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Efficacy and safety of 100% TCA CROSS for atrophic acne scar: A systematic review

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Systematic Review

ABSTRACT

Acne scars result from impaired healing following skin inflammation, with atrophic acne scars accounting for 98% of cases. Although various treatments are commonly used, no gold-standard therapy exists. Chemical reconstruction of skin scars using 100% trichloroacetic acid (100% TCA CROSS) has emerged as a novel intervention for atrophic acne scars. However, evidence supporting its efficacy and safety remains limited, necessitating further evaluation. This systematic review was conducted in accordance with PRISMA and SWiM guidelines. Literature searches were performed in PubMed, Cochrane Library, Google Scholar, and ScienceDirect. Studies were included if they involved patients with atrophic acne scars and utilized 100% TCA CROSS as the intervention, with comparators comprising other acne scar treatments. The primary outcome was efficacy, and the secondary outcome was safety. Only randomized controlled trials (RCTs) were included. Two independent reviewers assessed risk of bias, extracted data, and conducted qualitative analysis. Six studies met the eligibility criteria, with comparators including CO_2 laser pinpoint irradiation, microneedling, percutaneous collagen induction dermaroller, platelet-rich plasma (PRP) injection, and PRP injection with needling. One study favored the comparator, while five studies demonstrated no clear difference. Within-group analyses indicated improvements following 100% TCA CROSS. No severe complications were reported. Meta-analysis was not performed due to heterogeneity in outcome measures. In summary, 100% TCA CROSS appears effective and safe for atrophic acne scars.

INTRODUCTION

Acne is a common health disorder that affects up to 85% of adolescents and adults. It is usually treated as a mere cosmetic problem. However, few realize that acne is associated with negative social, emotional, and psychological impacts.[1,2] The detrimental effects for patients with acne do not end there. Up to 90% of these patients develop acne scarring, and 30% experience severe scarring.[3] Acne scars rarely heal fully over a patient's lifetime. Their presence can lead to psychosocial harm that may worsen the prior effects of acne. Such harms related to acne and its scars include mood disorders, loss of will to live, chronic depression, and suicidal thoughts.[4]

Abnormal healing after skin inflammation leads to acne scars. Excess, poorly controlled inflammation causes a strong defense response in nearby tissues. This reaction disrupts normal cell functions, including those of fibroblasts, and alters components such as collagen. As a result, skin structure is altered.[5] There are two types of acne scars: atrophic and hypertrophic. Atrophic scars are the most common type, found in 98% of patient.[6] They can appear as an ice pick, rolling, shallow boxcar, or deep boxcar. Most patients have several scar types.[7] Differences in scar appearance create heterogeneity, so tailored treatments are needed for the best results. This has led to the creation, development, and study of many acne scar interventions.[7]

Chemical reconstruction of skin scars (CROSS) is a monotherapy that uses chemical cauterization agents to treat acne scars. These agents provide controlled chemical cauterization of skin tissue.[8] Among these, 100% TCA is the most commonly used for CROSS due to being

inexpensive, accessible, and historically proven.[9] Although 100% TCA is effective at penetrating skin layers, traditional TCA peels caused more unwanted side effects than other agents.[10]

Seratus persen TCA CROSS may offer the best therapy for atrophic acne scars. However, research on this method is scarce, so its efficacy and safety are uncertain. There are no guidelines or protocols for the intervention. Therefore, this systematic review of randomized controlled trials can help assess its safety and efficacy. Evidence from this review could guide protocol development for 100% TCA CROSS monotherapy and support future research, including combination treatments that may enhance efficacy.[11]

METHODS

This research is a systematic review that adhered to the Preferred Reporting Items for PRISMA guidelines.

Eligibility criteria

The inclusion criteria were based on the Population, Intervention, Comparators, Outcome, and Study Design (PICOS) framework (Table 1). Included studies were human RCTs of patients with atrophic acne scars, any type or subtype, with either 100% TCA CROSS as the intervention or comparator. Exclusion criteria were a lack of full-text access or unreadable language. Studies that were not available in full or were not translatable by reviewers were excluded.

Table 1. PICOS framework

Framework	Detail
Population	Patients diagnosed with atrophic acne scar
Intervention	CROSS with 100% TCA
Comparison(s)	CROSS with TCA non-100%, CROSS with non-TCA chemical cauterization agents, and non-CROSS interventions
Outcome	Primary outcome is efficacy measured from reduction of acne scar severity using various standardized scales: SSI, GBS, Weighted Scale, or Quartile categories while secondary outcome is safety measured through incidence of severe complications: persistent erythema, permanent hyperpigmentation, hypopigmentation, herpes simplex flare-up, scarring, and keloid.
Study design	RCT

The main outcome was efficacy, measured as the percent reduction in atrophic acne scars. Due to a few studies, all scales and grading systems were included. The secondary outcome was safety, defined as severe complication rates. Severe complications at risk from 100% TCA CROSS included persistent erythema, permanent hyperpigmentation, hypopigmentation, herpes simplex flare-up, scarring, and keloid.[8,12]

Information sources

Electronic databases used were PubMed, Cochrane Library, Google Scholar, and ScienceDirect.

Search strategy

We identified relevant keywords using Boolean operators and tailored them to each database (Table 2). Searches were conducted on March 26, 2024, and included all studies available at that time.

Selection process

Rayyan software was utilized to identify and select studies. Two independent reviewers (VYS and UE) conducted the selection process. Data from four databases were imported, including titles, abstracts, and metadata. Automated duplicate detection was performed, followed by

manual deletion of duplicates. Studies not meeting eligibility criteria, as determined by title, abstract, or metadata, were excluded. Eligible studies were retrieved in full text. The selection process was documented using a PRISMA diagram.

Data items

Study characteristics were extracted, including author, year, country, study design, procedure for 100% TCA CROSS, research duration, and data collection timeframe. For each study, sample size, patient age range or mean, and types of atrophic acne scars were also recorded.

Study risk of bias assessment

The quality of included studies was assessed using the Cochrane Risk of Bias 2.0 (RoB 2.0) tool. Risk of bias was measured separately for each outcome. Results were presented as a traffic light table and a Robvis diagram.

Effect measures

The main outcome was efficacy, measured by reductions in acne scar severity (GBS, SSI, Weighted Scale, Quartile categories). The secondary outcome was safety, measured by the incidence of severe complications.

Synthesis methods

Due to differences in effect measures, a qualitative synthesis was conducted in accordance with SWiM guidelines. Study characteristics included author, year, country, study design, aim, duration, sample size, age range, sex, and conclusion. Outcomes included reductions in acne scar severity (measured by efficacy scales: GBS, SSI, weighted scale, quartile) and incidence of severe complications.

For the primary outcome, studies were grouped by comparator and vote counting was used based on the direction of effect, providing a comparative synthesis of between-group results. Directions were classified as favoring 100% TCA CROSS, favoring the comparator, or indicating no clear difference (based on confidence intervals or authors' reports). Within-group measurements were also described. For the secondary outcome, the incidence of severe complications in each study was documented and summarized descriptively.

RESULTS

Study selection

Data were searched in four electronic databases, and 559 studies were found (Table 2). The titles, abstracts, and other available metadata for those studies were imported into Rayyan.

Table 2. Search strategy and result

Database	Keywords	Result
PubMed	("Acne Vulgaris"[Mesh] OR "Acne") AND ("Cicatrix"[Mesh] OR "Scar" OR "Scars" OR "Scarring" OR "Atrophy"[Mesh] OR "Atrophic") AND "Chemical Reconstruction" AND ("TCA" OR "Trichloroacetic Acid")	24
Cochrane Library	(MeSH descriptor: [Acne Vulgaris] OR "Acne") AND (MeSH descriptor: [Cicatrix] OR Scar (Word variations) OR MeSH descriptor: [Atrophy] OR Atrophy (Word variations)) AND "Chemical Reconstruction" AND (MeSH descriptor: [Trichloroacetic Acid] OR "TCA")	12
Google Scholar	"Acne" AND ("Scar" OR "Scarring" OR "Scars" OR "Atrophy" OR "Atrophic") AND "Chemical Reconstruction" AND ("TCA" OR "Trichloroacetic Acid")	485
ScienceDirect	"Acne" AND ("Scar" OR "Scarring" OR "Scars" OR "Atrophy" OR "Atrophic") AND "Chemical Reconstruction" AND ("TCA" OR "Trichloroacetic Acid")	38
	Total	559

Automated detection was used to identify and manually delete 70 duplicate studies. Preliminary screening excluded 482 ineligible studies, primarily due to incorrect designs,

interventions, or populations. Seven studies were retrieved for full-text review; one was excluded due to lack of full text. Six studies met all eligibility criteria and were included. The selection process was documented in a PRISMA diagram (Figure 1).

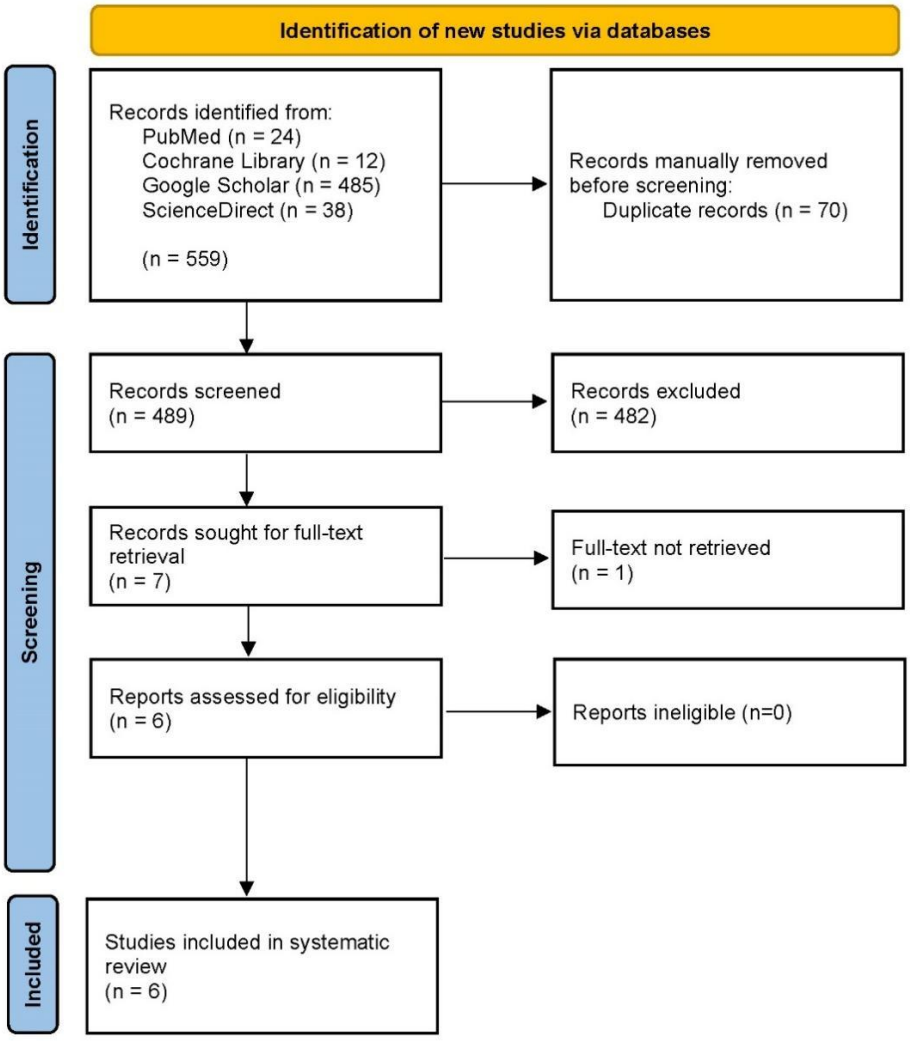

Figure 1. PRISMA 2020 flow diagram

Study characteristics

Six studies were included for both the primary and secondary outcomes. Extracted characteristics included author, year, country, study design, procedure for 100% TCA CROSS, research duration, and data collection timeframe. Additional data included sample size, patient age range or mean, and types of atrophic acne scars. These study characteristics are presented in Table 3.

Risk of bias in studies

The risk of bias was assessed using RoB 2.0 for each primary and secondary outcome. For the primary outcome, three studies had a low risk of bias, two had some concerns, and one had a high risk of bias. Dhollan and Thirunavukkarasu had one patient who was lost to follow-up, and their study was open-label, which raised concerns about the second and fourth bias domains. Ullah et al. did not describe their measurement method, raising concerns about the fourth bias domain. Leheta et al. reported that three patients in the same group were lost to follow-up after the first intervention session. This case raised concerns about the second bias domain and a high risk of bias in the third domain. The results for the risk of bias assessment of the primary outcome were visualized using Robvis (Figure 2).

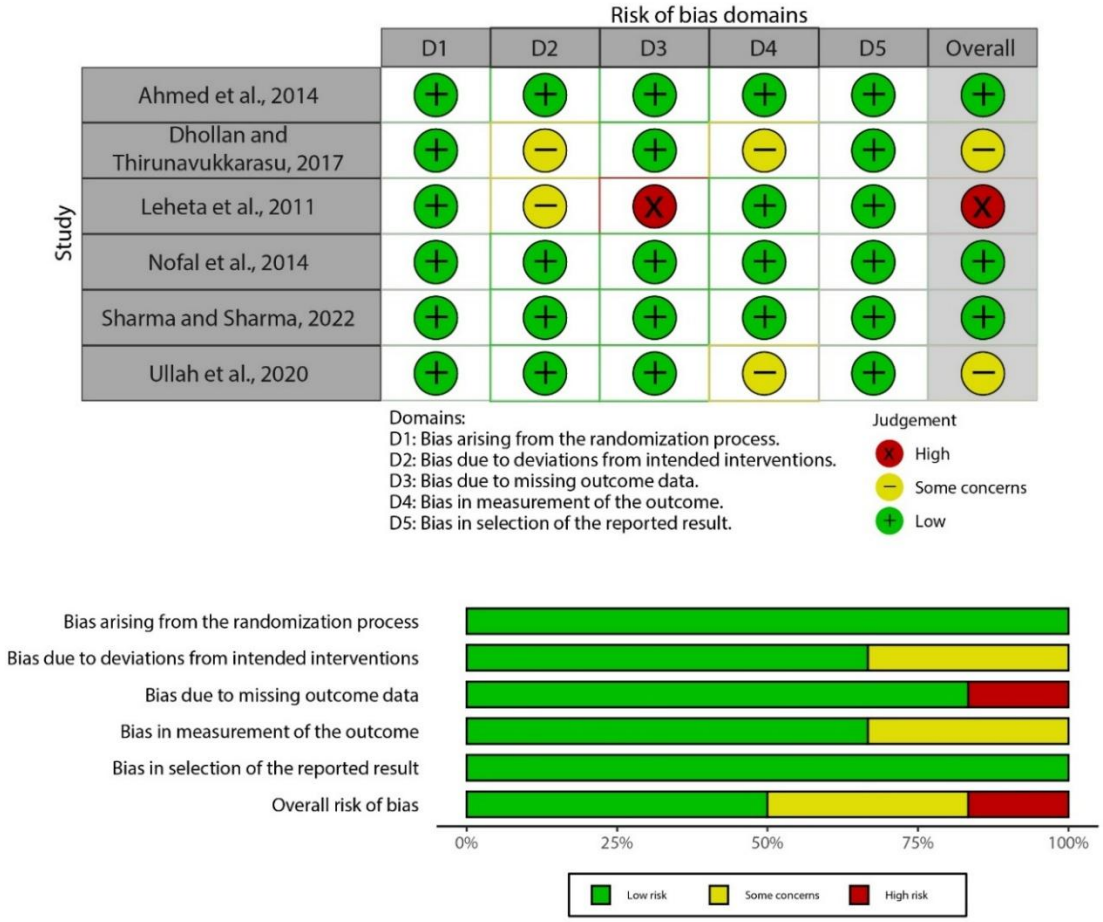

Figure 2. Risk of bias assessment of primary outcome using RoB 2.0

A separate risk-of-bias assessment for the secondary outcome was conducted because some RoB 2.0 domains depended on the assessed outcome. For the secondary outcome, two studies had a low risk of bias, three had some concerns, and one had a high risk of bias. Dhollan and Thirunavukkarasu, Sharma and Sharma, and Ullah et al. reported the incidence of severe complications descriptively and cumulatively, thereby raising concerns about bias in their assessment of the third domain.

Results of individual studies

Study outcomes were extracted separately from study characteristics, including the measurement scale, percentage reduction in scar severity, incidence of severe complications, incidence of comparator complications, and the study conclusion (Table 4).

Results of syntheses

Six RCTs were included, with study sample sizes ranging from 14 to 25; scar types included ice pick, boxcar, and rolling atrophic acne scars. Measurement scales used were either SSI, GBS, Weighted Scale, or Quartile categories. Across the six studies, the risk of bias for efficacy was mostly low, whereas that for safety was mostly some concerns.

For efficacy, 100% TCA CROSS showed no clear difference compared with its comparator in five of six studies, while one study favoured the comparator. However, each of the six studies described within-group improvement after 100% TCA CROSS. Regarding safety, no severe complications occurred in any of the studies

Table 3. Study characteristics

Author, year	Country	Study design	Comparator intervention	100% TCA CROSS			Comparator			Procedure of 100% TCA CROSS	Duration of research	Data collection timeframe
				Sample (n)	Age (year)	Scar Type	Sample (n)	Age (year)	Scar Type			
Ahmed et al., 2014[13]	Egypt	Pilot RCT	CO_2 laser pinpoint irradiation	14	19-36	Ice pick	14	19-36	Ice pick	Pressed hard on atrophic acne scar area with toothpick	Ten months	Four sessions with three weeks interval
Dhollan and Thirunavukkarasu, 2017[14]	India	RCT open-labelled	Microneedling	15	18-45	Ice pick, Boxcar, and Rolling	15	18-45	Ice pick, Boxcar, and Rolling	Pressed atrophic acne scar area with sharp toothpick	Six months	Four sessions with one month interval
Leheta et al., 2011[15]	Egypt	RCT	PCI dermaroller	15	19-36	Ice pick, Boxcar, and Rolling	15	20-42	Ice pick, Boxcar, and Rolling	Pressed and held atrophic acne scar area with blunt ended wooden applicator	NA	Four sessions with four weeks interval
Nofal et al. 2014[16]	Egypt	RCT	PRP injection	15	19-40	Ice pick, Boxcar, and Rolling	15	19-32	Ice pick, Boxcar, and Rolling	Pressed with cotton ended wooden applicator until frosting occurs	Ten months	Three sessions with two weeks interval
			PRP injection with needling				15	20-35				
Sharma and Sharma, 2022[17]	India	RCT	Microneedling	25	23.96 ± 4.267	Ice pick, Boxcar, and Rolling	25	24.52 ± 4.283	Ice pick, Boxcar, and Rolling	Pressed hard with sharp applicator	One year	Three sessions with four weeks interval
Ullah et al. 2020[18]	Pakistan	RCT	PCI dermaroller	49	20-39	Ice pick, Boxcar, and Rolling	49	20-39	Ice pick, Boxcar, and Rolling	Used special applicator	Nine months	Four sessions with four weeks interval

TCA, trichloroacetic acid; CROSS, chemical reconstruction of skin scars; RCT, randomized controlled trial; PCI, percutaneous collagen induction; NA, not available; PRP, platelet rich plasma.

Table 4. Study outcomes

Author, year	Measurement scale	Comparator intervention	Within-group reduction of scar severity		Between-group direction of Effect	Incidence of severe complications		Non-severe complications or side effects	
			100% TCA CROSS	Comparator		100% TCA CROSS	Comparator	100% TCA CROSS	Comparator
Ahmed et al., 2014[13]	SSI	CO_2 laser pinpoint irradiation	Good (51-70%): 21% Fair (30-50%): 50% Poor (<30%): 29%	Good (51-70%): 36% Fair (30-50%): 42.3% Poor (<30%): 22%	Favours Comparator	None reported	None reported	Reported side effects: 7.1% itch, 42.8% infection, 64.2% transient post inflammatory hyperpigmentation	Reported side effects: 14.2% infection, 14.2% transient post inflammatory hyperpigmentation.
Dhollan and Thirunavukkarasu, 2017[14]	GBS	Microneedling	Grade 3 (>75%): 14.28% Grade 2 (50-74%): 35.7% Grade 1 (25-49%): 28.5% Grade 0 (<25%): 21.4%	Grade 3 (>75%): 26.7% Grade 2 (50-74%): 46.7% Grade 1 (25-49%): 13.3% Grade 0 (<25%): 13.3%	No clear difference	None reported	None reported	Reported side effect: 21% significant post inflammatory hyperpigmentation.	No reported side effect.
Leheta et al., 2011[15]	Weighted Scale	PCI dermaroller	Significant (50-74%): 66.7% Moderate (25-49%): 25% Slight (<25%): 8.3% Mean: 75.3 ± 9.4	Significant (50-74%): 46.7% Moderate (25-49%): 33.3% Slight (<25%): 20% Mean: 68.3 ± 19.3	No clear difference	None reporter	None reported	Reported side effects: 100% burning sensation, 100% postcrust erythema, 50% transient post inflammatory hyperpigmentation.	Reported side effects: 100% transient erythema, 100% transient edema, 13.3% new acne lesions.

Author, year	Measurement scale	Comparator intervention	Within-group reduction of scar severity		Between-group direction of Effect	Incidence of severe complications		Non-severe complications or side effects	
			100% TCA CROSS	Comparator		100% TCA CROSS	Comparator	100% TCA CROSS	Comparator
Nofal et al., 2014[16]	GBS	PRP injection	Excellent (<75%): 0% Very good (50-74%): 26.7% Good (25-49%): 33.3% Poor (<25%): 40%	Excellent (<75%): 20% Very good (50-74%): 26.7% Good (25-49%): 20% Poor (<25%): 33.3%	No clear difference	None reported	None reported	Reported side effects: 26.7% transient post inflammatory hyperpigmentation.	Reported side effect: 6.7% mild bruise.
		PRP injection with needling		Excellent (<75%): 13.3% Very good (50-74%): 46.7% Good (25-49%): 13.3% Poor (<25%): 26.7%	No clear difference		None reported		Reported side effects: 100% transient erythema and 100% transient edema.
Sharma and Sharma, 2022[17]	GBS	Microneedling	Marked (>75%): 24% Moderate (50-75%): 60% Mild (25-50%): 16%	Marked (>75%): 16% Moderate (50-75%): 48% Mild (25-50%): 36%	No clear difference	None reported	None reported	Reported side effect: 68% focal post procedure hyperpigmentation.	Reported side effect: 8% diffuse post procedure hyperpigmentation.
Ullah et al., 2020[18]	Clinical with Quartile Grading Scale	PCI dermaroller	Excellent (>75%): 30.6% Good (51-75%): 32.6% Fair (26-50%): 26.5% Poor (<25%): 10.2%	Marked (>75%): 16% Moderate (50-75%): 48% Mild (25-50%): 36%	No clear difference	None reported	None reported	Reported side effects: 36.7% hyperpigmentation, 30.6% hypopigmentation	Reported side effects: 34.6% hyperpigmentation, 32.6% post procedural erythema

SSI, Scar Severity Index; GBS, Goodman and Baron Qualitative Global Scarring Grading System; TCA, trichloroacetic acid; CROSS, chemical reconstruction of skin scars; PCI, percutaneous collagen induction; PRP, platelet rich plasma.

Heterogeneity varied by comparator: against CO2 laser pinpoint irradiation, the direction of effect favoured the comparator; otherwise, there was no clear between-group difference. No consistent trends were observed in the other parameters. Exploratory sensitivity analyses (excluding studies with a high risk of bias and restricting to certain validated scales) did not change the conclusions for the direction of effect.

DISCUSSION

Trichloroacetic acid is a chemical cauterization agent that has long been effective and safe for superficial and combination chemical peels, but is considered risky for deeper chemical peeling. As a chemical cauterization agent, TCA induces necrosis of epidermal cells and dermal collagen, which in turn triggers a more optimal and controlled inflammatory response, resulting in tissue regeneration and eliminating the cosmetic abnormality of a scar.[12] The CROSS is a technique of focal TCA application on the depressed area of an atrophic acne scar by pressing it hard using an applicator. This technique was developed to realize the potential of TCA as a deep peeling agent, as it can penetrate the dermal layers deeply and effectively when applied at higher concentrations (60–100%). With this technique, the risk of severe complications in TCA applications (persistent erythema, permanent hyperpigmentation or hypopigmentation, herpes simplex flare-up, scarring, and keloid) is not to be feared.[8]

In all included studies, the 100% TCA CROSS group reduced acne scar severity.[13–18] Five included studies reporting reductions in acne scar severity before and after intervention, the 100% TCA CROSS group was statistically significant.[14–18]

Ahmed et al. compared 100% TCA CROSS with CO_2 laser pinpoint irradiation as therapy for ice-pick-type atrophic acne scars.[13] The CO_2 laser pinpoint irradiation was significantly more effective than 100% TCA CROSS, even though acne scar severity was reduced in both intervention groups. The CO_2 laser is considered the first-line therapy for acne scars, with high efficacy and minimal side effects, while 100% TCA CROSS is considered the first-line therapy for ice-pick-type atrophic acne scars.[19,20] The CO_2 laser pinpoint irradiation creates microscopic thermal wounds in the depressed area of the atrophic acne scar, which penetrates the dermal layer focally and precisely, stimulating prolonged neocollagenesis.[13,20] The reason CO_2 laser pinpoint irradiation was more effective than 100% TCA CROSS might be that the CO_2 laser damage and penetration were deeper, more focused, and more precise. In the included study, CO_2 laser pinpoint irradiation showed a greater reduction in ice-pick type atrophic acne scars than 100% TCA CROSS.

Two studies showed no clear between-group difference when comparing 100% TCA CROSS with microneedling.[14,17] However, when the efficacy for each type of atrophic acne scar was compared, microneedling was more effective for rolling and boxcar types, while 100% TCA CROSS was more effective for ice pick types.[14] 100% TCA CROSS was also more effective for severe scars, while microneedling offered benefits in other areas, such as whole-face rejuvenation. 100% TCA CROSS and microneedling were equally effective for atrophic acne scars, each with its own pros and cons; thus, the choice of therapy should fit the patient's needs. There is also potential for enhanced efficacy by combining the two interventions as combination therapy.[17]

Leheta et al. and Ullah et al. reported that 100% TCA CROSS was effective, with no clear between-group difference compared with PCI dermaroller.[15,18] Compared across types of atrophic acne scars, 100% TCA CROSS was significantly more effective for the ice pick type, while PCI dermaroller was significantly more effective for the rolling type. There was no significant difference between the two interventions for boxcar type, but 100% TCA CROSS was recommended.[15]

Nofal et al. reported that 100% TCA CROSS, PRP injection, and PRP injection with needling improved scars within groups and showed no clear between-group differences.[16] Between the three interventions, the difference in side effects and the patients' tolerance to the side effects were the more important considerations when choosing the best therapy for the patient.[16]

Overall, 100% TCA CROSS showed no clear between-group differences compared with

microneedling, PCI dermaroller, PRP injection, or PRP injection with needling, and showed less improvement than CO_2 laser pinpoint irradiation in direct comparison. Among interventions with no clear between-group difference, 100% TCA CROSS was more strongly recommended for ice-pick type atrophic acne scars and scars with higher severity. The highly concentrated TCA used in 100% TCA CROSS enabled the intervention to reach deeper into the tissue.[12] 100% TCA CROSS was likely more effective for ice-pick type atrophic acne scars and scars of higher severity because of its ability to reach deeper depths than other interventions.

Aside from the efficacy of 100% TCA CROSS, there were variations in intervention frequency across the six included studies. More frequent intervention sessions were associated with a greater reduction in atrophic acne scars.[15,17] In all studies that reported the significance of atrophic acne scar reduction before and after intervention, 100% TCA CROSS was significantly effective in all of them; thus, the correlation between efficacy and frequency of intervention could not be assessed in this review. Further study is needed to determine the optimal intervention frequency to produce the highest efficacy for 100% TCA CROSS for atrophic acne scars.

In all included studies, no severe complications were reported in the 100% TCA CROSS group. However, all studies reported side effects that need to be considered based on patients' tolerance and preferences. Side effects of 100% TCA CROSS reported in all six included studies: itch, infection, transient post-inflammatory hyperpigmentation, significant post-inflammatory hyperpigmentation, hypopigmentation, burning sensation, and post-crust erythema.[13–18] According to Sharma and Sharma, post-inflammatory hyperpigmentation in 100% TCA CROSS is focal.[17] The side effects of 100% TCA CROSS differed with all comparators, and each comparator had different side effects.

Hypopigmentation is considered a severe complication in this review, although the hypopigmentation reported in the studies was classified as non-severe. This description might reflect temporary hypopigmentation, which will recover shortly after the intervention, rather than permanent hyperpigmentation, a severe complication, even though none of the studies described the properties of the reported hypopigmentation. Thus, 100% TCA CROSS appeared safe with respect to the incidence of severe complications in the included studies.

An important topic related to the safety of 100% TCA CROSS is the procedure. There were procedure variations in the six included studies, especially in the type of applicator used. Generally, TCA is applied in CROSS using wooden applicators with a sharpened end. This application method was used by Ahmed et al. and Dhollan et al. in their studies.[13,14] However, other included studies used different applicators or techniques. Leheta et al. used a wooden applicator with a blunt end; Nofal et al. used a wooden applicator with a cotton-wrapped end; Sharma and Sharma only described using a sharp applicator; and Ullah et al. only said they used a special applicator.[15–18] The type of applicator used in the procedure could affect the risk of severe complications.[12] The difference in procedure for TCA application in these studies might be due to the difference in risk of severe complications. However, because no severe complications were reported in any of the studies, we found no association between TCA application and the incidence of severe complications. However, it is worth noting that these studies were not designed to research this topic. Further research on this topic, with a larger sample size, is needed.

This systematic review provides new insights into the efficacy and safety of 100% TCA CROSS based on available RCTs, but it also has unavoidable limitations. The scarcity of 100% TCA CROSS RCTs led to a limited number of included studies. Because of these limitations, the included studies were heterogeneous, with different comparators, measurement scales, outcome gradings, and intervention procedures. We did not conduct a meta-analysis for these reasons and therefore used a qualitative synthesis based on direction of effect. In addition, the total sample size across the six included studies was small, and the studies included only a limited number of countries. Thus, the results of this systematic review could not represent the general population. The results of this systematic review should be interpreted with caution.

CONCLUSION

100% TCA CROSS is effective and safe for the treatment of atrophic acne scars, as demonstrated by study-reported scales and the absence of severe complications. Further research is warranted to determine the optimal procedure for 100% TCA CROSS, including the development of a standardized protocol encompassing indication, tools, resources, and methods to enhance methodological consistency. Additional studies with larger sample sizes and a broader range of comparators are also recommended.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

REGISTRATION AND PROTOCOL

This review was not registered.

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DATA AVAILABILITY STATEMENT

Data used in this manuscript were published articles that were publicly available at PubMed, Cochrane Library, Google Scholar, or Science Direct. There was no generated data.

SUPLEMENTARY MATERIAL

There is no supplementary material associated with this article. All figures and tables are included within the manuscript.

AUTHOR CONTRIBUTIONS

VYS, UE, and AMA contributed to the work plan and manuscript revisions. VYS and UE contributed to data collection and synthesis. VYS contributed to the writing and proofreading of the manuscript. All authors have read and approved the final manuscript.

DECLARATION OF USING AI IN THE WRITING PROCESS

ChatGPT "GPT-5 Thinking" was used to assist in editing and proofreading to help with clarity and grammar. It was not used to generate, analyse, or interpret data. The authors are fully responsible for the end result.

LIST OF ABBREVIATIONS

TCA: Trichloroacetic Acid; CROSS: Chemical Reconstruction of Skin Scars; PRISMA: Preferred Reporting Items for Systematic Review and Meta-Analyses; SWiM: Synthesis without Meta-Analysis; RCT: Randomized Controlled Trials; PICOS: Population, Intervention, Comparators, Outcome, and Study Design; SSI: Scar Severity Index; GBS: Goodman and Baron Qualitative Global Scarring Grading System; RoB 2.0: Cochrane Risk of Bias 2.0; PCI: Percutaneous Collagen Induction; PRP: Platelet Rich Plasma.

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