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REVIEW

Positive identification through comparative dental analysis in mass disaster: a systematic review and meta-analysis

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Abstract

Purpose: The study aimed to assess the probability of achieving positive identification through comparative dental analysis (CDA) and to determine the factors that influence its success rate in mass disaster scenarios. Methods: An electronic literature search was conducted across six databases for observational studies that reported both the total number of mass disaster victims and the count of victims identified through CDA alone. A random-effect meta-analysis, using the proportion of victims identified with CDA as the effect size, was conducted alongside subgroup analyses based on the type of disaster (natural or non-natural), the disaster classification (open or closed), and the geographical region (i.e., Europe, Asia). Results: The search yielded 3133 entries, out of which 32 studies were deemed eligible. Most of the studies (96.8%) presented a low risk of bias. The meta-analysis revealed a mean weighted-proportion probability of 0.32, indicating that forensic odontology could identify about one-third of the victims in a mass disaster. The probability of comparative dental identification was three times higher in closed mass disasters compared to open disasters ($p<0.05$) and was higher in mass disasters occurring in North America and Europe compared to other regions ($p<0.05$). Conclusion: The current result suggested that CDA can identify approximately 32% of a victim in a hypothetical scenario, emphasizing the integral role of teeth and forensic odontology in victim identification framework.

Keywords Disaster victim identification · Forensic Dentistry · Mass Disaster · Odontology

Introduction

In mass disaster events, where several lives are lost due to an unexpected event caused by natural, accidental, or criminal causes [1], a human identification process becomes imperative to establish the identity of the deceased. This process of human identification holds significant importance from both humanitarian and criminal investigative perspectives [2]. On the humanitarian front, an individual's identity is integral to their basic human rights, imposing both ethical and scientific obligations on forensic specialists involved in the identification process [3]. In cases that involve natural disasters, such as earthquakes or tsunamis, the identification of a victim can offer closure to their loved ones and facilitate the resolution of various legal prerequisites. This allows the family to obtain a death certificate, which can have significant social implications as it provides essential information for end-of-life legal matters, including life insurance and inheritance [4]. Furthermore, from the investigative standpoint, the identification process can provide confirmation regarding the perpetrators of acts like terrorism. This serves as a foundation for devising effective counter-terrorism measures to mitigate the risk of further attacks [5]. After all, the identification of a victim — whether in the context of a mass disaster or not — is compulsory. However, the challenges become more pronounced in mass disasters, where

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forensic teams often deal with issues such as the overwhelming number of victims, limited human resources, and data availability constraints [6].

Identification of a victim should be accomplished through three primary identification methods following International Criminal Police Organization (INTERPOL) recommendations: genetics, friction ridge analysis, and dental data analysis, each with its inherent limitations. For instance, (I) DNA analysis is more expensive and time-consuming, and therefore is normally utilized as a last resort for identification purposes [7]; (II) fingerprints may not be obtainable from decomposed or charred bodies; and (III) clinical ante-mortem (AM) dental records may not be promptly available or are inexistent/incomplete [8]. Nevertheless, these scientific approaches to achieve positive identification shares a common prerequisite: they are comparative analysis and require AM and post-mortem (PM) data. It can be argued that if the prerequisites are met, positive identification becomes attainable. Even in these circumstances, the available AM and PM data must be sufficient both in quantity and quality to ensure a reliable comparison [9].

In dental identification, the AM dental data is compared to the PM data, a process referred to as comparative dental analysis (CDA) [10]. Despite its apparent simplicity, the CDA method and forensic odontology have inherent challenges to attain positive identification [11]. The uniqueness of dental features, for example, has been subject to debate [12], necessitating a certain degree of combination between therapeutic, morphological and pathological identifiers [13]. Additionally, the availability of dental records varies, posing challenges particularly in developing countries [14], or in cases where the local healthcare is directly affected by the disaster event itself (i.e., earthquakes that destroy dental data) [15].

These factors contribute to an uncertainty in achieving positive identification through CDA, as multiple variables can influence the likelihood of successfully identifying an individual through dental records. Over time, there has been a growing body of literature reporting cases of successful identification using dental comparison in mass disaster events. Therefore, to explore the scientific rigor of the CDA, this systematic review and meta-analysis aimed to assess the probability of achieving positive identification through CDA and what confluences its success rate. The guiding research question was: *What is the probability of an individual being identified through CDA in a mass disaster?*

Materials and methods

Eligibility criteria

This review was performed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [16]. The research question stated in the previous section was established based on population (*P*), exposure (*E*), comparison (*C*), and outcome (*O*) with the following criteria: *P* = human population, *E* = victims of mass disasters, *C* = comparative dental analysis to achieve positive identification, and *O* = positive identification. The term "mass disaster" means a sudden event — natural or man-made — resulting in multiple fatalities and subjected to a medicolegal investigation [17]. The term "positive identification" follows the terminology used by the American Board of Forensic Odontologists as "*AM and PM data match in sufficient detail to establish that they are from the same individual. In addition*, *there are no irreconcilable discrepancies*" [18].

This study included full-text peer-reviewed observational, cross-sectional, or case-report studies that reported both the total number of mass disaster victims and the count of victims identified through CDA alone, resulting in positive identifications. There were no restrictions on publication year, language, and status. Conversely, studies that only presented the count of positive identifications through dental comparison without the total number of victims, using dental identification as a secondary identifier, and reports in a non-mass disaster event were excluded. Additionally, systematic reviews, abstracts, books, book chapters, editorials, or letters to the editor were also excluded from the analysis.

Information sources

An electronic search (31st October 2023) was conducted across five databases: PubMed, Scopus, Virtual Health Library, and SciELO. Furthermore, an additional search in the grey literature (i.e., student thesis, dissertation) was carried out using the Open Access Theses and Dissertation (OATD) database.

Search strategy

Search strings were created to capture their relevance to victim identification in the context of mass disasters, with a focus on disaster victim identification (DVI) terminology. These initial search strings were subsequently modified to align with Medical Subject Headings (MeSH) and Descriptors in Health Sciences (DeCS), using a combination with the "OR" and "AND" Boolean operators (Table 1).

Table 1 Search strategies for each database

Database	Search Strategy	*n*
PubMed	("dental identification" OR "human identification" OR "victim identification" OR identification) AND ("disaster victim identification" OR "DVI" OR "mass disaster" OR "natural disaster")	510
Scopus	TITLE-ABS-KEY (("dental identification" OR "human identification" OR "victim identification" OR identification) AND ("disaster victim identification" OR "DVI" OR "mass disaster" OR "natural disaster")) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re"))	2026
Virtual Health Library (https://search.bvsalud.org/portal)	("human identification" OR "dental identification" OR identification OR "victim identification") AND ("disaster victim identification" OR "mass disaster" OR "natural disaster")	509
SciELO	"Disaster victim identification" OR DVI OR "human identification" OR "dental identification"	83
Open Access Theses and Dissertation	("forensic odontology" OR "forensic dentistry") AND ("disaster victim identification") OR ("human identification")	5

Table 2 Risk of bias assessment from Joanna Briggs institute's critical appraisal tools for case reports adapted for the current study

No	Critical Appraisal Questions	Interpretations in current study
1	Were patient's demographic characteristics clearly described?	The place and the nature of the mass disaster
2	Was the patient's history clearly described and presented as a timeline?	Not Applicable
3	Was the current clinical condition of the patient on presentation clearly described?	The overall condition of the victims. For example, victims that can be visually identified, body parts that were examined, the condition of the body.
4	Were diagnostic tests or assessment methods and the results clearly described?	The primary method that was used to identify the victim, both primary and secondary identifier or combined primary identifiers.
5	Was the intervention(s) or treatment procedure(s) clearly described?	The procedure of the question 4 method to achieve positive identification, the composition of the (multidisciplinary) forensic team, or the team management itself
6	Was the post-intervention clinical condition clearly described?	While evaluating the condition of the victim related to the mass disaster (question 3), has the emergency response efforts evaluated clearly in terms of effectiveness and success to achieve positive identification?
7	Were adverse events (harms) or unanticipated events identified and described?	The report of the unidentified victims, and if any, discussing the challenges and the reasons for the lack of identification.
8	Does the case report provide takeaway lessons?	Self-explanatory.

Selection process

Study selection was performed collaboratively by two reviewers, RMB and NA, both forensic odontologists with over 8 years of experience in both clinical and research in forensic odontology. The initial search results were registered in EndNote 20 (Thomson Reuters, Toronto, Canada), categorized based on their database of origin. The preliminary phase of selection involved the application of EndNote's built-in function for automated duplicate identification, followed by a manual examination by the reviewers. The remaining studies were exported to Microsoft Excel 365 (Microsoft Ltd, Washington, USA) utilizing tab-delimited output tools within Endnote 20 and later curated manually. In the second phase of study selection, the titles and abstracts of the articles were evaluated. Studies unrelated to the topic of interest were excluded at this phase. In case of doubts the article was retained for further consideration in the subsequent selection phase. The third study selection was accomplished after full text read, and the studies that remained after the third selection underwent data collection process.

Data collection

Qualitative data collected from the eligible studies consisted of authorship information, year of publication, year of the disaster, location of the disaster, type of disaster, total number of victims, and the number of victims positively identified through the CDA method.

Study risk of bias assessment

The risk of bias assessment was performed qualitatively through Joanna Briggs Institute's Critical Appraisal Tools for Case Reports [19]. It should be noted that since the question given in the tool cannot directly translate into forensic studies, we used these questions as a guideline to read and interpret the studies (Table 2). Additionally, publication bias analysis was performed using Begg's rank correlation test.

Synthesis methods

Meta-analysis was used to provide a quantitative estimation of the overall outcomes within the included studies. In the context of this study, a random-effect model with proportion as the effect size was utilized to ascertain the approximate proportion of victims identified through dental identification, given the total number of victims.

The meta-analysis was carried out using R version 4.3.1 (R Foundation for Statistical Computing, Vienna, Austria) with meta version 6.5 package [20]. Within this framework, random-effect model with logit-transformed proportion effect size was implemented through the metaprop function utilizing the DerSimonian-Laird estimator and inverse variance method. To calculate heterogeneity, the I^2 statistics were employed. Furthermore, for an in-depth analysis of the data, an a-priori subgroup analysis was performed using categorical moderators such as the type of disaster (i.e., natural, or non-natural), the disaster classification (i.e., open or closed) and the country region (i.e., Europe, Asia, etc.).

Results

The literature search initially retrieved 3133 studies with 884 duplicates, which were detected both by automatic EndNote and manual detection. After an initial exclusion of titles ($n = 1904$) and abstracts ($n = 236$) due to the absence of any relevance to the research question, 109 studies remained for full-text reading. The exclusion reasoning was as follows: the disaster was already reported in another eligible study ($n = 14$), lack/absence of report of overall identification or dental identification ($n = 44$), studies were not accessible ($n = 18$), or not reporting a mass disaster ($n = 3$). Additional records were added from citation searching, resulting in four additional studies (Fig. 1).

Study characteristics

The summarized qualitative analysis from around the globe can be seen in Table 3. The reported year of disasters ranged from 1964 to 2018, with a total of 3 to 15,892 victims and 1 to 2493 victims identified through CDA alone. Thirty-seven disasters were man-made or human-error accident [21–45], and seven disasters were of natural cause [6, 46–51]. Of 32 eligible studies, five studies reported multiple disasters [26, 27, 31, 33, 37], resulting in a total of 44 disasters analyzed.

The highest proportional value of a victim identified was from Eysines Air Crash (1987) where all victims (16/16) were identified through CDA [31]. Additionally, the lowest proportional value was seen from Sharm al-Shaykh bombing, where only one person out of 88 victims was identified through CDA [33]. Most of the disasters reported that the absence of AM data or unclear AM data when available

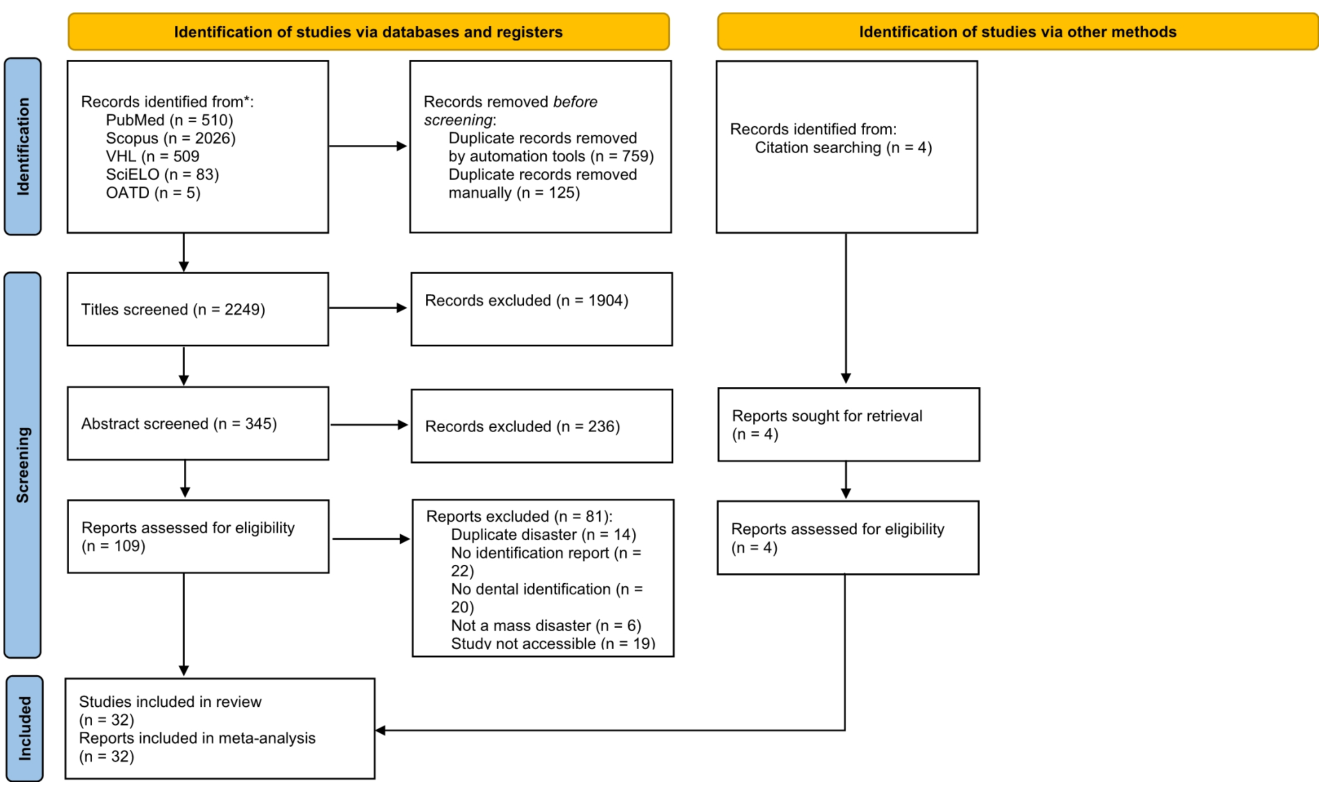

Fig. 1 PRISMA flowchart

Table 3 Summary of the eligible studies sorted by year of occurrence

Study ID	Author	Disaster	Place of Disaster	Year of Occurrence	Total Number of Reported Victim(s)	Total Number of Victim(s) Identified from CDA
1	Cecchi et al.	Trans World Airlines 707 – 331	Italy	1964	50	38
2	Ligthelm A.J	South African Airways Boeing 707–320 C	Namibia	1968	123	31
3	Cecchi et al.	Leonardo da Vinci Airport Terrorist Attacks	Italy	1973	31	5
4	Dumancic et al.	Hellas Express 410	Croatia	1974	152	6
5	Dumancic et al.	British Airline and Slovenian Inex Adria Collision	Croatia	1976	176	37
6	Cairns et al.	Air New Zealand DC-10	New Zealand	1979	257	155
7	Bastiaan R.J	Victorian Bushfire	Australia	1983	72	14
8	Poisson et al.	Eysines Air Crash	France	1987	16	16
9	Ligthelm A.J	South African Airways Boeing 747-244B	Mauritius	1987	159	5
10	Cecchi et al.	Uganda Airlines 707–338 C	Italy	1988	33	2
11	Cecchi et al.	Nubia Ship Accident	Egypt	1988	33	12
12	Solheim et al.	Scandinavian Star Ferry	Denmark	1990	158	107
13	van der Kuijl et al.	MartinAir DC-10	Portugal	1992	56	55
14	Poisson et al.	Saint-Martial de Mirambeau Air Crash	France	1993	15	8
15	Hiss & Kahana	Suicide Bombing Accidents	Israel	1993	171	22
16	Soomer et al.	M/S Estonia	Finland	1994	94	57
17	Hutt et al.	ALIT 5148 Air Crash	France	1995	87	56
18	Nambiar et al.	Malaysian Airlines Fokker 50	Malaysia	1995	34	7
19	Valenzuela et al.	Bailen Bus Accident	Spain	1996	28	16
20	Valenzuela et al.	Illescas Bus Accident	Spain	1997	10	8
21	Poisson et al.	Bordeaux-Sarlat Regional Express Train	France	1997	13	12
22	Peng et al.	SilkAir Air Crash	Indonesia	1997	104	2
23	Brkic et al.	Petrinja Mass Graves	Croatia	1997	46	7
24	Brkic et al.	War Victims Mass Graves	Croatia	2000	1000	206
25	Gill J.R	World Trade Centre	U.S.A	2001	2749	387
26	Cecchi et al.	Vetotene Street Building Collapse	Italy	2001	8	1
27	Bux et al.	DHC-6 Twin Otter	Nepal	2002	18	10
28	Cecchi et al.	MSU Italian Military Base	Iraq	2003	28	4
29	Petju et al.	Thailand tsunami	Thailand	2004	5395	2493
30	Cecchi et al.	Sharm al-Shaykh Bombing	Egypt	2005	88	1
31	Hinchliffe et al.	Comair CRJ-100	U.S.A	2006	49	47
32	Tena & Bajo	Spanair MD 88	Spain	2008	152	7
33	Hinchliffe et al.	Victorian Bushfire	Australia	2009	173	69
34	Bush et al.	Colgan Air flight 3407	U.S.A	2009	50	38
35	Trengrove H.	Christcurch Earthquake	New Zealand	2011	181	58
36	Iino & Aoki	Tohoku Tsunami	Japan	2011	15,892	1259
37	Obafunwa et al.	DANA Air Crash	Nigeria	2012	152	15
38	Dahal et al.	Nepal earthquake	Nepal	2015	400	6
39	Toupenay et al.	13 November Paris Terrorist Attacks	France	2015	129	7
40	Beauthier et al.	Brussels Airport	Belgium	2016	35	14
41	Quatrehomme et al.	Promenade de Anglais Terrorist Attack	France	2016	84	15
42	Gin et al.	California Wildfire	U.S.A	2018	84	5
43	Dahal et al.	US Bangla Bombardier DHC8-Q400	Nepal	2018	49	19
44	Novia & Yudianto	Nganjuk Toll Road Accident	Indonesia	2020	3	1

were the main reasons of difficulties ($n=10$) [27, 29, 32, 36, 37, 41, 44, 46, 49, 52], followed by difficulties in body recovery, body conditions and fragment analysis ($n=8$) [6, 24, 33, 34, 46, 48, 50, 51]. Additionally, difficulties related to the team and body management ($n=7$) [24, 27, 33, 35, 46, 49, 50], and the lack of experienced, trained, or skilled personnel in the team were reported ($n=4$) [6, 27, 46, 48].

Risk of bias

All the eligible studies reported to have a low risk of bias, except the study by Van der Kuijl et al. (1995) [21]. Begg's rank correlation test indicated that publication bias was not present in our systematic review ($p > 0.05$).

Meta-analysis

The overall result of the meta-analysis revealed that the mean weighted proportion of victims that can be identified through CDA alone in mass disaster is 0.32 (CI 0.25–0.4), with considerable heterogeneity ($I^2 = 0.99$) (Fig. 2).

Through sub-group comparison, only two sub-groups yielded significant results: disaster classification and region (Table 4). Closed disasters tend to have a significantly higher CDA proportion ($n = 24$, 0.49), compared to open disasters ($n = 20$, 0.15). In the region subgroup, it is seen that mass disasters that happens in North America have the highest proportion of positive identification through CDA ($n = 4$, 0.47), followed by Europe ($n = 22$, 0.42), Oceania ($n = 3$, 0.37), Asia ($n = 11$, 0.2), and Africa ($n = 4$, 0.08.

Discussion

Human identification, as a fundamental right, underscores the critical importance of searching for, rescuing, and naming missing individuals [3]. This critical endeavor demands rigorous scientific procedures by forensic specialists, as incomplete or inadequate PM assessments can lead to delayed or even erroneous identifications, constituting an important violation of human rights [53].

Several studies have emphasized the crucial role of forensic odontologists in DVI [2, 54]; however, quantifying the practical impact of CDA has remained elusive. This study utilizes a meta-analysis methodology to provide a quantified evaluation of CDA's potential contribution in mass disaster scenarios, presenting evidence to fill the existing knowledge gap. Through our analysis, the number of individuals most likely to be identified through CDA was presented, providing valuable insights for enhancing disaster preparedness, optimizing response efforts, and supporting education and training in the field.

The current outcomes of the mean weighted proportion meta-analysis yield a value of 0.32, indicating the ability of CDA to identify approximately one-third of victims in a hypothetical scenario, leaving the remaining two-thirds potentially identifiable through DNA and/or fingerprint analysis, or even a combination of these primary identification methods. In simpler terms, if a mass disaster involves 100 victims, CDA could potentially contribute to the identification of at least 32 individuals. Nevertheless, it is important to acknowledge that every disaster unfolds differently and uniquely, and CDA's effectiveness may be subject to various factors such as the level of damage to the body, conditions of remains, and the availability of resources [9].

Two sub-group analyses yielded significant results: one based on disaster classification (open or closed) and the other on geographical region (Europe, North America, etc.). These categorizations of open and closed disasters were based on victim information availability [55]. For example, a terrorist attack or landslide is considered an open disaster due to the uncertainty regarding the number and identities of the involved individuals. Conversely, incidents with preexisting lists, such as airline accidents with passenger manifests, are categorized as closed disasters. An exception may occur when a certain disaster involves passenger manifests and crashes into an open space such as a housing complex or building. In such cases, the disaster will be considered an open disaster. While the DVI protocol phases (Scene, PM, AM, and Reconciliation) remain the same for both classifications [1], AM and PM dental data is obtained significantly faster in closed disasters due to the availability of pre-existing records. Consequently, closed disasters tend to have a higher CDA probability compared to open disasters.

Three regions displayed noticeably higher CDA success rates: North America, Europe, and Oceania. This variation reflects differences in how dental records are managed and stored. The availability of AM data — which is a crucial part for CDA — hinges on robust record-keeping systems. Notably, all regions with high CDA probabilities are known for utilizing electronic dental record (EDR) [56–58]. These records have significant advantages over paper records because they simplify data transfer, management, and storage [59]. They also withstand destruction even in instances where healthcare facilities are destroyed during a mass disaster event [2]. This point is further evidenced by Petju et al. (2007), which found significant discrepancies in victim identification rates between regions based on the availability and quality of dental records following the 2004 Indian Ocean tsunami in Thailand [49]. These findings underscore the crucial role of efficient record-keeping systems in supporting successful CDA in mass disaster scenarios. However, implementing effective EDR systems requires careful consideration of user-friendliness, data standardization, ethics, and robust security measures.

Various factors can increase the probability of positive identification through CDA, such as scenarios involving severe incineration or various forms of DNA degradation. Conversely, numerous challenges reported by the reviewed studies can reduce the probability of positive identification through CDA. These challenges include four key aspects: (1) the scarcity of AM data, (2) difficulties in evidence

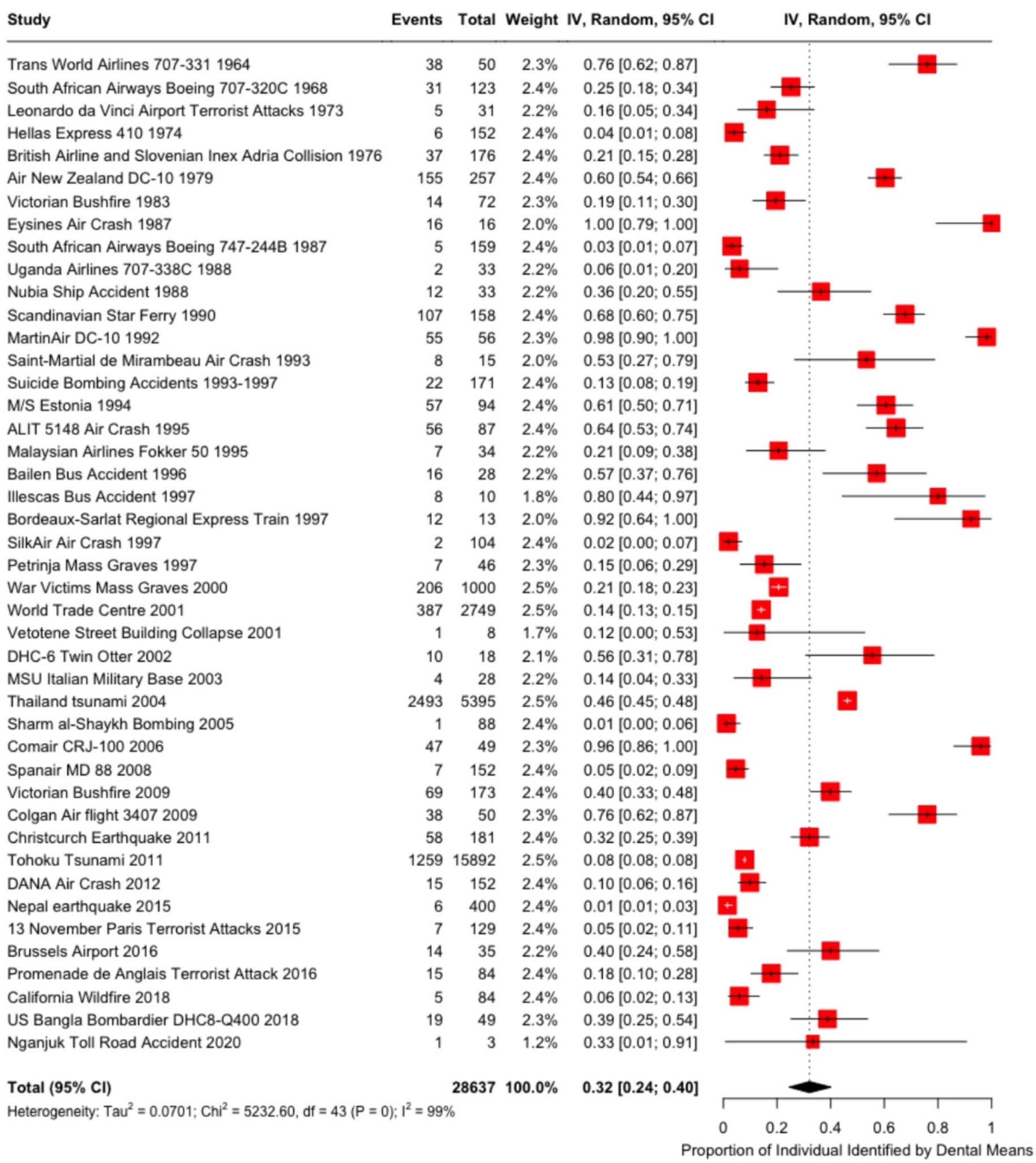

Fig. 2 Meta-analysis of the probability of a victim to be identified through comparative dental analysis

recovery, (3) issues related to team and body management, and (4) the varying levels of experience among forensic odontologists within the team.

Firstly, the scarcity of AM data is a well-known challenge influenced by factors such as the presentation (electronic or not), in other words, the dentists' record-keeping practices and accessibility [46]. Furthermore, this issue is aggravated in populations where individuals do not seek for dental care, or communities do not have access to healthcare [32]. The interpretation of dental records can also be challenging due

Table 4 Sub-group analysis for each variable

Sub-group	*n*	Weighted Proportion	95% CI	
			Lower	Upper
Type				
Man-Made	37	0.35	0.26	0.44
Natural	7	0.19	0.04	0.39
Classification*				
Closed	24	0.49	0.34	0.64
Open	20	0.15	0.08	0.24
Region*				
Europe	22	0.41	0.29	0.55
North America	4	0.47	0.09	0.86
Asia	11	0.2	0.06	0.38
Oceania	3	0.37	0.15	0.62
Africa	4	0.08	0.01	0.19

* = Statistically significant result ($p<0.05$), n = number of studies in each sub-group. CI = Confidence Interval

to the presence of codes, symbols, illegible notations, possible errors, and translation from foreign languages [60]. Even when AM data is available, variations in formats hinder a seamless comparison process [7]. While efforts have been made to standardize and simplify these records [60], a global directive from reputable organizations such as International Dental Federation or the INTERPOL is imperative. It is widely known that INTERPOL provides a standardized form and guidelines [1], however, the absence of official directive detailing its utilization and explanation of standardized odontogram abbreviation formats should be addressed.

Secondly, difficulties with the recovery of evidence (teeth) will affect the quality of PM data. Common causes that might be interconnected are the exposure of body remains to seawater and body decomposition that may lead to tooth loss due to periodontal tissue degradation, or trauma-induced dental fractures [61]. Bodies found near habitats of mammalian carnivores were also observed to have been scavenged, with some missing body parts [62]. In a mass disaster scenario with a high number of victims, a proficient team composed of experienced forensic odontologists is highly advisable. Collaborative efforts on an international scale or partnerships between governmental and academic bodies become imperative in ensuring that professional odontologists manage every mass disaster, thereby enhancing the effectiveness of victim identification processes [14].

Finally, it must be noted that the results obtained in this study are solely representative of the existing DVI reports available in the current scientific literature. By quantifying the eventual percentage of positive identifications after dental comparisons, we were able to present evidence to support the use of odontology not only as a primary method for human identification, but also as a solid and reliable tool in the forensic field. Because this is an overall idea of the potential of positive identification using CDA in mass disasters, judgements regarding its application in practice should be case-specific. This is to say that the effectiveness of dental human identification depends directly on the availability and quality of antemortem records, which varies from case to case. Future studies in the field are endorsed to test the association between the geographic availability of dental records and the effectiveness of CDA per region, or the operational difference between DVI operation to support a certain identification method. This way, strategies dedicated to educating the clinical practice regarding dental record production and keeping could be drawn, eventually promoting best practices with recommendations tailored for each country and transforming forensic odontology into an even more palpable solution.

Conclusion

This study provides evidence-based confirmation of the importance of CDA in the context of human identification in mass disaster. The current meta-analysis result suggests CDA potential to identify approximately one-third of victims in a hypothetical mass disaster scenario. Notably, this proportion is comparable to the significance of other primary identifiers, such as friction ridge analysis and genetics, emphasizing the integral role of teeth in the overall victim identification framework.

Key points

1. This study quantified dental identification probability based on existing reports in the literature.
2. Dental identification is useful in mass disaster cases.
3. Overall, at least 32% of mass disaster victims cases may be identified through dental identification.
4. Closed disasters have a higher probability of successful dental identification.

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Declarations

Competing interests The authors have no competing interests to declare that are relevant to the content of this article.

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