Review article

pISSN, eISSN 0125-5614
M Dent J 2026; 46 (2) : 149-184

Ranking of interproximal reduction techniques by intrapulpal temperature changes: a systematic review and network meta-analysis

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Objective: Interproximal reduction generates friction and subsequent heat that may lead to pulpal necrosis. This systematic review and network meta-analysis aimed to evaluate and rank the mean intrapulpal temperature increase (°C) associated with various interproximal reduction systems and cooling conditions to identify thermally safe protocols for clinical practice.

Materials and methods: A comprehensive search of PubMed, Scopus, Embase, WorldCat, and Google Scholar was conducted through January 31, 2026. Experimental and clinical studies evaluating the mean intrapulpal temperature increase (°C) during interproximal reduction in human permanent teeth were included. Internal validity was assessed using the QUIN and RoB 2 tools. A Bayesian network meta-analysis using a random-effects model was performed to calculate mean differences and 95% credible intervals. The thermal safety of 11 protocols was ranked using surface under the cumulative ranking curve (SUCRA) probabilities.

Results: Eight studies involving 712 interproximal measurement units, comparing 11 protocols, were included in the systematic review. Rotary tungsten carbide with coolant demonstrated the highest probability of minimizing temperature rise (SUCRA = 91.56%), followed by rotary low speed with coolant (SUCRA = 87.30%). However, differences among these highly ranked protocols and the control (hand without coolant) were not statistically significant. Conversely, non-cooled mechanical techniques were consistently ranked lower, with rotary tungsten carbide without coolant posing the highest thermal risk (SUCRA = 0.61%).

Conclusions: Rotary tungsten carbide, rotary low speed, rotary, and disc protocols (all with coolant), alongside hand without coolant, provide comparable thermal safety. Continuous water cooling is critical for motorized interproximal reduction. Motorized techniques without coolant pose significant thermal risks, particularly rotary tungsten carbide without coolant, which generates the highest temperature rise and should be avoided. When a dry working field is clinically necessary, oscillating and hand protocols without coolant serve as favorable alternatives.

Systematic review registration: PROSPERO CRD42022293226

Keywords: heat, interproximal reduction, network meta-analysis, orthodontics, temperature

How to cite: Kaewsirirat P, Chaweewannakorn C, Saengfai NN, **Satravaha Y**. Ranking of interproximal reduction techniques by intrapulpal temperature changes: a systematic review and network meta-analysis. M Dent J 2026;46(2): 149-184.

Introduction

Interproximal reduction (IPR)—alternatively known as stripping, slenderization, or reproximation—is a procedure used to reduce the mesiodistal width of teeth. This procedure is performed using various protocols, including manual handheld strips and motorized systems such as rotary burs (diamond or tungsten carbide), diamond discs, and oscillating stripping systems. It is primarily indicated to create space for aligning mild to moderate crowding, resolving Bolton tooth-size

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Received: 27 March 2026 **Revised:** 20 May 2026 **Accepted:** 23 May 2026

discrepancies, and improving the stability of results [1]. Besides space creation, IPR can enhance dental and gingival aesthetics. For instance, it is effective in preventing or reducing black triangles, which often appear after aligning crowded teeth in adult patients [2]. The shift toward non-extraction goals has made IPR a key component for achieving optimal results with clear aligners. This approach allows for precise tooth reshaping, helping clinicians maintain stable arch dimensions without resorting to overexpansion or tooth removal [3]. However, despite these benefits, the friction generated during IPR produces heat that is transmitted to the dentine–pulp complex [4-6]. In a classic *in vivo* study on Macaca rhesus monkeys, applying external heat to the enamel of healthy permanent teeth (both anterior and posterior) for 5 to 20 seconds demonstrated that an intrapulpal temperature rise of 5.5°C was associated with irreversible pulpal injury in 15% of cases. This risk increased to 60% with a rise of 11.1°C, and total pulpal necrosis invariably occurred when the temperature increased by 16.6°C [7]. In orthodontic practice, mechanical IPR generates substantial frictional heat. Without adequate cooling, this friction can easily elevate intrapulpal temperatures beyond these critical thresholds, risking pulpal degradation. Therefore, understanding the thermal behavior of different IPR protocols is essential to maintain biological safety limits during chairside procedures [8].

Several technical and biological factors influence the magnitude of this temperature rise. The thickness of the residual dentin acts as a thermal barrier; therefore, teeth with thinner calcified tissues are at a higher risk of thermal damage. Instrument variables also play a significant role, including the type of tool, rotational speed, and the amount of pressure applied by the clinician. While manual handheld strips are generally associated with lower heat generation due to their slow application, motorized systems are faster but more likely to produce high frictional temperatures [9]. These factors interact dynamically during treatment; for instance, high speed and increased clinician pressure may further compound thermal risks, particularly in teeth with thin residual dentin. Among these variables, the presence or absence of a coolant is the most critical and influential factor governing pulpal safety. Water coolant is the most effective method for dissipating frictional heat and preventing odontoblast aspiration. However, the use of water coolant can obstruct clinical visibility and cause patient discomfort, which leads some practitioners to perform IPR dry [10]. Evidence suggests that using high-speed rotary instruments without any coolant, particularly on mandibular incisors, can easily exceed the 5.5°C danger threshold [11, 12].

The current literature on IPR-related temperature changes consists primarily of *in vitro* studies focusing on pairwise comparisons of two or three techniques, often yielding inconsistent results due to variations in experimental setups [5, 6, 11-15]. Furthermore, *in vitro* models may overestimate temperature changes because they lack physiological pulpal blood flow and periodontal tissues, which act as natural heat sinks *in vivo* [4]. A preliminary database search identified one closely related review which compared heat generation specifically between manual metal strips and motor stripping discs. While that review shares a similar objective, it was limited to a conventional pairwise meta-analysis of only four *in vitro* studies restricted to those two modalities [16]. Furthermore, outcome measures vary across primary literature, with some studies reporting absolute maximum temperatures (T_{max}) and others reporting net temperature rises (ΔT). This methodological heterogeneity and data fragmentation make conventional pairwise meta-analysis insufficient to simultaneously compare

and safely rank the 11 distinct interventions involved in our current review. Network meta-analysis (NMA) provides an appropriate statistical framework to overcome these limitations. By applying mathematical standardization to continuous temperature outcomes, NMA seamlessly integrates both direct and indirect evidence from multiple studies. This allows for the simultaneous comparison and comprehensive ranking of all 11 IPR protocols under a unified statistical model, identifying thermally safe protocols for clinical practice [17, 18]. This systematic review and NMA aims to evaluate and rank the intrapulpal temperature changes associated with different IPR systems and cooling conditions to identify thermally safe protocols for clinical practice.

Materials and Methods

Protocol and Registration

This systematic review and NMA was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement and its extension for NMA [17, 18]. The study protocol was prospectively registered in the International Prospective Register of Systematic Reviews (PROSPERO) under the registration number CRD42022293226.

Search Strategy and Information Sources

PubMed, Scopus, Embase, and WorldCat were searched from inception through January 31, 2026, without language or publication restrictions. WorldCat was utilized to capture grey literature, including academic theses and dissertations, to minimize publication bias. The search strategy was constructed using PICO terms, combining MeSH terms (specifically for PubMed and Embase) and free-text keywords (for all databases) related to teeth, interproximal reduction, and intrapulpal temperature changes (detailed in Supplementary Table S4: Full Electronic Search Strategy). For non-English articles, screening and data extraction were facilitated by DeepL Translator (version 2026, DeepL SE, Cologne, Germany). Additionally, the first 200 results from Google Scholar, sorted by relevance, and the reference lists of all included studies were manually screened to identify further eligible literature [19]. Duplicates were identified and removed using EndNote software (version 21, Clarivate, Philadelphia, PA, USA). A post-hoc search amendment was conducted to include the Thai Journal Online (ThaiJo) database through May 10, 2026, using identical search terms, which yielded no additional primary studies that met the inclusion criteria.

Eligibility Criteria

Studies were selected based on the PICOS framework:

- Participants (P): Studies were included if they evaluated permanent human teeth. For *in vitro* designs, this encompassed extracted sound human teeth (free from caries, extensive restorations, or anatomical defects) with no age-of-extraction restrictions. For *in vivo* clinical trials, this included healthy human participants (with no specific age restrictions, provided they possessed fully erupted permanent dentition) undergoing orthodontic treatment with sound interproximal contact points.
- Interventions (I) and Comparators (C): Any manual or mechanical IPR technique with or without cooling protocols.
- Outcome (O): Mean changes in intrapulpal temperature measured in degrees Celsius (°C).
- Study Design (S): *In vitro* experimental studies and *in vivo* clinical trials.

Exclusion Criteria

Studies were excluded from this systematic review if they met any of the predefined exclusion

parameters. Specifically, secondary literature—encompassing systematic reviews, narrative reviews, traditional meta-analyses, case reports, and case series—was omitted to ensure that the quantitative data synthesis relied entirely on primary experimental or clinical trials. Furthermore, to eliminate confounding baseline variables, investigations involving primary teeth or endodontically treated teeth were excluded. Single-arm or non-comparative descriptive designs that lacked a parallel concurrent comparator group were strictly excluded, as they are mathematically incapable of providing the continuous mean differences necessary for network node integration.

Data Extraction and Classification of Interventions

Two independent reviewers (PK and CC) extracted the data using a standardized extraction form, with any disagreements resolved through discussion with a third reviewer (NNS). For studies reporting multiple subgroups (e.g., varying rotational speeds or different tooth types), data were pooled using the standard Cochrane formula to generate a single representative mean and standard deviation for each standardized intervention category. To ensure methodological consistency across the network, this pooling approach was applied to datasets from Baysal, *et al.* [11], Omer and Sanea [6], and Pereira, *et al.* [15]. IPR methods were categorized based on the primary instrument and the cooling condition (with or without coolant). The primary techniques included discs, handheld strips (Hand), oscillating systems (Osc), and rotary systems (subdivided by bur type, such as diamond or tungsten carbide (TC), and speed). This classification resulted in 11 intervention nodes:

1. Disc with coolant: Stripping disc with air-water spray
2. Disc without coolant: Stripping disc used dry
3. Hand without coolant: Handheld strips used dry
4. Osc with coolant: Oscillating stripping system with air-water spray
5. Osc without coolant: Oscillating stripping system used dry
6. Rotary low speed with coolant: Low-speed micromotor with air-water spray
7. Rotary low speed without coolant: Low-speed micromotor used dry
8. Rotary TC with coolant: Tungsten carbide bur with air-water spray
9. Rotary TC without coolant: Tungsten carbide bur used dry
10. Rotary with coolant: High-speed diamond bur with air-water spray
11. Rotary without coolant: High-speed diamond bur used dry

Risk of Bias Assessment

The internal validity of the included studies was evaluated independently by two reviewers, with disagreements resolved by the third reviewer. The risk of bias assessment for *in vitro* studies was performed using the Quality Assessment Tool for *In Vitro* Studies (QUIN Tool) across 12 standardized domains [19]. Each domain was scored as 2 (adequately specified), 1 (inadequately specified), or 0 (not specified), and the overall percentage score was used to classify the studies into low risk (>70%), moderate risk (50%–70%), or high risk (<50%) of bias. For the *in vivo* study, the Cochrane Risk of Bias tool (RoB 2) was utilized to evaluate bias across five distinct chronological domains [20].

Network Meta-Analysis and Statistical Synthesis

The Bayesian network meta-analysis followed a random-effects model using MetaInsight [21]. Within the MetaInsight computational framework, Bayesian inference was automated using standard

vague (non-informative) priors for both treatment effects and the between-study heterogeneity variance. The underlying Markov Chain Monte Carlo (MCMC) sampling was conducted using the software's predefined automated convergence algorithms to ensure stability. Model convergence was verified internally within the R-backed interface, and consistency between direct and indirect evidence was rigorously confirmed via the automated node-splitting approach. This model addressed variability across different study designs and experimental settings. Outcomes were reported as mean differences (MDs) with 95% credible intervals (CrIs). The 11 IPR protocols were ranked by surface under the cumulative ranking curve (SUCRA) values, where higher percentages indicate better thermal safety [22]. It is important to note that while SUCRA values provide a relative hierarchy of the interventions, a higher SUCRA percentage does not inherently imply statistical significance between the compared protocols. The node-splitting approach was used to identify any inconsistency between direct and indirect evidence. Subgroup analyses were planned to explore potential sources of heterogeneity, such as tooth type. However, these subgroup analyses were ultimately not feasible to execute due to the limited number of included studies (n=8) and insufficient data stratification within the primary literature. Subdividing the data would have broken the statistical links within the network loops, leading to unresolvable disconnected nodes. Funnel plots and Egger's test were omitted because the limited number of studies (n=8) lacks sufficient statistical power for detecting publication bias [23].

Sensitivity Analysis

The sensitivity analysis involved removing the *in vivo* study to check the stability of the rankings. This compared findings from the full network against data from *in vitro* models alone. The focus was on how physiological heat sinks, specifically pulpal blood flow and periodontal tissues, influenced temperature changes compared to laboratory conditions. To evaluate network robustness, the primary and sensitivity analyses were statistically compared based on relative treatment estimates (mean differences) and Surface Under the Cumulative Ranking Curve (SUCRA) values. Stability was pre-defined as the preservation of the relative treatment ranking hierarchy (ensuring no major inversions of the top- and bottom-ranked protocols) accompanied by a substantial overlap in the 95% credible intervals (CrIs) between both models.

Certainty of Evidence Assessment

The certainty of evidence for all treatment comparisons was evaluated using the Confidence in NMA (CINeMA) framework. Confidence was assessed across six domains: within study bias, reporting bias, indirectness, imprecision, heterogeneity, and incoherence. Each pairwise estimate was categorized as having high, moderate, low, or very low confidence based on the structured evaluation of contributing studies [24].

Results

Study Selection

The initial electronic database search yielded a total of 1,243 records, distributed as follows: PubMed (n=140), Scopus (n=894), Embase (n=25), and WorldCat (n=184). An additional 200 records were identified through a manual search of the first 200 Google Scholar results. The systematic study selection process, following the PRISMA 2020 flow diagram, is illustrated in Figure 1.

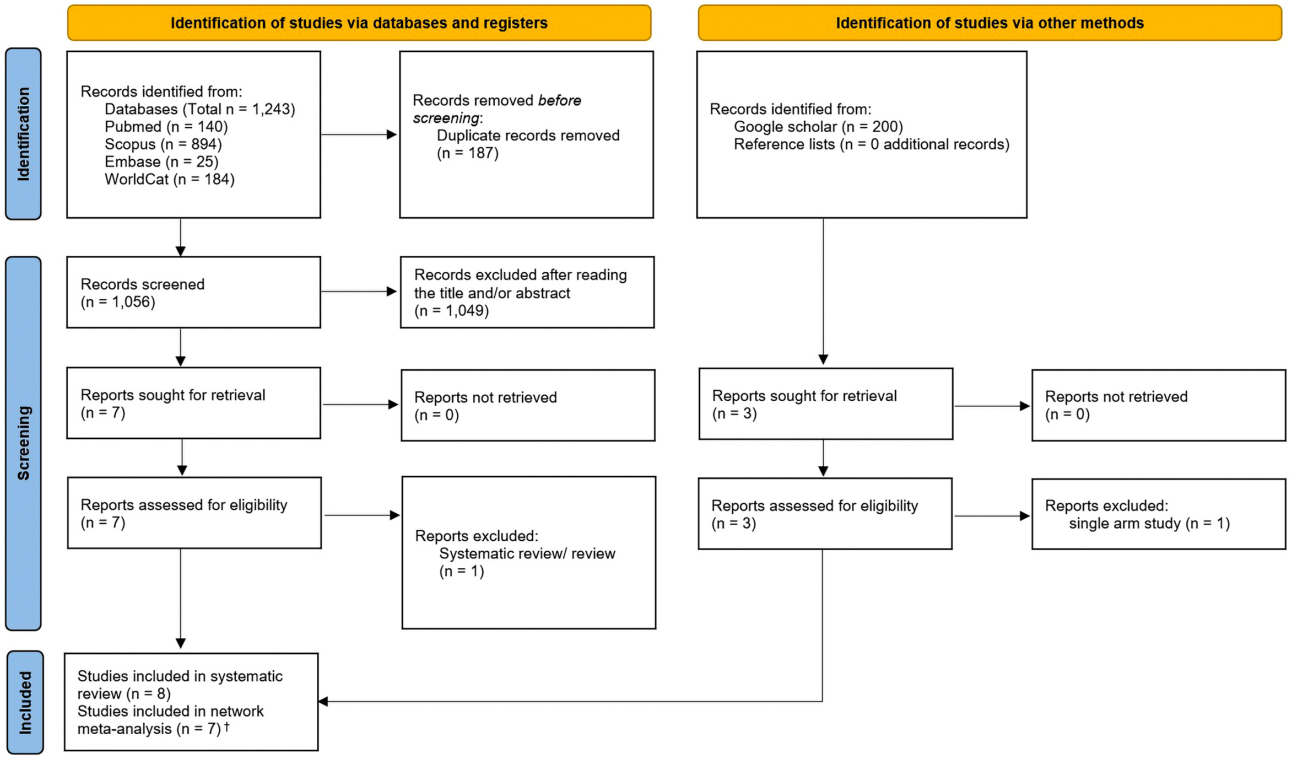


Figure 1 PRISMA 2020 flow diagram. †one study excluded from NMA due to significant local inconsistency discovered during node-splitting analysis

After the removal of duplicates and subsequent screening of titles and abstracts, a total of 10 reports were then sought for full text eligibility assessment. Upon detailed review, two studies were excluded: one review article and one single arm study. Consequently, eight studies met the inclusion criteria for the systematic review. However, to maintain strict methodological and statistical consistency within the quantitative analysis, the final core NMA model synthesized seven *in vitro* studies. The single *in vivo* report was not excluded during the initial screening because it fully satisfied our baseline clinical eligibility criteria; however, it was systematically transitioned to a dedicated sensitivity analysis framework. This decision was mathematically driven by the node-splitting analysis, which identified that its divergent methodology introduced significant local inconsistency into the full network, which was successfully resolved upon its isolation.

Characteristics of the Included Studies

A total of eight studies (seven *in vitro* and one *in vivo*) were included in this systematic review, providing a cumulative sample size of 712 interproximal measurement units. Of these, seven studies were ultimately included in the quantitative network meta-analysis (NMA), whereas one study was excluded from the NMA synthesis due to significant local inconsistency detected during node-splitting analysis. The extracted data and specific IPR protocols for each study are summarized in Table 1. Key parameters include study design, intervention groups, sample size per group, operational speed, and cooling conditions. Furthermore, the table reports the primary outcome—mean intrapulpal temperature rise ($\Delta T \pm SD$)—along with the specific measurement instruments included Type J/Type K thermocouples and a thermal camera.

Table 1 Characteristics and quantitative findings of the included studies.

Study (Study Type, Year)	Intervention Group (Actual Device Used)	Interproximal measurement units (n)	Speed	Cooling Condition	Measurement Device	Mean D
Amuk, *et al*. [12] (*In vitro*, 2019)	Disc (Perforated diamond disc)	n = 30 (10 Max. lateral incisors, 10 Mand. canines, 10 Mand. incisors)	Low speed (Micromotor)	Without coolant	Thermal camera (FLIR E60)	6.20 ± 1.78
	Rotary TC (Tungsten carbide bur)	n = 30 (10 Max. lateral incisors, 10 Mand. canines, 10 Mand. incisors)	High speed (Air-rotor)	Without coolant		7.40 ± 2.49
	Rotary (Diamond bur)	n = 30 (10 Max. lateral incisors, 10 Mand. canines, 10 Mand. incisors)	High speed (Air-rotor)	Water coolant		3.95 ± 0.85
	Rotary (Diamond bur)	n = 30 (10 Max. lateral incisors, 10 Mand. canines, 10 Mand. incisors)	High speed (Air-rotor)	Without coolant		6.03 ± 1.22
Banga, *et al*. [4] (*In vivo*, 2020)	Hand (Metal hand strip)	n = 17 (Max. & Mand. premolars)	Manual	Without coolant	Thermocouple (Type K)	0.53 ± 0.18
	Osc (IPR kit)	n = 17 (Max. & Mand. premolars)	Oscillating system	Without coolant		1.22 ± 0.19
	Rotary TC (Tungsten carbide bur)	n = 17 (Max. & Mand. premolars)	High speed (Air-rotor)	Water coolant		2.09 ± 0.52

Table 1 Characteristics and quantitative findings of the included studies. (continued)

Study (Study Type, Year)	Intervention Group (Actual Device Used)	Interproximal measurement units (n)	Speed	Cooling Condition	Measurement Device	Mean D
Baysal, *et al.* [11] (*In vitro*, 2007)	Hand (Metal strip)	n = 30 (10 Mand. incisors, 10 Mand. canines, 10 Mand. premolars)	Manual	Without coolant	Thermocouple (Type J)	0.69 ± 1.37‡
	Disc (Perforated disc)	n = 30 (10 Mand. incisors, 10 Mand. canines, 10 Mand. premolars)	Low speed (Micromotor)	Without coolant		2.91 ± 1.73‡
	Rotary TC (Tungsten carbide bur)	n = 30 (10 Mand. incisors, 10 Mand. canines, 10 Mand. premolars)	High speed (Air-rotor)	Without coolant		4.17 ± 1.96‡
Dara, *et al.* [5] (*In vitro*, 2023)	Hand (Metal strip)	n = 21 (Premolars)	Manual	Without coolant	Thermocouple (Type K)	2.52 ± 0.43
	Disc (Diamond disc)	n = 21 (Premolars)	Low speed (Micromotor)	Without coolant		4.31 ± 0.46
	Rotary (Diamond bur)	n = 21 (Premolars)	High speed (Air-rotor)	Without coolant		4.02 ± 0.46

Table 1 Characteristics and quantitative findings of the included studies. (continued)

Study (Study Type, Year)	Intervention Group (Actual Device Used)	Interproximal measurement units (n)	Speed	Cooling Condition	Measurement Device	Mean D
Omer and Sanea [6] (*In vitro*, 2019)	Hand (Manual strip)	n = 13 (Premolars)	Manual	Without coolant	Thermocouple (Type K)	0.27 ± 0.16
	Disc (Diamond disc)	n = 13 (Premolars)	Low speed (Micromotor)	Water coolant		0.51 ± 0.50
	Disc (Diamond disc)	n = 26 (Premolars)	Low speed (Micromotor)	Without coolant		1.07 ± 0.69‡
	Osc (IPR kit)	n = 13 (Premolars)	Oscillating system	Water coolant		0.46 ± 0.68
	Osc (IPR kit)	n = 26 (Premolars)	Oscillating system	Without coolant		0.56 ± 0.40‡
Omer and Sanea [6] (*In vitro*, 2019)	Rotary (Diamond bur)	n = 13 (Premolars)	High speed (Air-rotor)	Water coolant	Thermocouple (Type K)	0.66 ± 0.93
	Rotary (Diamond bur)	n = 26 (Premolars)	High speed (Air-rotor)	Without coolant		1.43 ± 0.94‡
Pereira, *et al.* [15] (*In vitro*, 2014)	Hand (Metal strip)	n = 39† (13 Mand. incisors, 13 Mand. premolars, 13 Mand. molars)	Manual	Without coolant	Thermocouple (Type J)	1.04 ± 0.33‡
	Disc (Perforated disc)	n = 39† (13 Mand. incisors, 13 Mand. premolars, 13 Mand. molars)	Low speed (Micromotor)	Without coolant		2.57 ± 0.32‡

Table 1 Characteristics and quantitative findings of the included studies. (continued)

Study (Study Type, Year)	Intervention Group (Actual Device Used)	Interproximal measurement units (n)	Speed	Cooling Condition	Measurement Device	Mean D
Sehgal, *et al.* [13] (*In vitro*, 2019)	Hand (Diamond strip)	n = 20† (Premolars)	Manual	Without coolant	Thermocouple (Type J)	2.80 ± 0.41
	Rotary (Diamond bur)	n = 20† (Premolars)	Low speed (Micromotor)	Water coolant		1.65 ± 0.81
	Rotary (Diamond bur)	n = 20† (Premolars)	Low speed (Micromotor)	Without coolant		3.50 ± 0.95
	Rotary (Diamond bur)	n = 20† (Premolars)	High speed (Air-rotor)	Water coolant		1.90 ± 1.07
Voodi, *et al.* [14] (*In vitro*, 2021)	Hand (Manual strip)	n = 20 (Premolars)	Manual	Without coolant	Thermocouple (Type K)	1.39 ± 0.30
	Disc (Diamond disc)	n = 20 (Premolars)	Low speed (Micromotor)	Water coolant		1.34 ± 0.78
	Disc (Diamond disc)	n = 20 (Premolars)	Low speed (Micromotor)	Without coolant		4.31 ± 1.48
Voodi, *et al.* [14] (*In vitro*, 2021)	Rotary TC (Tungsten carbide bur)	n = 20 (Premolars)	High speed (Air-rotor)		Thermocouple (Type K)	0.55 ± 0.30
	Rotary TC (Tungsten carbide bur)	n = 20 (Premolars)	High speed (Air-rotor)			3.95 ± 1.84

Max.: Maxillary; Mand.: Mandibular.

†For Pereira, *et al*. [15] and Sehgal, *et al*. [13], the values represent the number of interproximal surfaces/readings (78 surfaces from 39 teeth and 80 surfaces from 40 teeth, respectively) as reported in the primary studies for statistical analysis.

‡Pooled Data: Values for Baysal, *et al*. [11], Omer and Sanea [6], and Pereira, *et al*. [15] represent weighted means and pooled standard deviations derived from their respective subgroups (e.g., different speeds or tooth categories).

Risk of Bias Assessment

The risk of bias assessment for the included studies is summarized in Table 2. The overall risk of bias across the studies ranged from low to moderate. For the seven *in vitro* studies, the QUIN tool was used to evaluate twelve criteria. Most studies were categorized as having a low to medium risk of bias (>50% score). Common strengths included clearly stated aims and detailed explanations of the methodology. However, some concerns were noted regarding the inability to blind operators to the instrument used during the IPR procedure. The *in vivo* study was assessed using the Cochrane RoB 2 tool and was judged as a low risk or some concerns. Similar to the *in vitro* studies, operator blinding was not feasible. Furthermore, the *in vivo* study showed a low risk of bias in the domains of missing outcome data and selection of the reported results. The interreviewer agreement for the risk of bias assessment was high, with a Cohen's Kappa coefficient of 0.85, indicating strong reliability between the assessors. No studies were excluded based on the risk of bias assessment, as all provided sufficient data for the NMA.

Network Geometry

Figure 2 displays the network of evidence for the 11 IPR protocols evaluated in this study. Each node in the diagram represents a specific intervention, with the node size being proportional to the total sample size included for that protocol. The lines connecting the nodes represent direct head-to-head comparisons, and their thickness is proportional to the number of studies available for each pair. The network is fully connected with no isolated nodes, which allows for the estimation of both direct and indirect evidence across all protocols.

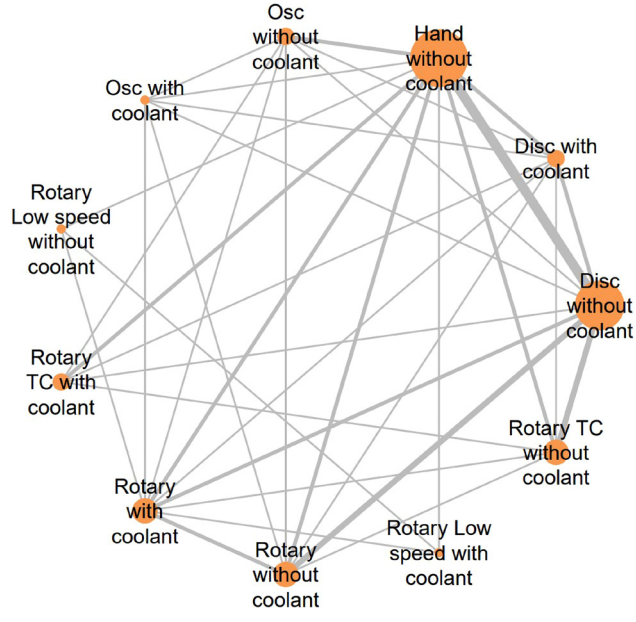


Figure 2 Network geometry of the 11 IPR protocols.

Table 2 Summary of risk of bias assessment of included studies.

Study	Study Type	Assessment Tool	Score (%) / Judgment	Overall Risk of Bias
Amuk et al. [12]	*In vitro*	QUIN	83.30%	Low risk
Banga et al. [4]	*In vivo*	RoB 2	Some concerns	Medium risk†
Baysal et al. [11]	*In vitro*	QUIN	70.80%	Low risk
Dara et al. [5]	*In vitro*	QUIN	75.00%	Low risk
Omer and Sanea [6]	*In vitro*	QUIN	75.00%	Low risk
Pereira et al. [15]	*In vitro*	QUIN	83.30%	Low risk
Sehgal et al. [13]	*In vitro*	QUIN	83.30%	Low risk
Voodi et al. [14]	*In vitro*	QUIN	75.00%	Low risk

† 'Some concerns' in RoB 2 is interpreted as moderate/medium risk in the context of systematic reviews.

Assessment of Inconsistency

Local inconsistency within the network was evaluated using the node-splitting method, which allows for the comparison of direct and indirect evidence for each specific node. In the initial analysis of the full network, significant local inconsistency was identified. Specifically, the comparison between rotary TC with coolant and disc without coolant exhibited a substantial discrepancy between direct and indirect evidence (P = 0.001075; Supplementary Figure S1).

The presence of this significant inconsistency indicated that the pooled network estimates were likely influenced by study heterogeneity or an outlier, which could potentially bias the final results and treatment rankings. Consequently, a detailed investigation was conducted to identify the source of this conflict, prompting a sensitivity analysis (as detailed in Sensitivity Analysis). This procedure ensured that the final results reported in this study were derived from a stable and consistent network model, thereby providing more reliable estimates of the treatment effects.

Sensitivity Analysis

To address the local inconsistency identified in the full network, a sensitivity analysis was conducted by excluding the single *in vivo* study due to its divergent methodology. Following this exclusion, the refined network comprised 7 studies with 661 interproximal measurement units. Re-evaluation using the node-splitting method confirmed that the previously identified inconsistency was resolved, with all comparison nodes demonstrating agreement between direct and indirect evidence ($p > 0.05$). Despite this exclusion, the network still retained all 11 standardized intervention categories. When directly compared against the primary 8-study network, the relative hierarchy of the treatment rankings remained highly consistent, with only minor ranking shifts observed specifically within the oscillating system protocols, while rotary tungsten carbide with coolant consistently maintained the top rank. Furthermore, a substantial, near-total overlap was observed in the 95% credible intervals between both models, confirming the high stability and robustness of our findings.

Network Meta-Analysis Results

The NMA was performed using the refined dataset (excluding the single *in vivo* study) to evaluate the thermal safety of the 11 IPR protocols. A subgroup analysis based on tooth type was not feasible due to the disproportion of tooth categories across the included studies; thus, the results represent the pooled thermal effects across all tooth types. The overall findings are summarized in the league table (Table 3) and the forest plot (Figure 3).

Compared to the control group (hand without coolant), three specific protocols demonstrated a statistically significant increase in intrapulpal temperature: disc without coolant, rotary TC without coolant, and rotary without coolant. In contrast, protocols utilizing water coolant, oscillating systems (with or without coolant), and rotary low speed without coolant did not show a statistically significant temperature increase relative to the control.

Direct comparisons between identical instruments used with and without water cooling revealed significant thermal differences for specific protocols. Rotary TC exhibited the most substantial reduction in heat when used with coolant (MD 3.85; 95% CrI: 2.34, 5.39). Significant cooling effects were also observed for the disc (MD 1.65; 95% CrI: 0.63, 2.74) and rotary (MD 1.65; 95% CrI: 0.58, 2.70) protocols. However, for the oscillating system, the thermal difference between the cooled and non-cooled versions was not statistically significant (MD 0.10; 95% CrI: -1.56, 1.76).

Table 3 League table of relative effectiveness of the 11 IPR methods on intrapulpal temperature changes.

Disc with coolant	1.65 (0.63, 2.74)*	-0.07 (-1.10, 0.98)	0.22 (-1.29, 1.75)	0.32 (-1.16, 1.82)	-0.91 (-2.66, 0.91)	0.95 (-0.82, 2.77)	-1.08 (-2.60, 0.40)	2.77 (1.51, 4.02)*	-0.28 (-1.48, 0.96)	1.37 (0.19, 2.58)*
	Disc without coolant	-1.72 (-2.45, -1.02)*	-1.43 (-2.86, -0.06)*	-1.33 (-2.73, 0.02)	-2.56 (-4.17, -0.94)*	-0.71 (-2.34, 0.93)	-2.73 (-4.19, -1.35)*	1.11 (0.09, 2.10)*	-1.93 (-2.92, -0.97)*	-0.28 (-1.20, 0.60)
		Hand without coolant	0.29 (-1.09, 1.69)	0.39 (-0.98, 1.76)	-0.84 (-2.33, 0.71)	1.01 (-0.50, 2.57)	-1.01 (-2.43, 0.36)	2.83 (1.81, 3.84)*	-0.21 (-1.15, 0.75)	1.44 (0.51, 2.36)*
			Osc with coolant	0.10 (-1.56, 1.76)	-1.13 (-3.10, 0.88)	0.72 (-1.25, 2.74)	-1.30 (-3.19, 0.56)	2.54 (0.93, 4.15)*	-0.50 (-1.98, 0.99)	1.14 (-0.31, 2.62)
				Osc without coolant	-1.23 (-3.17, 0.75)	0.62 (-1.33, 2.63)	-1.40 (-3.28, 0.44)	2.44 (0.87, 4.00)*	-0.60 (-2.04, 0.87)	1.05 (-0.39, 2.48)
					Rotary Low speed with coolant	1.86 (0.14, 3.56)*	-0.18 (-2.23, 1.82)	3.67 (1.88, 5.41)*	0.63 (-0.93, 2.16)	2.28 (0.56, 3.95)*
						Rotary Low speed without coolant	-2.03 (-4.10, -0.03)*	1.82 (0.01, 3.58)*	-1.23 (-2.79, 0.32)	0.42 (-1.30, 2.11)
							Rotary TC with coolant	3.85 (2.34, 5.39)*	0.80 (-0.76, 2.42)	2.45 (0.91, 4.03)*
								Rotary TC Without coolant	-3.05 (-4.22, -1.83)*	-1.40 (-2.54, -0.23)*
									Rotary with coolant	1.65 (0.58, 2.70)*
										Rotary without coolant

Results are expressed as mean differences (MD) and 95% credible intervals (95% CrIs). Comparisons should be read from left to right, with the estimate located at the intersection of the column- and row-defining interventions. A negative MD value (< 0) indicates that the row intervention results in a lower intrapulpal temperature rise than the column intervention. * Statistically significant difference (95% CrI does not include zero).

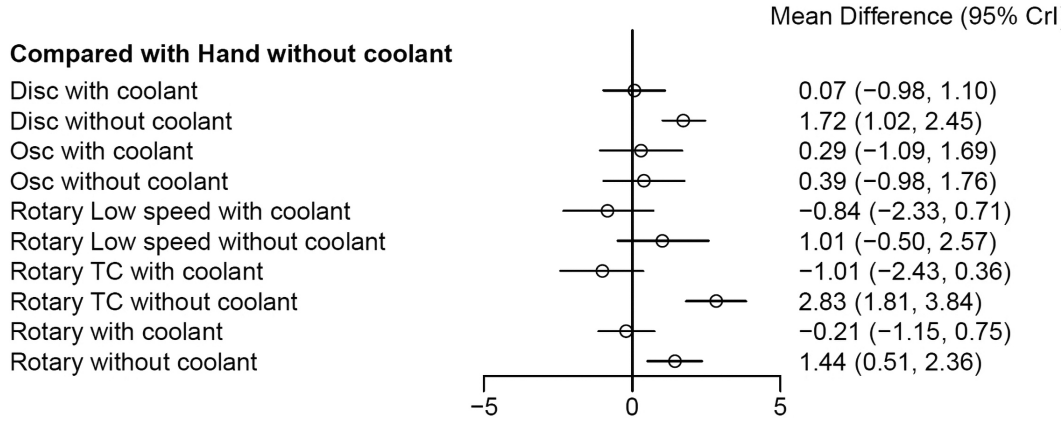


Figure 3 Forest plot of the NMA showing the mean differences in intrapulpal temperature rise of all IPR protocols compared to hand without coolant.

Treatment Ranking

The relative thermal safety of the 11 IPR protocols was determined using Surface Under the Cumulative Ranking (SUCRA) values (Table 4). Higher SUCRA percentages represent a greater probability of the protocol being the least intrapulpal temperature rise (Figure 4). Based on the ranking analysis, rotary TC with coolant was identified as the least intrapulpal temperature rise (SUCRA 91.56%), followed by rotary low speed with coolant (SUCRA 87.30%) and rotary with coolant (SUCRA 72.32%). Hand without coolant (63.79%) and disc with coolant (61.26%) also demonstrated favorable safety profiles. However, despite these numerical differences in SUCRA values, the differences among these top ranked protocols were not statistically significant when compared to the hand without coolant control or even among themselves (Table 3). This indicates that these five protocols offer comparable clinical thermal safety, suggesting that any of these methods could be utilized with similar safety outcomes. Furthermore, Oscillating systems showed consistent safety rankings regardless of coolant use (SUCRA 53.74% with coolant and 50.25% without coolant). The thermal difference between the cooled and non-cooled versions of the oscillating system was statistically non-significant (MD 0.10; 95% CrI: -1.56, 1.76).

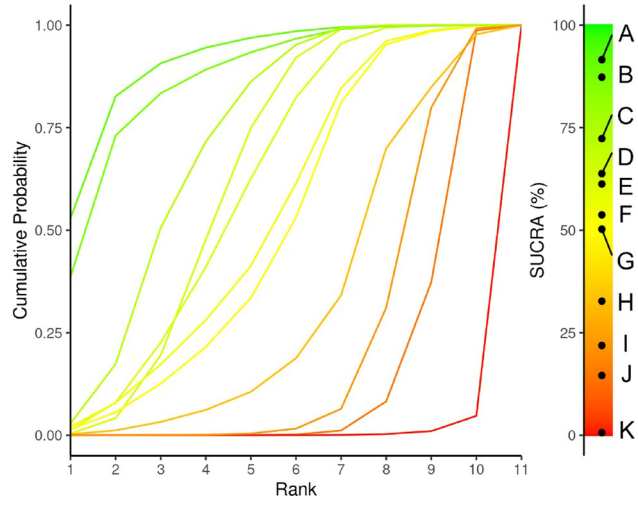


Figure 4 SUCRA plot for the 11 IPR protocols. Due to space limitations, protocols are labeled in descending order of thermal safety (from lowest to highest probability of intrapulpal temperature rise during IPR procedures) as follows: (A) Rotary TC with coolant; (B) Rotary low speed with coolant; (C) Rotary with coolant; (D) Hand without coolant; (E) Disc with coolant; (F) Osc with coolant; (G) Osc without coolant; (H) Rotary Low speed without coolant; (I) Rotary without coolant; (J) Disc without coolant; and (K) Rotary TC without coolant.

Table 4 SUCRA rankings and probabilities of the 11 IPR protocols for intrapulpal temperature rise.

Treatment	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6	Rank 7	Rank 8	Rank 9	Rank 10	Rank 11	SUCRA
Disc with coolant	0.01	0.07	0.15	0.18	0.22	0.20	0.13	0.04	0.00	0.00	0.00	61.26
Disc without coolant	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.07	0.29	0.61	0.01	14.57
Hand without coolant	0.00	0.04	0.15	0.28	0.27	0.17	0.07	0.01	0.00	0.00	0.00	63.79
Osc with coolant	0.02	0.06	0.09	0.11	0.13	0.20	0.23	0.12	0.03	0.01	0.00	53.74
Osc without coolant	0.01	0.04	0.07	0.09	0.12	0.20	0.28	0.14	0.03	0.01	0.00	50.25
Rotary Low speed with coolant	0.39	0.34	0.10	0.06	0.04	0.03	0.02	0.01	0.00	0.00	0.00	87.30
Rotary Low speed without coolant	0.00	0.01	0.02	0.03	0.04	0.08	0.15	0.36	0.15	0.13	0.02	32.70
Rotary TC with coolant	0.53	0.30	0.08	0.04	0.02	0.02	0.01	0.00	0.00	0.00	0.00	91.56
Rotary TC without coolant	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.95	0.61
Rotary with coolant	0.03	0.14	0.33	0.21	0.15	0.09	0.04	0.01	0.00	0.00	0.00	72.32
Rotary without coolant	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.25	0.49	0.19	0.01	21.89

In contrast, most protocols performed without water cooling were consistently ranked lower and demonstrated a statistically significant increase in temperature relative to the control. Rotary without coolant (SUCRA 21.89%) and disc without coolant (SUCRA 14.57%) showed high probability of intrapulpal temperature rise during IPR procedures. Rotary TC without coolant was identified as the highest intrapulpal temperature rise, yielding the lowest SUCRA value of 0.61%.

Certainty of Evidence

The certainty of evidence was evaluated through the CINeMA framework. Overall, the confidence ratings ranged from moderate to high. High confidence was achieved in several key comparisons, including hand without coolant versus disc without coolant and rotary without coolant, as well as rotary with coolant versus rotary TC without coolant. For the remaining comparisons, the evidence was primarily downgraded to moderate confidence due to imprecision, particularly in protocols involving oscillating systems that exhibited wide intervals in treatment estimates. Importantly, this lower certainty reflects a current scarcity of published data on oscillating systems rather than a demonstrated clinical hazard. This distinction underscores that the downgrading stems strictly from statistical uncertainty due to the limited number of available studies, rather than a compromise in the mechanical safety inherently provided by the tool's design. Additionally, some concerns regarding heterogeneity were identified in comparisons between various motorized instruments, reflecting the experimental variability across the studies. Incoherence was generally not a concern across the network, except for the comparison between non-cooled oscillating systems and water-cooled rotary burs.

Publication Bias

Publication bias was not formally assessed using funnel plots or statistical tests for asymmetry (e.g., the Egger's test) because the total number of studies included in this NMA was fewer than ten [25].

Discussion

This NMA establishes a comprehensive hierarchy of thermal safety for 11 IPR protocols based on a robust model. Our findings identify rotary TC with coolant demonstrating the lowest probability of intrapulpal temperature increase. However, the differences among the top-ranked protocols (i.e., rotary TC with coolant, rotary low-speed with coolant, rotary with coolant, hand without coolant, and disc with coolant) were not statistically significant. This indicates the existence of a safety cluster where these methods demonstrated no statistically significant differences in thermal elevation among themselves. However, it is crucial to note that the absence of statistical significance does not definitively imply absolute clinical equivalence. Given the limited sample sizes and wide credible intervals in certain network links, this lack of significant difference should be interpreted with caution rather than as a proof of complete thermal parity. Conversely, dry mechanical stripping poses a significant thermal hazard. Rotary TC without coolant was identified as the highest-risk protocol for intrapulpal temperature increase, alongside other non-cooled motorized instruments such as disc without coolant and rotary without coolant.

In the absence of coolant, Rotary TC without coolant exhibited the highest temperature rise, significantly higher than Rotary without coolant and disc without coolant. This is driven by both material properties and cutting mechanics. Unlike diamond instruments, which abrade the enamel and generate heat through continuous friction across a broad surface area, TC burs operate via a shearing mechanism using high-speed metallic flutes. When used dry, the high thermal conductivity of the TC metal alloy rapidly transfers the intense frictional heat from this shearing action directly into the pulpal chamber. Conversely, when water coolant was introduced, Rotary TC transitioned to the lowest probability of intrapulpal temperature increase. This response is directly related to the bur's flute geometry, which acts as highly efficient internal irrigation channels. These flutes facilitate superior coolant circulation directly to the cutting edge and immediate clearance of enamel chips. Diamond instruments are highly prone to clogging, where debris becomes trapped between the abrasive grits [26]. This clogging creates a smear layer on the tool's surface that increases baseline friction and obstructs the cooling efficiency of water, explaining why Rotary with coolant did not achieve the same level of thermal stability as Rotary TC with coolant [27].

When comparing low-speed and high-speed instruments in non-coolant situations, the significant temperature rise associated with non-cooled diamond discs challenges the common assumption that low speed instruments are inherently cooler. Despite operating at lower rotational speeds, the disc without coolant generated a higher mean temperature rise than rotary without coolant. This phenomenon can be attributed to the physical dimensions of the instrument. Discs possess a larger surface contact area compared to cylindrical or tapered burs. This expansive contact generates continuous and extensive friction against the enamel surface [11]. Furthermore, low speed micromotors typically deliver higher torque. This mechanical characteristic often prompts clinicians to apply greater and prolonged pressure to achieve the

desired amount of enamel reduction, which leads to rapid heat accumulation [28].

The consistent safety profile of oscillating stripping systems maintained favorable rankings regardless of whether water coolant was applied. The thermal difference between the cooled and non-cooled oscillating protocols was statistically non-significant. This thermal stability is attributed to their motion dynamics. Unlike the continuous 360-degree rotation of burs or discs, the reciprocating or back-and-forth motion of oscillating systems ensures intermittent tooth contact, thereby preventing the continuous accumulation of heat [6]. Consequently, oscillating systems present a safe motorized alternative for IPR, particularly in clinical scenarios where maintaining a dry working field is preferred for optimal visibility or moisture control. While this NMA relies on *in vitro* data, these findings must be interpreted within a biological context. Clinically, active pulpal microcirculation and the heat-dissipating capacity of periodontal tissues naturally buffer against thermal stress, suggesting that *in vitro* models may slightly overestimate absolute temperature rises [29]. However, anatomical variations influence thermal vulnerability. For instance, mandibular incisors possess minimal residual dentin thickness compared to premolars or molars, reducing their natural insulation. Consequently, heat transfers to the pulp more rapidly in these anterior teeth [12].

Furthermore, modern biological evidence indicates that pulpal protection should be evaluated based on cellular stress rather than solely the traditional 5.5°C threshold [7]. Although the dental pulp initiates a defense response via heat shock protein 70 (HSP70) during thermal stress, prolonged heat can overwhelm this mechanism and trigger apoptosis [9]. This biological risk is further compounded by instrument wear. Abrasive tools can lose cutting efficiency within minutes; as instruments dull, clinicians often apply greater pressure, which significantly increases injurious heat conduction [30]. Therefore, selecting high SUCRA, water-cooled protocols is essential not only to prevent immediate necrosis but also to preserve the long term regenerative capacity of the pulp-dentin complex.

Continuous water cooling is essential to mitigate thermal risks during motorized IPR. Water acts as a heat sink, dissipating frictional energy at the tooth surface before it reaches the pulp [10]. Although aerosol generation is a major concern in dental practice today, performing motorized IPR without coolant carries a high risk of pulpal necrosis and is not clinically viable. Rather than using dry instrumentation, clinicians should combine continuous water cooling with high volume suction to safely manage both thermal and infection risks [31].

When comparing our findings with the existing literature, our results are in strong agreement with previous studies [6, 13], which consistently advocate that continuous water cooling and controlled speeds are essential for thermal safety during IPR. Similarly, our quantitative results corroborate earlier reports warning against the dangerous temperature rises associated with dry protocols [11, 12]. However, this network meta-analysis advances the current evidence base by moving beyond traditional pairwise comparisons, providing a comprehensive probability ranking of 11 distinct protocols simultaneously to establish a clearer clinical hierarchy.

Several limitations of this NMA should be acknowledged. First, the small number of included studies precluded a formal quantitative assessment of publication bias. Second, the reliance on *in vitro* data may overestimate clinical thermal risks, as laboratory models lack the physiological thermoregulation provided by pulpal microcirculation

and periodontal tissues. Third, there was significant heterogeneity across studies regarding tooth type and residual dentin thickness, both of which act as critical biological insulators. Fourth, the included studies utilized different temperature measurement techniques and devices—such as variations in internal thermocouple types (e.g., K-type or T-type) and the application of external infrared thermographic cameras. These methodological differences in sensor positioning, calibration, and recording precision can inherently influence the absolute temperature values captured. Therefore, the quantitative thermal estimates should be interpreted with caution. Moderate certainty in oscillating systems is primarily attributed to the limited number of available studies, not due to inherent mechanical safety concerns. Furthermore, this analysis highlights a major gap in the literature: the lack of *in vivo* clinical trials. This became evident when the inclusion of the single available *in vivo* study caused significant network inconsistency, necessitating its exclusion. This inconsistency indicates that physiological factors in the oral cavity alter thermal dynamics differently than laboratory models. Therefore, future research should prioritize *in vivo* studies to validate these safety rankings in clinical settings.

Clinical Implications

Based on the quantitative findings and biological contexts discussed, the practical recommendations for safely performing motorized IPR can be distinctly structured as follows:

What clinicians should do:

- **Utilize continuous water cooling** as a mandatory protocol for all rotary and disc-based IPR to act as an effective heat sink.
- **Select oscillating systems** if maintaining a dry working field is clinically necessary, as their intermittent reciprocating motion naturally prevents dangerous heat accumulation.
- **Combine water coolant with high-volume suction** to safely and simultaneously manage both pulpal thermal risks and aerosol generation.

What clinicians should avoid:

- **Strictly avoid dry mechanical stripping** with continuous high-speed rotary burs (especially tungsten carbide) or diamond discs, as these represent the most significant thermal hazards capable of causing irreversible pulpal damage.
- **Avoid applying excessive or prolonged pressure** against the enamel, particularly when abrasive instruments begin to wear or dull, as this exponentially increases frictional heat conduction into the pulp chamber.

Conclusions

Based on the included *in vitro* studies, this NMA demonstrates that the rotary TC with coolant, rotary low speed with coolant, rotary with coolant, disc with coolant, and hand without coolant protocols provide comparable thermal safety during IPR. Continuous water cooling remains the most critical factor for minimizing intrapulpal temperature rise during motorized IPR. In contrast, performing motorized IPR without coolant poses a significant thermal risk. Specifically, the rotary TC without coolant protocol generates the highest temperature rise and should be avoided. When a dry working field is clinically necessary, the Osc without coolant and hand without coolant protocols serve as favorable alternatives.

Acknowledgments

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Funding sources

This research received no external funding

References

1. Livas C, Jongsma AC, Ren Y. Enamel reduction techniques in orthodontics: a literature review. ***Open Dent J***. 2013 Oct;7:146-151. doi: 10.2174/1874210601307010146.
2. Zachrisson BU, Minster L, Ogaard B, Birkhed D. Dental health assessed after interproximal enamel reduction: caries risk in posterior teeth. ***Am J Orthod Dentofacial Orthop***. 2011 Jan;139(1):90-98. doi: 10.1016/j.ajodo.2010.09.002.
3. Chudasama D, Sheridan JJ. Guidelines for contemporary air-rotor stripping. ***J Clin Orthod***. 2007 Jun;41(6):315-320.
4. Banga K, Arora N, Kannan S, Singh AK, Malhotra A. Evaluation of temperature rise in the pulp during various IPR techniques-an in vivo study. ***Prog Orthod***. 2020 Nov;21(1):40. doi: 10.1186/s40510-020-00340-6.
5. Dara A, Datla PKV, Priya CVP, Manda A, Kandikatla P, Polineti P. Evaluation and comparison of thermal changes in the pulp chamber in different Inter proximal reduction techniques: an in-vitro study. ***Uttar Pradesh J Zool***. 2023;44(24):303-310. doi: 10.56557/UPJOZ/2023/v44i243843.
6. Omer ABA, Sanea JA. A Comparison of thermal changes among four different interproximal reduction systems in orthodontics. ***J Contemp Dent Pract***. 2019 Jun;20(6):738-742.
7. Zach L, Cohen G. Pulp response to externally applied heat. ***Oral Surg Oral Med Oral Pathol***. 1965 Apr; 19:515-530. doi: 10.1016/0030-4220(65)90015-0.
8. Kwon SJ, Park YJ, Jun SH, Ahn JS, Lee IB, Cho BH, *et al.* Thermal irritation of teeth during dental treatment procedures. ***Restor Dent Endod***. 2013 Aug;38(3):105-112. doi: 10.5395/rde.2013.38.3.105.
9. Lau XE, Liu X, Chua H, Wang WJ, Dias M, Choi JJE. Heat generated during dental treatments affecting intrapulpal temperature: a review. ***Clin Oral Investig***. 2023 May;27(5):2277-2297. doi: 10.1007/s00784-023-04951-1.
10. Farah RI. Effect of cooling water temperature on the temperature changes in pulp chamber and at handpiece head during high-speed tooth preparation. ***Restor Dent Endod***. 2018 Dec;44(1):e3. doi: 10.5395/rde.2019.44.e3
11. Baysal A, Uysal T, Usumez S. Temperature rise in the pulp chamber during different stripping procedures. ***Angle Orthod***. 2007 May;77(3):478-482. doi: 10.2319/0003-3219(2007)077[0478:TRITPC]2.0.CO;2.
12. Gul Amuk N, Kurt G, Cakmak G, Er O. Evaluation of time-dependent temperature changes during different interdental stripping procedures by thermal imaging: an in vitro study. ***Oral Health Prev Dent***. 2019;17(6):591- 598. doi: 10.3290/j.ohpd.a43274.
13. Sehgal M, Sharma P, Juneja A, Kumar P, Verma A, Chauhan V. Effect of different stripping techniques on pulpal temperature: in vitro study. ***Dental Press J Orthod***. 2019 Jan-Feb;24(1):39-43. doi: 10.1590/2177-6709.24.1.039-043.oar.
14. Voodi S, Gorantla S, Muddada V, Lenka RR, Gurugubelli VK, Konathala SS. Evaluation of the temperature rise in the pulp chamber during different interproximal reduction procedures – an in vitro study. ***IJDSIR***. 2021 Mar;4(2):470-478.
15. d'Ornellas Pereira JC Jr, Weissheimer A, de Menezes LM, de Lima EM, Mezomo M. Change in the pulp chamber temperature with different stripping techniques. ***Prog Orthod***. 2014 Sep;15(1):55. doi: 10.1186/s40510-014-0055-8.
16. Kaewsirirat P, Chaweewannakorn C, Viwattanatipa N, Nanthavanich Saengfai N. Comparison of heat generation between manual metal strips and motor stripping discs for interproximal reduction: a systematic review and meta-analysis. ***Thai J Orthod***. 2025 May;15(1):56-67.
17. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, *et al.* The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. ***BMJ***. 2021 Mar;372:n71. doi: 10.1136/bmj.n71.
18. Hutton B, Catalá-López F, Moher D. The PRISMA statement extension for systematic reviews incorporating network meta-analysis: PRISMA-NMA. ***Med Clin (Barc)***. 2016 Sep;147(6):262-266. doi: 10.1016/j.medcli.2016.02.025.
19. Sheth VH, Shah NP, Jain R, Bhanushali N, Bhatnagar V. Development and validation of a risk-of-bias tool for assessing in vitro studies conducted in dentistry: The QUIN. ***J Prosthet Dent***. 2024 Jun;131(6):1038-1042. doi: 10.1016/j.prosdent.2022.05.019.

20. Sterne JAC, Savović J, Page MJ, Elbers RG, Blencowe NS, Boutron I, *et al*. RoB 2: a revised tool for assessing risk of bias in randomised trials. ***BMJ***. 2019 Aug;366:l4898. doi: 10.1136/bmj.l4898.
21. Owen RK, Bradbury N, Xin Y, Cooper N, Sutton A. MetaInsight: An interactive web-based tool for analyzing, interrogating, and visualizing network meta-analyses using R-shiny and netmeta. ***Res Synth Methods***. 2019 Dec;10(4):569-581. doi: 10.1002/jrsm.1373.
22. Nevill CR, Cooper NJ, Sutton AJ. A multifaceted graphical display, including treatment ranking, was developed to aid interpretation of network meta-analysis. ***J Clin Epidemiol***. 2023 May;157:83-91. doi: 10.1016/j.jclinepi.2023.02.016.
23. Singh J, Gsteiger S, Wheaton L, Riley RD, Abrams KR, Gillies CL, *et al*. Bayesian network meta-analysis methods for combining individual participant data and aggregate data from single arm trials and randomised controlled trials. ***BMC Med Res Methodol***. 2022 Jul;22(1):186. doi: 10.1186/s12874-022-01657-y.
24. Nikolakopoulou A, Higgins JPT, Papakonstantinou T, Chaimani A, Del Giovane C, Egger M, *et al*. CINeMA: An approach for assessing confidence in the results of a network meta-analysis. ***PLoS Med***. 2020 Apr;17(4):e1003082. doi: 10.1371/journal.pmed.1003082.
25. Page MJ, Higgins JPT, Sterne JAC. Chapter 13: Assessing risk of bias due to missing evidence in a meta-analysis [updated August 2024]. In: Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, *et al*, editors. Cochrane Handbook for Systematic Reviews of Interventions. Version 6.5. Cochrane, 2024. Available from: cochrane.org/handbook.
26. Ercoli C, Rotella M, Funkenbusch PD, Russell S, Feng C. In vitro comparison of the cutting efficiency and temperature production of 10 different rotary cutting instruments. Part I: Turbine. ***J Prosthet Dent***. 2009 Apr;101(4):248-261. doi: 10.1016/S0022-3913(09)60049-4.
27. Regev M, Judes H, Ben-Hanan U. Wear mechanisms of diamond coated dental burs. ***Tribol-Mater Surf Interfaces***. 2010;4(1):38-42. doi: 10.1179/175158310X12626998129798.
28. Thomas MS, Kundabala M. Pulp hyperthermia during tooth preparation: the effect of rotary--instruments, lasers, ultrasonic devices, and airborne particle abrasion. ***J Calif Dent Assoc***. 2012 Sep;40(9):720-731.
29. Runnacles P, Arrais CAG, Maucoski C, Coelho U, De Goes MF, Rueggeberg FA. Comparison of in vivo and in vitro models to evaluate pulp temperature rise during exposure to a Polywave® LED light curing unit. ***J Appl Oral Sci***. 2019 May;27:e20180480. doi: 10.1590/1678-7757-2018-0480.
30. Ciora E, Miron M, Bojoga D, Lungeanu D, Jivanescu A. Evaluation of the pulp chamber temperature during tooth veneer preparation using burs with different degrees of wear-a preliminary in vitro study. ***Dent J (Basel)***. 2023 Aug;11(8):197. doi: 10.3390/dj11080197.
31. Harrel SK, Molinari J. Aerosols and splatter in dentistry: a brief review of the literature and infection control implications. ***J Am Dent Assoc***. 2004 Apr;135(4):429-437. doi: 10.14219/jada.archive.2004.0207.

Supplementary Table S1 PRISMA 2020 Checklist.

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Page 1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page 2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Page 4
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Page 5
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Page 5
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Page 5
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Page 5
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Page 6
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Page 6

Supplementary Table S1 PRISMA 2020 Checklist. (continued)

Section and Topic	Item #	Checklist item	Location where item is reported
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Page 6
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Page 6
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Page 6
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Page 6
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Page 6
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	Page 6-7
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Page 6-7
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Page 6-7
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Page 6-7
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	Page 7

Supplementary Table S1 PRISMA 2020 Checklist. (continued)

Section and Topic	Item #	Checklist item	Location where item is reported
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Page 7
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Page 7
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Page 7
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Page 7
Study characteristics	17	Cite each included study and present its characteristics.	Page 8-12
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Page 13
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/ credible interval), ideally using structured tables or plots.	Page 8-12
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Page 13
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Page 14-15
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Page 14-15
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Page 14

Supplementary Table S1 PRISMA 2020 Checklist. (continued)

Section and Topic	Item #	Checklist item	Location where item is reported
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Page 16
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Page 16
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Page 19-21
	23b	Discuss any limitations of the evidence included in the review.	Page 19-21
	23c	Discuss any limitations of the review processes used.	Page 19-21
	23d	Discuss implications of the results for practice, policy, and future research.	Page 19-21
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Page 5
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Page 5
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Page 5
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Page 21
Competing interests	26	Declare any competing interests of review authors.	Page 21
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, *et al.* The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71. This work is licensed under CC BY 4.0. To view a copy of this license, visit https://creativecommons.org/licenses/by/4.0/

Supplementary Table S2 PRISMA 2020 for Abstracts Checklist.

Section and Topic	Item #	Checklist item	Reported (Yes/No)
TITLE			
Title	1	Identify the report as a systematic review.	Yes
BACKGROUND			
Objectives	2	Provide an explicit statement of the main objective(s) or question(s) the review addresses.	Yes
METHODS			
Eligibility criteria	3	Specify the inclusion and exclusion criteria for the review.	Yes
Information sources	4	Specify the information sources (e.g. databases, registers) used to identify studies and the date when each was last searched.	Yes
Risk of bias	5	Specify the methods used to assess risk of bias in the included studies.	Yes
Synthesis of results	6	Specify the methods used to present and synthesise results.	Yes
RESULTS			
Included studies	7	Give the total number of included studies and participants and summarise relevant characteristics of studies.	Yes
Synthesis of results	8	Present results for main outcomes, preferably indicating the number of included studies and participants for each. If meta-analysis was done, report the summary estimate and confidence/credible interval. If comparing groups, indicate the direction of the effect (i.e. which group is favoured).	Yes
DISCUSSION			
Limitations of evidence	9	Provide a brief summary of the limitations of the evidence included in the review (e.g. study risk of bias, inconsistency and imprecision).	No
Interpretation	10	Provide a general interpretation of the results and important implications.	Yes
OTHER			
Funding	11	Specify the primary source of funding for the review.	No
Registration	12	Provide the register name and registration number.	Yes

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, *et al.* The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71. This work is licensed under CC BY 4.0. To view a copy of this license, visit https://creativecommons.org/licenses/by/4.0/

Supplementary Table S4 Full Electronic Search Strategy.

Database	Search Strategy (Keywords & Boolean Operators)	Results
PubMed	("teeth s"[All Fields] OR "teeths"[All Fields] OR "tooth"[MeSH Terms] OR "tooth"[All Fields] OR "teeth"[All Fields] OR "tooth s"[All Fields] OR "tooths"[All Fields] OR ("teeth s"[All Fields] OR "teeths"[All Fields] OR "tooth"[MeSH Terms] OR "tooth"[All Fields] OR "teeth"[All Fields] OR "tooth s"[All Fields] OR "tooths"[All Fields]) OR "Human tooth"[All Fields] OR "Human teeth"[All Fields]) AND ("interproximal reduction"[All Fields] OR "proximal reduction"[All Fields] OR ("stripped"[All Fields] OR "stripping"[All Fields] OR "strippings"[All Fields]) OR "slenderization"[All Fields] OR "re-approximation"[All Fields] OR "coronoplasty"[All Fields] OR ("slice"[All Fields] OR "slice s"[All Fields] OR "sliced"[All Fields] OR "slices"[All Fields] OR "slicing"[All Fields]) OR ("mesio distal"[All Fields] AND ("reduction"[All Fields] OR "reductions"[All Fields])) OR (("hollywood"[All Fields] OR "hollywood s"[All Fields]) AND "trim"[All Fields]) OR "interproximal enamel reduction"[All Fields] OR "proximal stripping"[All Fields]) AND ("hot temperature"[MeSH Terms] OR ("hot"[All Fields] AND "temperature"[All Fields]) OR "hot temperature"[All Fields] OR "heat"[All Fields] OR ("temperature"[MeSH Terms] OR "temperature"[All Fields] OR "temperatures"[All Fields] OR "temperature s"[All Fields]) OR "pulp chamber"[All Fields] OR ("thermocouple"[All Fields] OR "thermocouples"[All Fields]) OR "thermal change"[All Fields] OR "temperature change"[All Fields])	140
Scopus	("tooth" OR "teeth" OR "Human tooth" OR "Human teeth") AND ("interproximal reduction" OR "proximal reduction" OR "stripping" OR "slenderization" OR "re-approximation" OR "coronoplasty" OR "slicing" OR "mesio-distal reduction" OR "hollywood trim" OR "interproximal enamel reduction" OR "proximal stripping") AND ("heat" OR "temperature" OR "pulp chamber" OR "thermocouple" OR "thermal change" OR "temperature change") (Search: **All Fields**)	894
Embase	(tooth OR OR teeth OR 'human tooth' OR 'human teeth') AND ('interproximal reduction' OR 'proximal reduction' OR stripping OR slenderization OR 're approximation' OR coronoplasty OR slicing OR 'mesio-distal reduction' OR 'hollywood trim' OR 'interproximal enamel reduction' OR 'proximal stripping') AND (heat OR temperature OR 'pulp chamber' OR thermocouple OR 'thermal change' OR 'temperature change')	25
WorldCat	ti:("tooth" OR "teeth") AND ti:("interproximal reduction" OR "IPR" OR "stripping") AND ti:("heat" OR "temperature change" OR "thermal change") (Format: **Thesis/Dissertation**)	184
Google Scholar	("Interproximal reduction" OR stripping OR IPR) AND (temperature OR heat) AND pulp (Screened: **First 200 results**)	200
	Total	1443

Supplementary Table S5 Detailed Data Extraction and Pooling Strategy.

Study	Intervention Group	interproximal measurement units (n)	Reported Data	Extraction / Pooling Strategy	Final Value for NMA
Amuk et al.	Disc (Dry)	Mixed sample of Maxillary Lateral Incisors, Mandibular Canines, and Mandibular Incisors (n=30)	Mean = 6.02, SD = 1.78	Direct Extraction: Reported mean for the total mixed group.	6.02 ± 1.78
	Rotary TC (Dry)	Mixed sample of Maxillary Lateral Incisors, Mandibular Canines, and Mandibular Incisors (n=30)	Mean = 7.04, SD = 2.49	Direct Extraction: Reported mean for the total mixed group.	7.04 ± 2.49
	Rotary (Dry)	Mixed sample of Maxillary Lateral Incisors, Mandibular Canines, and Mandibular Incisors (n=30)	Mean = 6.03, SD = 1.22	Direct Extraction: Reported mean for the total mixed group.	6.03 ± 1.22
	Rotary (Water-cooling)	Mixed sample of Maxillary Lateral Incisors, Mandibular Canines, and Mandibular Incisors (n=30)	Mean = 3.95, SD = 0.85	Direct Extraction: Reported mean for the total mixed group.	3.95 ± 0.85
Banga et al.	Hand (Dry)	Maxillary and Mandibular Premolars (n=17)	Mean = 0.53, SD = 0.18	Direct Extraction: Single tooth type used.	0.53 ± 0.18
	Osc (Dry)	Maxillary and Mandibular Premolars (n=17)	Mean = 1.22, SD = 0.19	Direct Extraction: Single tooth type used.	1.22 ± 0.19
	Rotary TC (Water-cooling)	Maxillary and Mandibular Premolars (n=17)	Mean = 2.01, SD = 0.52	Direct Extraction: Single tooth type used.	2.09 ± 0.52
Baysal et al.	Hand (Dry)	Subgroup 1: Incisors (n=10)	Mean = 1.21, SD = 1.48	Statistical Pooling: Weighted mean and pooled SD calculated from 3 subgroups.	0.69 ± 1.37
		Subgroup 2: Canines (n=10)	Mean = 1.03, SD = 1.30		
		Subgroup 3: Premolars (n=10)	Mean = -0.18, SD = 0.97		
	Disc (Dry)	Subgroup 1: Incisors (n=10)	Mean = 2.37, SD = 1.31	Statistical Pooling: Weighted mean and pooled SD calculated from 3 subgroups.	2.91 ± 1.73
		Subgroup 2: Canines (n=10)	Mean = 2.51, SD = 1.25		
		Subgroup 3: Premolars (n=10)	Mean = 3.84, SD = 2.21		

Supplementary Table S5 Detailed Data Extraction and Pooling Strategy. (continued)

Study	Intervention Group	interproximal measurement units (n)	Reported Data	Extraction / Pooling Strategy	Final Value for NMA
	Rotary TC (Dry)	Subgroup 1: Incisors (n=10)	Mean = 5.63, SD = 1.73	Statistical Pooling: Weighted mean and pooled SD calculated from 3 subgroups.	4.17 ± 1.96
		Subgroup 2: Canines (n=10)	Mean = 3.22, SD = 1.70		
		Subgroup 3: Premolars (n=10)	Mean = 3.65, SD = 1.67		
Dara et al.	Hand (Dry)	Premolars (n=21)	Mean = 2.52, SD = 0.43	Direct Extraction: Single tooth type used.	2.52 ± 0.43
	Disc (Dry)	Premolars (n=21)	Mean = 4.31, SD = 0.46	Direct Extraction: Single tooth type used.	4.31 ± 0.46
	Rotary (Dry)	Premolars (n=21)	Mean = 4.02, SD = 0.46	Direct Extraction: Single tooth type used.	4.02 ± 0.46
Omer and Sanea	Hand (Dry)	Premolars (n=13)	Mean = 0.27, SD = 0.16	Direct Extraction	0.27 ± 0.16
	Rotary (Dry) Speed 1	Premolars (n=13)	Mean = 1.91, SD = 0.77	Statistical Pooling: Weighted mean and pooled SD calculated from 2 subgroups	n = 26 1.43 ± 0.94
	Rotary (Dry) Speed 2	Premolars (n=13)	Mean = 0.95, SD = 0.86		
	Rotary (Water-cooling)	Premolars (n=13)	Mean = 0.66, SD = 0.93	Direct Extraction	0.66 ± 0.93
	Osc (Dry) Speed 1	Premolars (n=13)	Mean = 0.36, SD = 0.28	Statistical Pooling: Weighted mean and pooled SD calculated from 2 subgroups	n = 26 0.56 ± 0.40
	Osc (Dry) Speed 2	Premolars (n=13)	Mean = 0.76, SD = 0.41		
	Osc (Water-cooling)	Premolars (n=13)	Mean = 0.46, SD = 0.68	Direct Extraction	0.46 ± 0.68

Supplementary Table S5 Detailed Data Extraction and Pooling Strategy. (continued)

Study	Intervention Group	interproximal measurement units (n)	Reported Data	Extraction / Pooling Strategy	Final Value for NMA
	Disc (Dry) Speed 1	Premolars (n=13)	Mean = 1.37, SD = 0.75	Statistical Pooling: Weighted mean and pooled SD calculated from 2 subgroups	n = 26 1.07 ± 0.69
	Disc (Dry) Speed 2	Premolars (n=13)	Mean = 0.77, SD = 0.47		
	Disc (Water-cooling)	Premolars (n=13)	Mean = 0.51, SD = 0.50	Direct Extraction	0.51 ± 0.50
Pereira et al.	Hand (Dry)	Subgroup 1: Incisors (n=13)	Mean=1.24, SD=0.30	Statistical Pooling: Weighted mean and pooled SD calculated from 3 subgroups.	1.04 ± 0.33
		Subgroup 2: Premolars (n=13)	Mean=0.96, SD=0.39		
		Subgroup 3: Molars (n=13)	Mean=0.92, SD=0.18		
	Disc (Dry)	Subgroup 1: Incisors (n=13)	Mean=2.58, SD=0.27	Statistical Pooling: Weighted mean and pooled SD calculated from 3 subgroups.	2.57 ± 0.32
		Subgroup 2: Premolars (n=13)	Mean=2.64, SD=0.29		
		Subgroup 3: Molars (n=13)	Mean=2.48, SD=0.38		
Sehgal et al.	Hand (Dry)	Premolars (n=20)	Mean = 2.80, SD = 0.41	Direct Extraction: Single tooth type used.	2.80 ± 0.41
	Rotary (Low speed) (Dry)	Premolars (n=20)	Mean = 3.50, SD = 0.95	Direct Extraction: Single tooth type used.	3.50 ± 0.95
	Rotary (Low speed) (Water-cooling)	Premolars (n=20)	Mean = 1.65, SD = 0.81	Direct Extraction: Single tooth type used.	1.65 ± 0.81
	Rotary (Water-cooling)	Premolars (n=20)	Mean = 1.90, SD = 1.07	Direct Extraction: Single tooth type used.	1.90 ± 0.07
Voodi et al.	Hand (Dry)	Premolars (n=20)	Mean = 1.39, SD = 0.30	Direct Extraction: Single tooth type used.	1.39 ± 0.30
	Disc (Dry)	Premolars (n=20)	Mean = 4.31, SD = 1.48	Direct Extraction: Single tooth type used.	4.31 ± 1.48

Supplementary Table S5 Detailed Data Extraction and Pooling Strategy. (continued)

Study	Intervention Group	interproximal measurement units (n)	Reported Data	Extraction / Pooling Strategy	Final Value for NMA
	Disc (Water-cooling)	Premolars (n=20)	Mean = 1.34, SD = 0.78	Direct Extraction: Single tooth type used.	1.34 ± 0.78
	Rotary TC (Dry)	Premolars (n=20)	Mean = 3.95, SD = 1.84	Direct Extraction: Single tooth type used.	3.95 ± 1.84
	Rotary TC (Water-cooling)	Premolars (n=20)	Mean = 0.55, SD = 0.30	Direct Extraction: Single tooth type used.	0.55 ± 0.30

Supplementary Table S6 Detailed Quality Assessment of *In Vitro* Studies using QUIN tool.

Criteria	Baysal 2007	Pereira 2014	Amuk 2019	Sehgal 2019	Omer 2019	Voodi 2021	Dara 2023
1. Clearly stated aims/objectives	2	2	2	2	2	2	2
2. Sample size calculation	0	2	2	2	0	2	0
3. Detailed sampling technique	2	2	2	2	2	2	2
4. Details of comparison groups	2	2	2	2	2	2	2
5. Standardized methodology	2	2	2	2	2	2	2
6. Operator details (Single)	2	2	2	2	2	1	2
7. Randomization	1	2	2	2	2	1	2
8. Specified outcome measurement	2	2	2	2	2	2	2
9. Assessor details	0	0	0	0	0	0	0
10. Blinding	0	0	0	0	0	0	0
11. Statistical analysis	2	2	2	2	2	2	2
12. Results presentation	2	2	2	2	2	2	2
Total Score (Max 24)	17	20	20	20	18	18	18
Percentage (%)	70.80%	83.30%	83.30%	83.30%	75.00%	75.00%	75.00%
Risk of Bias Level	Low	Low	Low	Low	Low	Low	Low

Supplementary Table S7 Detailed Quality Assessment of *In Vivo* Studiy using RoB 2.0.

Bias Domain	Judgment
D1: Randomization process	Some concerns
D2: Deviations from intended interventions	High risk*
D3: Missing outcome data	Low risk
D4: Measurement of the outcome	Some concerns
D5: Selection of the reported result	Low risk
Overall Risk of Bias	Moderate / Some concerns

*Note: High risk in D2 is inherent to clinical trials comparing different dental instruments where operator blinding is not feasible.
The quality assessment of the study by Banga et al. (2020) revealed an overall moderate risk of bias. While the study demonstrated high internal validity regarding data completeness and reporting, the lack of detailed randomization protocols and the inability to blind the operator (inherent to the nature of IPR procedures) contributed to 'some concerns' in the overall judgment. However, the use of objective digital thermometry minimizes the potential impact of detection bias.

Supplementary Table S8 Confidence rating of each outcome.

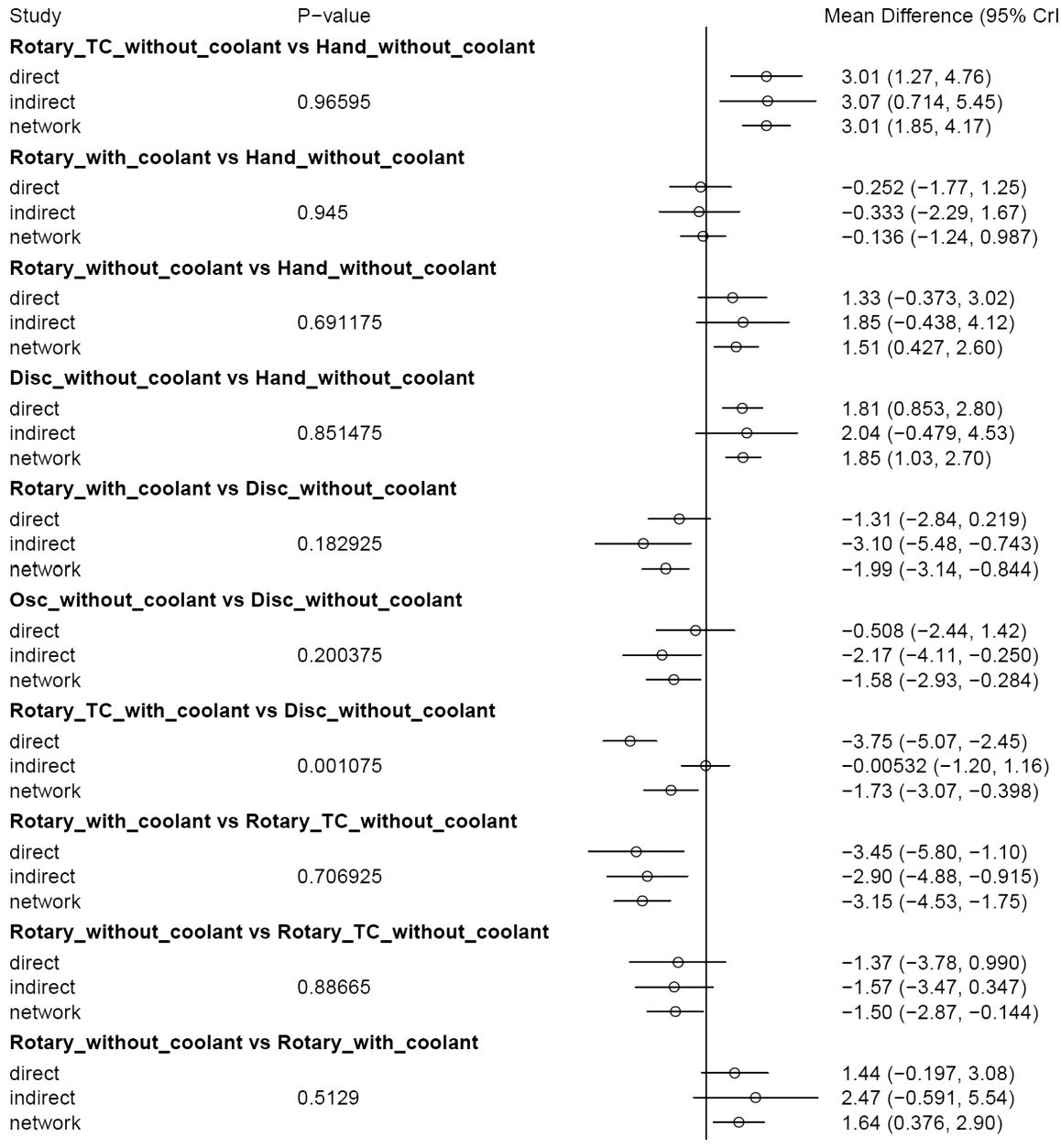
Comparison	Number of Studies	Within-study bias	Reporting bias	Indirectness	Imprecision	Heterogeneity	Incoherence	Confidence rating
Mixed evidence								
Disc with coolant vs Disc without coolant	2	--	Low risk	No concerns	No concerns	No concerns	No concerns	High
Disc with coolant vs Hand without coolant	2	--	Low risk	No concerns	No concerns	Some concerns	No concerns	High
Disc with coolant vs Osc with coolant	1	--	Low risk	No concerns	Some concerns	Some concerns	Some concerns	Moderate
Disc with coolant vs Osc without coolant	1	--	Low risk	No concerns	Some concerns	No concerns	No concerns	High
Disc with coolant vs Rotary TC with coolant	1	--	Low risk	No concerns	No concerns	Some concerns	No concerns	High
Disc with coolant vs Rotary TC without coolant	1	--	Low risk	No concerns	No concerns	No concerns	Major concerns	Moderate
Disc with coolant vs Rotary with coolant	1	--	Low risk	No concerns	No concerns	Some concerns	No concerns	High
Disc with coolant vs Rotary without coolant	1	--	Low risk	No concerns	No concerns	No concerns	No concerns	High
Disc without coolant vs Hand without coolant	5	--	Low risk	No concerns	No concerns	No concerns	No concerns	High
Disc without coolant vs Osc with coolant	1	--	Low risk	No concerns	No concerns	No concerns	Some concerns	High
Disc without coolant vs Osc without coolant	1	--	Low risk	No concerns	No concerns	No concerns	No concerns	High
Disc without coolant vs Rotary (TC) without coolant	2	--	Low risk	No concerns	No concerns	No concerns	No concerns	High
Disc without coolant vs Rotary TC with coolant	1	--	Low risk	No concerns	No concerns	No concerns	Some concerns	High
Disc without coolant vs Rotary TC without coolant	1	--	Low risk	No concerns	Some concerns	No concerns	Major concerns	Moderate
Disc without coolant vs Rotary with coolant	2	--	Low risk	No concerns	No concerns	No concerns	Some concerns	High
Disc without coolant vs Rotary without coolant	3	--	Low risk	No concerns	No concerns	Some concerns	Some concerns	High
Hand without coolant vs Osc with coolant	1	--	Low risk	No concerns	Some concerns	No concerns	No concerns	High
Hand without coolant vs Osc without coolant	2	--	Low risk	No concerns	No concerns	Some concerns	No concerns	High
Hand without coolant vs Rotary (Low speed) with coolant	1	--	Low risk	No concerns	No concerns	Some concerns	Some concerns	Moderate
Hand without coolant vs Rotary (Low speed) without coolant	1	--	Low risk	No concerns	No concerns	Some concerns	No concerns	High
Hand without coolant vs Rotary (TC) with coolant	1	--	Low risk	No concerns	No concerns	No concerns	No concerns	High

Supplementary Table S8 Confidence rating of each outcome. (continued)

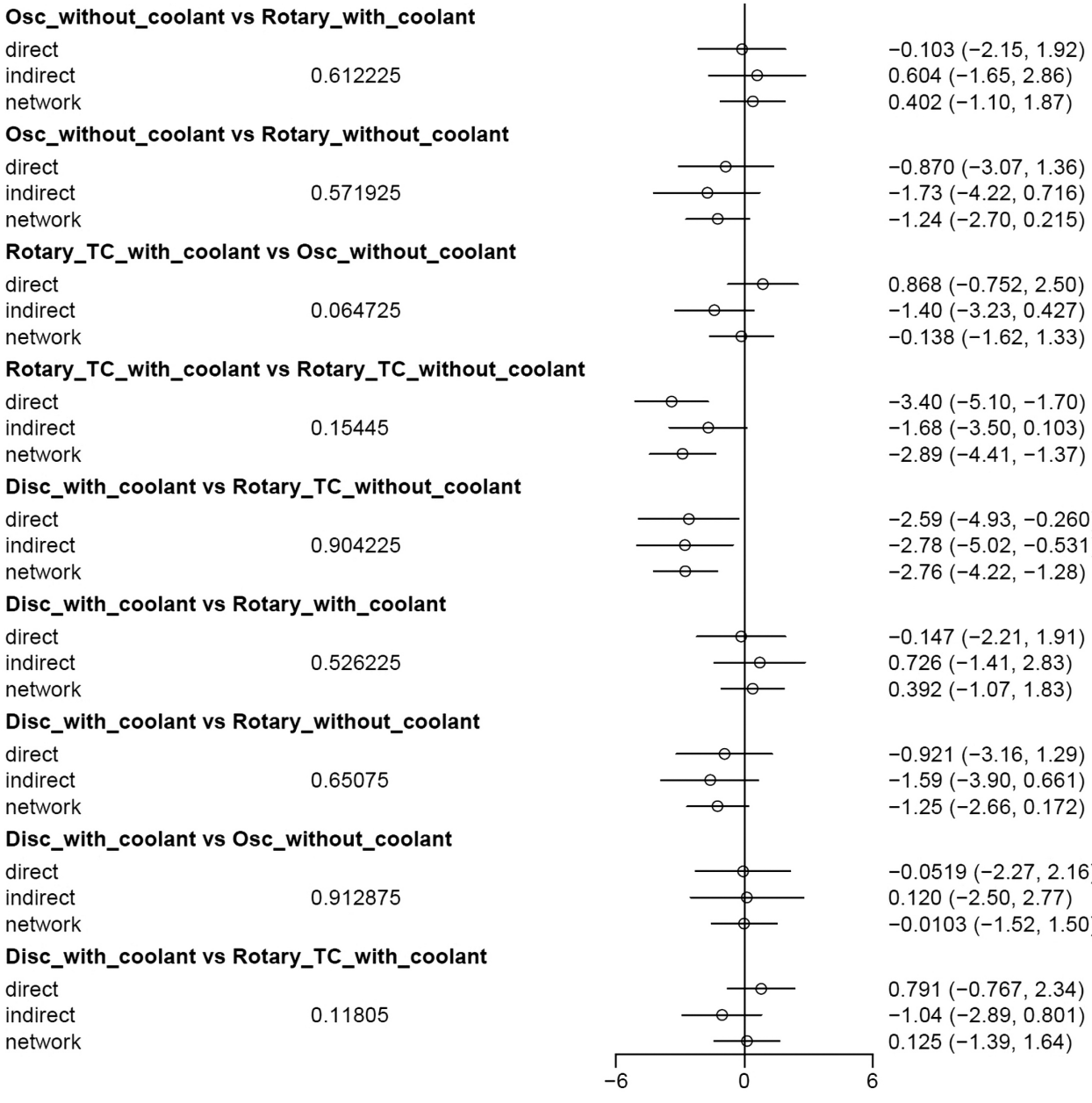
Comparison	Number of Studies	Within-study bias	Reporting bias	Indirectness	Imprecision	Heterogeneity	Incoherence	Confidence rating
Mixed evidence								
Hand without coolant vs Rotary (TC) without coolant	1	--	Low risk	No concerns	No concerns	No concerns	No concerns	High
Hand without coolant vs Rotary TC with coolant	1	--	Low risk	No concerns	No concerns	Some concerns	No concerns	High
Hand without coolant vs Rotary TC without coolant	1	--	Low risk	No concerns	No concerns	No concerns	No concerns	High
Hand without coolant vs Rotary with coolant	2	--	Low risk	No concerns	No concerns	Some concerns	No concerns	High
Hand without coolant vs Rotary without coolant	2	--	Low risk	No concerns	No concerns	No concerns	No concerns	High
Osc with coolant vs Osc without coolant	1	--	Low risk	No concerns	Some concerns	Some concerns	No concerns	High
Osc with coolant vs Rotary with coolant	1	--	Low risk	No concerns	Some concerns	No concerns	Major concerns	Moderate
Osc with coolant vs Rotary without coolant	1	--	Low risk	No concerns	No concerns	Some concerns	No concerns	High
Osc without coolant vs Rotary (TC) with coolant	1	--	Low risk	No concerns	No concerns	Some concerns	No concerns	High
Osc without coolant vs Rotary with coolant	1	--	Low risk	No concerns	No concerns	Some concerns	Major concerns	Moderate
Osc without coolant vs Rotary without coolant	1	--	Low risk	No concerns	No concerns	Some concerns	No concerns	High
Rotary (Low speed) with coolant vs Rotary (Low speed) without coolant	1	--	Low risk	No concerns	No concerns	No concerns	Major concerns	High
Rotary (Low speed) with coolant vs Rotary with coolant	1	--	Low risk	No concerns	Some concerns	No concerns	No concerns	High
Rotary (Low speed) without coolant vs Rotary with coolant	1	--	Low risk	No concerns	No concerns	Some concerns	Some concerns	High
Rotary (TC) without coolant vs Rotary with coolant	1	--	Low risk	No concerns	No concerns	No concerns	No concerns	High
Rotary (TC) without coolant vs Rotary without coolant	1	--	Low risk	No concerns	No concerns	No concerns	No concerns	High
Rotary TC with coolant vs Rotary TC without coolant	1	--	Low risk	No concerns	No concerns	No concerns	Major concerns	Moderate
Rotary with coolant vs Rotary without coolant	2	--	Low risk	No concerns	No concerns	No concerns	No concerns	High

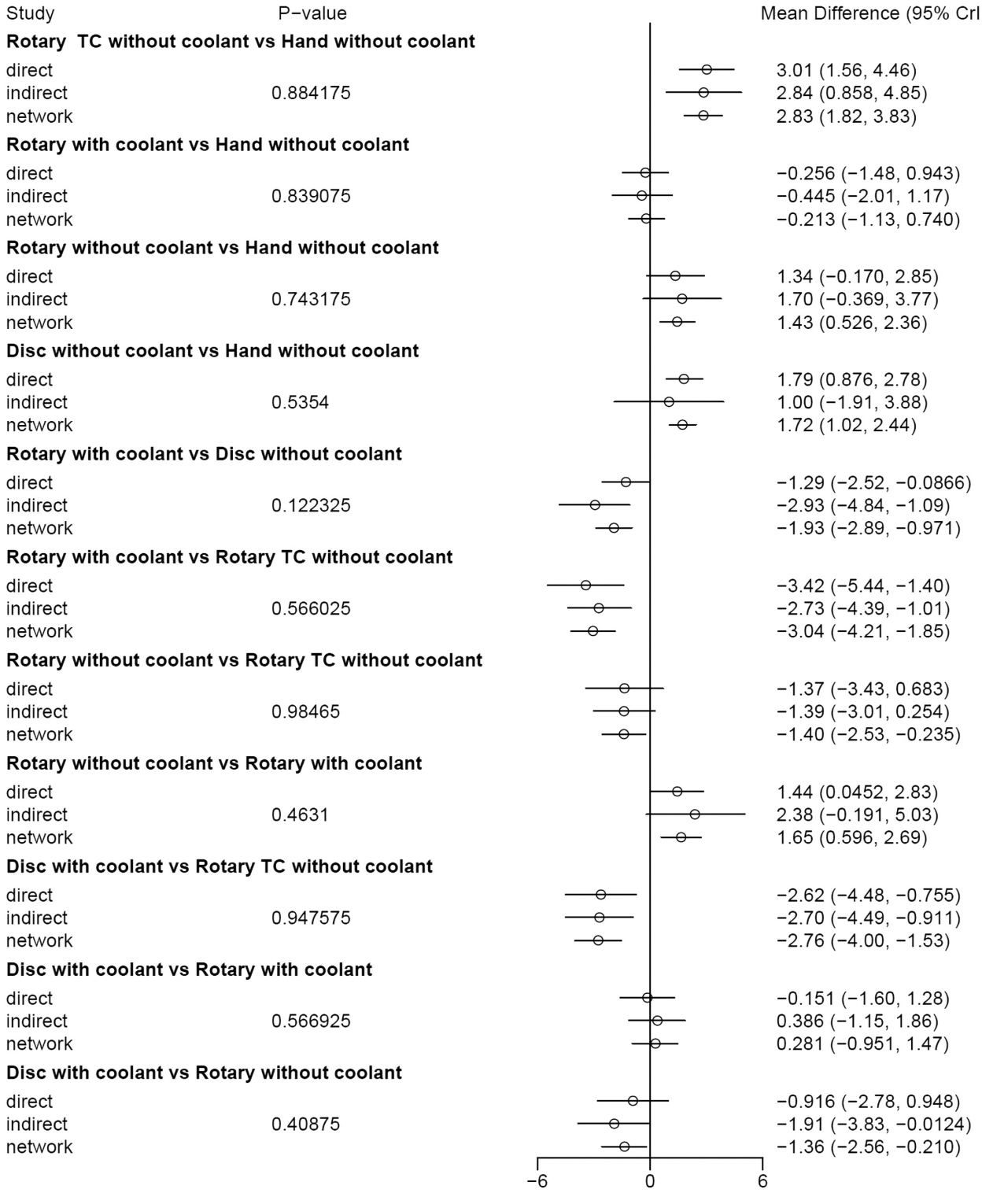
Confidence rating of each outcome using CINeMA (Confidence in Network Meta-Analysis, https://cinema.ispm.unibe.ch/) web application (Institute of Social and Preventative Medicine, University of Bern, Switzerland).

Inconsistency test with notesplitting model for all studies



Inconsistency test with notesplitting model with studies excluded





Supplementary Figure S1 Assessment of Inconsistency (Node-splitting).