were identified using their keywords or abstracts. Once identified and selected based on the inclusion criteria, these studies were translated into English using the AI tool DeepL Translate to extract their details.[15] The search considered articles published from the inception of each database until April 30, 2024.

Inclusion and exclusion criteria

The inclusion criteria were as follows: 1) Populations: human permanent teeth, 2) Intervention: motor stripping discs, 3) Comparison: manual metal strips, 4) Outcome: Mean difference in temperature change of each group, and 5) Study design: both in vivo and in vitro studies conducted in clinical and non-clinical settings.

The exclusion criteria were as follows: 1) Animal studies, case reports, letters, and conference abstracts; 2) studies lacking clear data on pulpal temperature changes or full-text availability were excluded after three unsuccessful attempts to contact the authors for relevant data.

Literature selection and data extraction

After two researchers (PK and CC) had completed the literature selection, data were extracted, and quality was assessed independently according to the specific inclusion and exclusion criteria. Inter-reviewer reliability was assessed using Cohen's kappa (κ) coefficient to evaluate the consistency between two independent reviewers in literature selection and data extraction. Cohen's κ assesses agreement beyond chance, with values interpreted as follows: $\kappa \leq 0.20$ indicating poor agreement, $0.21 \leq \kappa \leq 0.40$ indicating fair agreement, $0.41 \leq \kappa \leq 0.60$ indicating moderate agreement, $0.61 \leq \kappa \leq 0.80$ indicating substantial agreement, and $\kappa > 0.80$ indicating almost perfect agreement. A Cohen's κ of 0.90 was obtained, indicating perfect agreement between the reviewers. Any discrepancies between the two researchers were resolved through open discussion and consensus. In cases where disagreement persisted, a third researcher (NN) was consulted to facilitate resolution. In addition to recording the outcomes of interest (mean difference in temperature change of each group), information on study design, types of teeth, and stripping procedures was extracted to construct a table of the characteristics of the included studies.

Risk of bias assessment of the included studies

The risk of bias in individual studies included in this systematic review and meta-analysis was evaluated using relevant tools specific to the study type. The QUIN tool was utilized for in vitro studies, assessing potential bias across 12 domains.[16]

Statistical analysis

Meta-analysis

The meta-analysis process involved systematic steps to synthesize and analyze data on temperature differences resulting from IPR with manual metal strips and motor stripping discs in non-clinical settings. It was guided by the following principles:

1. Data Extraction and Synthesis: The data extracted from eligible studies included standardized mean differences (SMDs), 95 % confidence intervals (CI), and sample sizes. These data were pooled using STATA software (version 18; StataCorp LLC, College Station, TX, USA) to calculate overall effect sizes.
2. Heterogeneity Assessment: Heterogeneity among studies was assessed using the Q test and the I^2 statistic. The Q test evaluates whether observed variations in effect sizes are compatible with chance alone, with a significant P value (< 0.05) indicating substantial heterogeneity. The I^2 statistic quantifies the percentage of total variation across studies due to heterogeneity rather than chance, with 25 %, 50 %, and 75 % indicating low, moderate, and high heterogeneity, respectively.
3. Statistical Models: The statistical model used depended on the level of heterogeneity observed. The fixed effects model was used when I^2 was < 50 % and the Q test had a non-significant P value (> 0.10), assuming a common effect size across studies due to minimal heterogeneity. The random effects model was used when I^2 was ≥ 50 % and/or the Q test had a significant P value (≤ 0.10), accounting for potential variability in effect sizes across studies.
4. Subgroup Analysis: Subgroup analyses were conducted based on tooth type to explore potential sources of heterogeneity and to assess whether specific study characteristics influenced the observed temperature differences between manual metal strips and motor stripping discs.
5. Forest Plot: A forest plot was created to visually represent the meta-analysis results, displaying individual study effect sizes (SMDs) and their 95 % CIs, providing a comprehensive overview of the pooled estimates and their variability.
6. Statistical Significance: Results were considered statistically significant at a threshold of $P < 0.05$, indicating temperature differences between the two techniques that were unlikely to occur by chance alone.

Assessment of publication bias

Publication bias was evaluated based on asymmetry in the funnel plot. Egger's linear regression quantitative test was also used to objectively assess publication bias.

Sensitivity analysis

The effect size after removing individual studies was analyzed to evaluate the reliability of the combined results and decrease heterogeneity among studies.

Results

Study selection and characteristics

The literature search yielded 1,204 articles. After removing duplicates and screening titles and abstracts against the eligibility criteria, the full texts of the remaining articles were evaluated. Ultimately, four in vitro studies were included (Figure 1).[17-20]

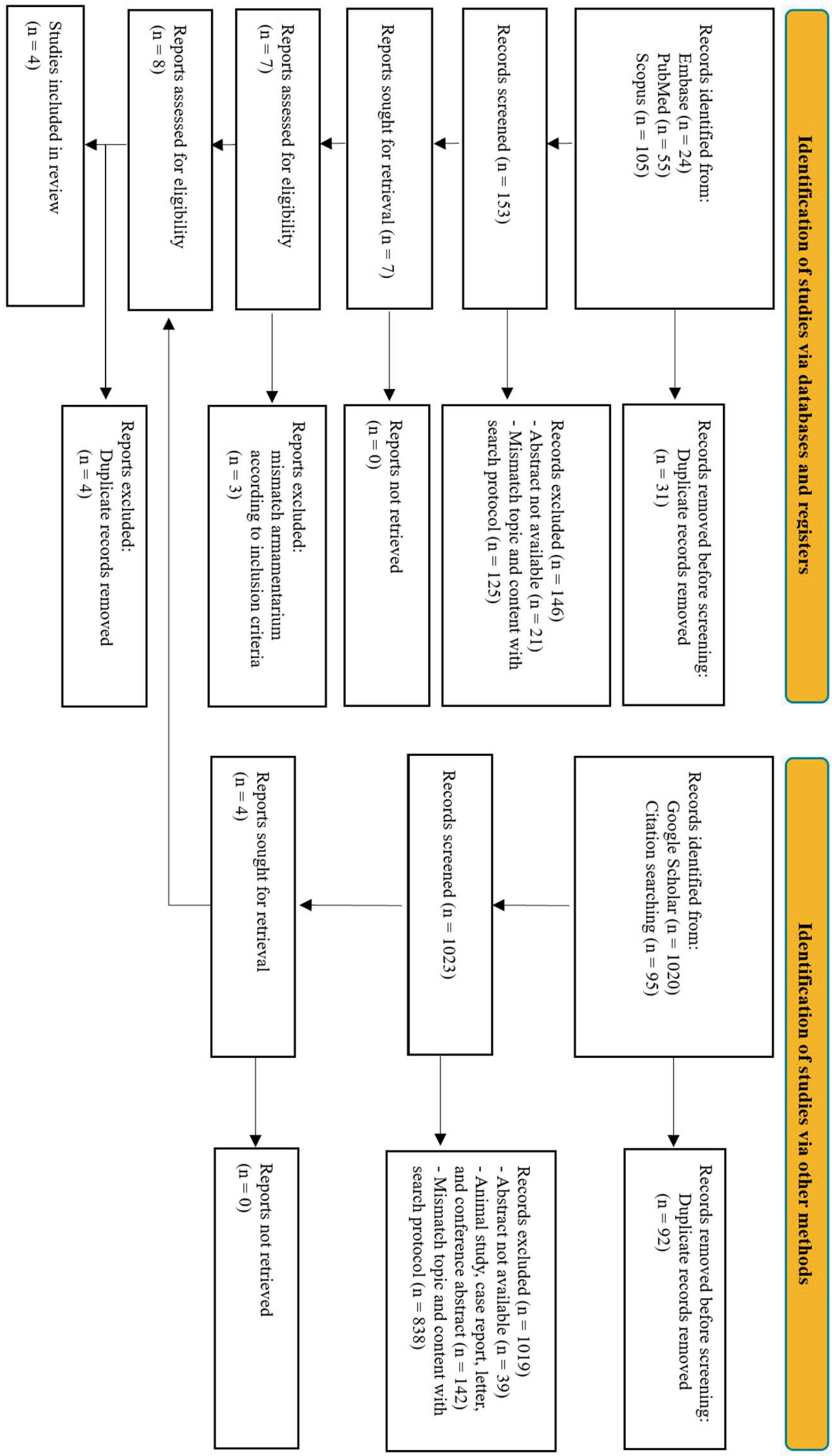

Figure 1 PRISMA flowchart of the selection of eligible studies

Table 1 Characteristics of the included studies

No.	Author, year	Study design	Thermocouple type	Armamentarium	Procedure	Tooth type	Temperature change (°C)		
							N (sides)	Mean difference	Standard deviation
1	Baysal et al.	In vitro	J type	Metal handheld stripper (double side 6 mm; GH Company, Hanover, Germany)	20 strokes on the mesial and distal of each tooth without any type of coolant.	Incisor	20	1.21	1.48
						Canine	20	1.30	1.30
						Premolar	20	−0.18	0.97
				Perforated stripping disc (8934 A.220; Komet, Lemgo, Germany)	Low speeds (< 15,000 rpm) with a contra-angle handpiece for 10 seconds each without any type of coolant.	Incisor	20	2.37	1.31
						Canine	20	2.51	1.25
						Premolar	20	3.84	2.21
2	Pereira et al.	In vitro	J type	Metal handheld stripper (single-sided 6 mm; KG Sorensen, São Paulo, Brazil)	Stripping to 0.50 mm of interproximal enamel without any type of coolant.	Incisor	13	1.24	0.30
						Premolar	13	0.96	0.39
						First molar	13	0.92	0.18
				Two-sided perforated stripping disc (KG Sorensen, São Paulo, Brazil)	Low-speed stripping to 0.50 mm of interproximal enamel without any type of coolant.	Incisor	13	2.58	0.27
						Premolar	13	2.64	0.29
						First molar	13	2.48	0.38
3	Omer and Sanea	In vitro	K type	Manual metal strip (Not specifying type and brand)	Striping for 20 seconds without any type of coolant.	Premolar	24	0.27	0.16
				One-sided diamond stripping disc (RaintreeEssix, Inc., Metairie, CA, USA)	The lowest recommended speed (8,500 rpm) for 20 seconds without any type of coolant.	Premolar	24	1.37	0.75
					The highest recommended speed (12,000 rpm) for 20 seconds without any type of coolant.	Premolar	24	0.77	0.47
4	Dara et al.	In vitro	K type	Metal handheld stripper (type and brand not specified)	Stripping to 1 mm of interproximal enamel without any type of coolant.	Premolar	42	2.52	0.63
				Diamond stripping disc (Strauss, Ra'anana, Israel)	Low speeds (below 15,000 rpm) stripping to 1 mm of interproximal enamel without any type of coolant.	Premolar	42	4.31	0.56

The characteristics of the included studies were extracted according to the use of motor stripping discs and manual metal strips (Table 1).

Risk of bias assessment

The QUIN tool was used to evaluate the risk of bias in all four in vitro studies across 12 domains.[16] The overall risk of bias in the included studies was assessed to be low to medium (Table 2).

Meta-analysis

The meta-analysis included data from 354 tooth surfaces with reported temperature differences in degrees Celsius (Figure 2). The SMD and a random-effects model were used to analyze the data.

Table 2 Risk of bias in the included studies

Quality assessment of the in vitro studies using the QUIN tool														
Study	1. Clearly Stated Aims/Objectives	2. Sample Size Calculation	3. Explanation of Sampling Technique	4. Comparison Group	5. Methodology	6. Operator Details	7. Randomization	8. Method of Measurement of Outcome	9. Outcome Assessor Details	10. Blinding	11. Statistical Analysis	12. Presentation of Results	Final score	Risk of Bias*
Pereira et al.	2	2	2	2	2	0	2	2	0	0	2	2	75 %	Low
Omer and Sanea	2	0	2	2	2	0	2	2	0	0	2	2	66.67 %	Medium
Baysal et al.	2	0	1	2	2	1	0	2	0	0	2	2	58.33 %	Medium
Dara et al.	2	0	2	2	2	1	2	2	0	0	2	2	70.83 %	Low

* Score: adequately specified = 2; inadequately specified = 1; not specified = 0.
Final score = (total score × 100) / (2 × number of criteria applicable); > 70 % = low risk of bias; 50 %–70 % = medium risk of bias; and < 50 % = high risk of bias.

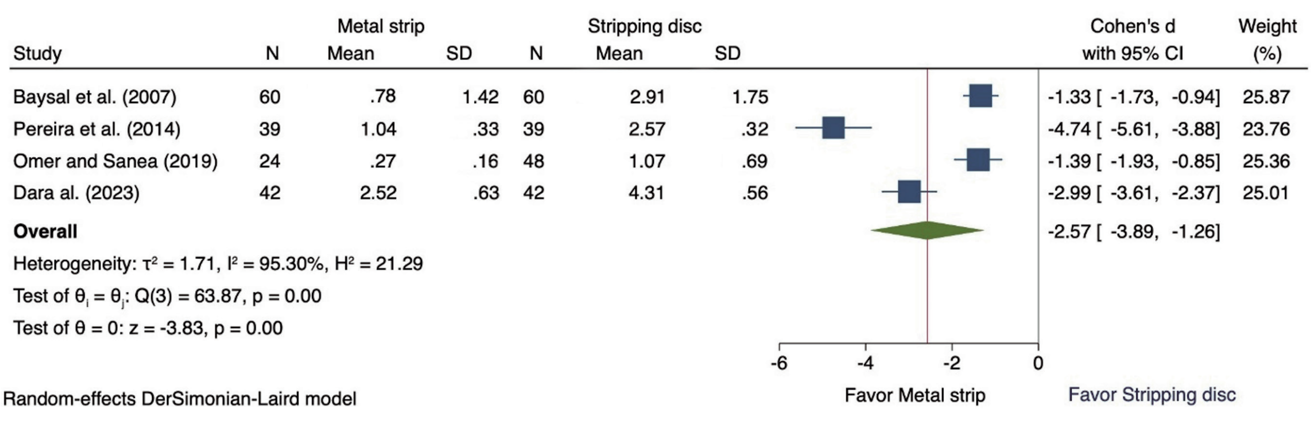

Figure 2 Forest plot of temperature change differences across all tooth types

Subgroup analysis

A subgroup analysis was conducted to reduce heterogeneity by analyzing only premolar teeth (Figure 3).

Publication bias

Egger's test was statistically significant, suggesting that some publication bias may be attributed to factors such as heterogeneity in the included studies, influencing the asymmetric shape of the funnel plot (Figure 4).

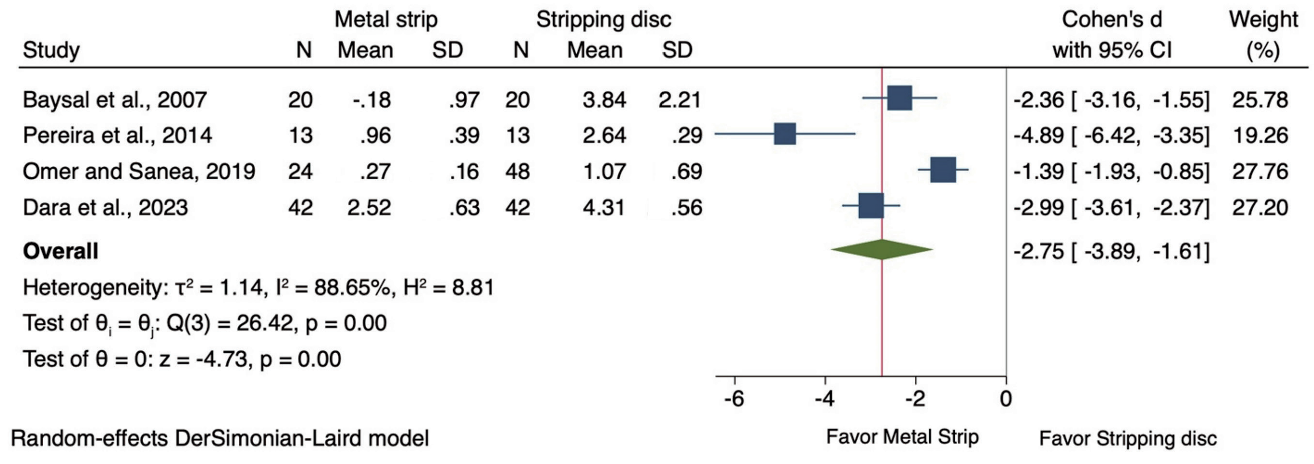

Figure 3 Forest plot of temperature change differences for premolar teeth

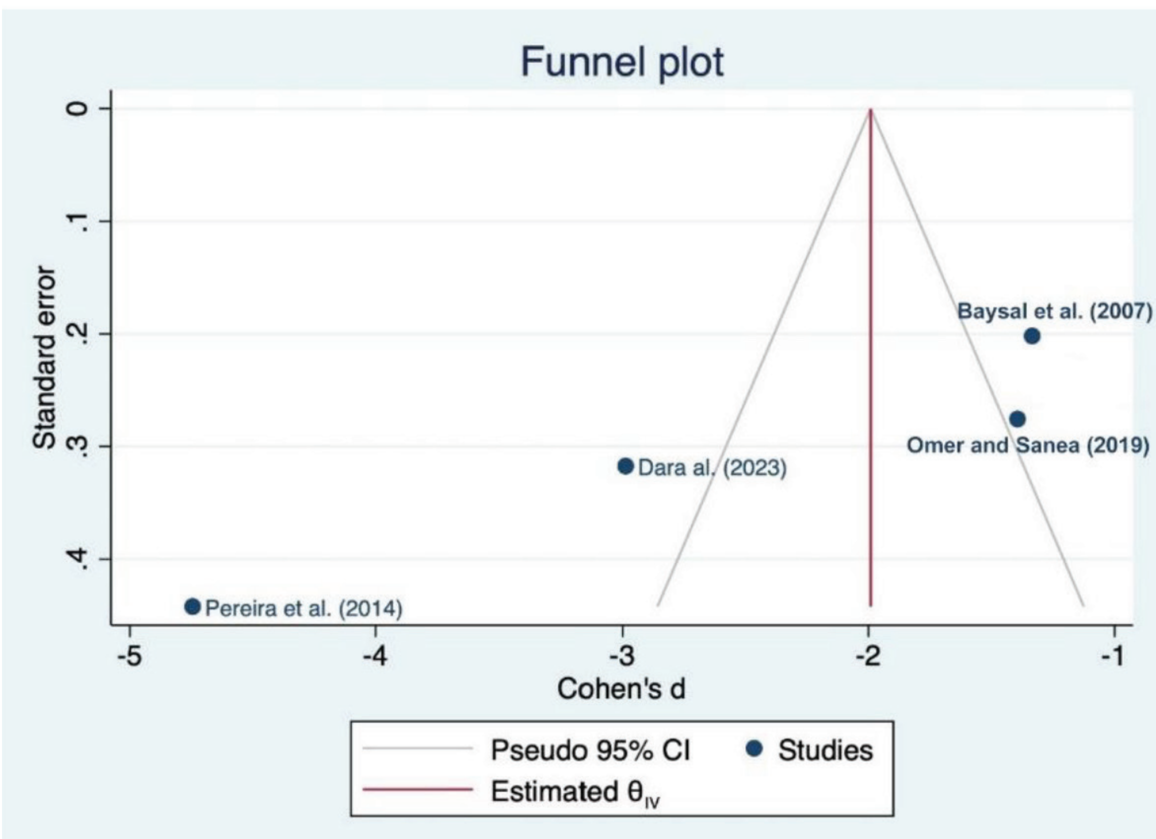

Figure 4 Funnel plot of the meta-analysis to assess publication bias

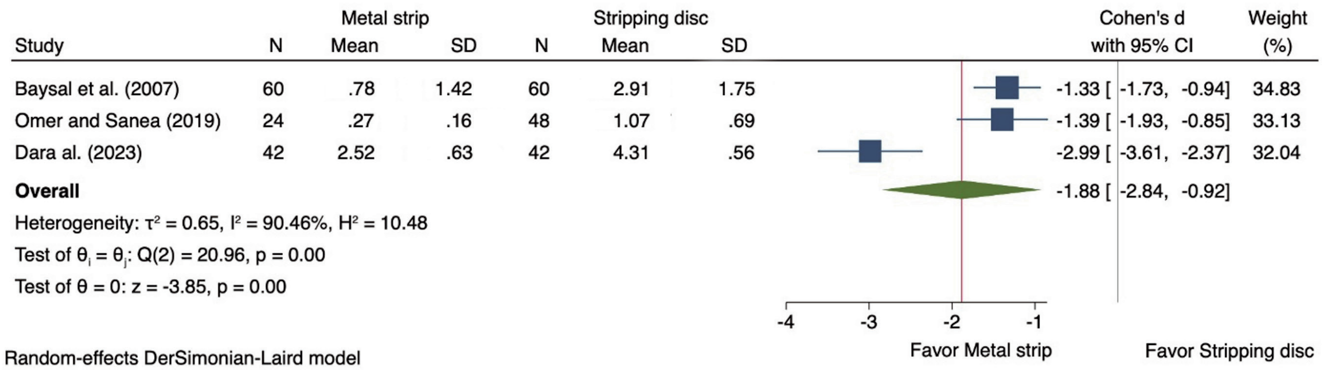

Figure 5 Forest plot of sensitivity analysis

Sensitivity analysis

A sensitivity analysis was conducted, excluding the study of Pereira et al., as it was an outlier in the publication bias analysis (Figure 5). However, this analysis still yielded similar results favoring metal strips (MD = −1.88, 95% CI = −2.84, −0.92) with high heterogeneity (I^2 = 90.46 %).

Discussion

This systematic review and meta-analysis is the first to compare temperature differences in degrees Celsius between motor stripping discs and manual metal strips during IPR, aiming to include all strong study designs for a comprehensive comparison. Despite its broad inclusion criteria, the search primarily yielded in vitro studies. In vivo studies, particularly clinical research involving human participants, were unavailable. Consequently, while this review offers valuable insights, it has inherent limitations when using its findings in clinical settings.

This systematic review and meta-analysis included 354 tooth surfaces from four studies retrieved from four databases, adhering to the PRISMA workflow, with a low to moderate risk of bias. In the included studies, using manual metal strips caused temperature rises between −0.18°C and 2.52°C, while using motor stripping discs caused temperature rises between 0.77°C and 4.31°C.[17-20] The temperature rise did not exceed the 5.50°C threshold that may cause irreversible pulpitis, as reported by Zach and Cohen,[14] in both procedures. Therefore, these procedures were found to be safe for performing IPR. However, Amuk et al. reported different results; they reported that motor stripping discs raised temperatures between 5.54°C and 7.30°C. However, this study was not included in our review as it did not meet the inclusion criteria, which required the use of manual metal strips.[21]

A random-effects model was used due to variations in IPR procedures across studies. The findings of our meta-analysis favored metal strips in terms of temperature rise. It showed that motor stripping discs generated more heat than manual metal strips by around 2.57°C, based on all tooth types (95 % CI = −3.89, −1.26, I^2 = 95.30 %). Our subgroup analysis included only premolar teeth due to variations in tooth thickness across tooth types. Residual dentin thickness was the key factor affecting the rise in intrapulpal temperature. Tooth thickness, especially enamel thickness, varies among tooth types. Premolars and molars generally have thicker enamel than mandibular central incisors. The enamel on the distal aspect was thicker than the enamel on the mesial aspect by an average of 0.10 mm (95 % CI = 0.09, 0.12).[22] The results showed similar trends, and heterogeneity decreased but remained high (MD = −2.75°C, 95 % CI = −3.89,

−1.61; I^2 = 88.65 %). Egger's test was statistically significant, suggesting that some publication bias may be attributed to factors such as heterogeneity in the included studies, influencing the shape of the funnel plot. The sensitivity analysis, excluding the outlier study by Pereira et al.,[18] showed similar results favoring metal strips (MD = −1.88°C, 95 % CI = −2.84, −0.92), with high heterogeneity. This study showed the trend in temperature changes, with motor-driven procedures generating more heat than manual procedures.

Regarding the implications of our findings, friction from mechanical procedures generates heat.[23] While our findings show that both manual and motor IPR techniques increase the pulpal temperature within safe limits, Amuk et al. reported contrasting results, indicating that motor stripping discs can raise the temperature by up to 7.30°C, exceeding the 5.50°C threshold. This discrepancy likely arises from variations in methods, such as different types of motor stripping discs, shorter stripping durations, or tooth types. The conflicting findings emphasize the need for standardized research protocols to ensure the comparability and reliability of results. The study by Amuk et al. was not included in our review due to a mismatch in the armamentarium, specifically the use of metal strips according to our inclusion criteria.[21] Understanding these methodological differences is crucial for determining the thermal safety of IPR procedures in clinical practice.[21]

The recommendation for IPR, especially motor-driven procedures, is intermittent stripping because heat dissipation can occur during rest periods, resulting in a lower temperature rise.[24] Moreover, air coolant is insufficient; water coolant should be used to prevent harmful critical temperature changes.[25] Studies have compared temperature changes during IPR and found that using a diamond bur with water cooling results in lower temperature changes than with air cooling.[19,21,26]

Our systematic review and meta-analysis had several limitations. Firstly, it included only in vitro studies, which may not reflect actual clinical environments due to the absence of blood circulation typical of the vital pulp. Its absence contributes significantly to heat dissipation and leads to a risk of overestimating pulp temperature changes due to the lack of blood and dentine fluid flow and periodontal tissues.[27] Consequently, the generalizability of our findings to vital human dentition may be limited.

Secondly, heterogeneity remained high in both the subgroup and sensitivity analyses despite efforts to investigate its sources. This variability may arise from factors such as variations in tooth types, procedures, and instruments. Therefore, careful consideration is advised when interpreting our findings. The various types of teeth have different thicknesses. Even in the same tooth type, the age of the teeth may influence their mineral content and the size of their pulp chamber.[28] In addition, differences in the armamentarium, procedure, and thermal measurement, such as one-sided or two-sided strippers, grit size, thickness, design, duration, and stroke of the procedure, as well as the amount of tooth reduction, are important factors.[13] Future research should focus more on clinical trials.

Thirdly, Banga et al. reported the only in vivo study examining temperature change during IPR performed on patients for whom extraction of premolars had been advised using an airotor handpiece and bur, handheld metal strip, and orthodontic IPR kit. They found that all three methods were safe, and using coolant, either water or air, could reduce the heat generated by the dental procedure.[29] Future studies should include various tooth types because many past studies have mainly focused on premolars. The variation in armamentariums and procedures should be considered. Moreover, many thermal measurement devices, such as thermocouples or thermal cameras, can be explored.[30]

Conclusion

The temperature change is greater with motor stripping discs than with manual metal strips by around 2.57°C (95 % CI = −3.89, −1.26). A subgroup analysis of premolars supported this finding, with motor stripping discs causing a greater temperature change by around 2.75°C (95 % CI = −3.89, −1.61).

Author contributions

PK: Validation, Formal analysis, Investigation, Resources, Data Curation, Writing-Original Draft, Writing-Review & Editing, Visualization, Project administration; CC: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data Curation, Supervision; NV: Writing-Review & Editing, Supervision; NS: Conceptualization, Methodology, Validation, Resources, Writing-Original Draft, Writing-Review & Editing, Supervision, Project administration.

Disclosure statement

The authors have no conflicts of interest.

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