Artificial intelligence in detecting dentomaxillofacial fractures in diagnostic imaging: a scoping review protocol

Silviana Farrah Diba 1,2, Dwi Cahyani Ratna Sari 3, Yana Supriatna 4,5, Igi Ardiyanto 6, Bagas Suryo Bintoro 7,8

ABSTRACT

Introduction The dentomaxillofacial (DMF) area, which includes the teeth, maxilla, mandible, zygomaticum, orbits and midface, plays a crucial role in the maintenance of the physiological functions despite its susceptibility to fractures, which are mostly caused by mechanical trauma. As a diagnostic tool, radiographic imaging helps clinicians establish a diagnosis and determine a treatment plan; however, the presence of human factors in image interpretation can result in missed detection of fractures. Therefore, an artificial intelligence (AI) computing system with the potential to help detect abnormalities on radiographic images is currently being developed. This scoping review summarises the literature and assesses the current status of AI in DMF fracture detection in diagnostic imaging.

Methods and analysis This proposed scoping review will be conducted using the framework of Arksey and O’Malley, with each step incorporating the recommendations of Levac et al. By using relevant keywords based on the research questions, PubMed, Science Direct, Scopus, Cochrane Library, Springerlink, Institute of Electrical and Electronics Engineers, and ProQuest will be the databases used in this study. The included studies are published in English between 1 January 2000 and 30 June 2023. Two independent reviewers will screen titles and abstracts, followed by full-text screening and data extraction, which will comprise three components: research study characteristics, comparator and AI characteristics.

Ethics and dissemination This study does not require ethical approval because it analyses primary research articles. The research findings will be distributed through international conferences and peer-reviewed publications.

INTRODUCTION

Dentomaxillofacial (DMF) injuries can affect hard and soft tissues of the upper, middle and lower face, extending from the area of the frontal bone to the mandible, including the teeth and oral cavity. In 2019, 178 million new fractures were reported worldwide, with a prevalence of facial bone fractures of 10.7 million. These numbers are noteworthy given the significant role as these regions play in the sustainability of physiological processes such as respiration, speaking, mastication and vision. The most common causes of DMF fractures are road traffic accidents, physical assaults and falls. In addition, the incidence of these aetiologies differs based on the demographic, sociocultural and fracture characteristics.

Maxillofacial injury not only results in psychological and social-financial consequences but also causes clinical complications such as diplopia and eyelid ptosis, neurosensory complications including paraesthesia and facial nerve paralysis, hearing loss and hyposmia. In addition, oroantral communication, a condition in which an abnormal pathway forms between the maxillary sinus and the oral cavity, may occur and lead to fistulas or chronic sinus disease. Thus, the clinician should establish an appropriate treatment plan, beginning with diagnosing the fracture based on subjective, objective and diagnostic imaging examinations to restore physiological functions. Radiographic techniques for imaging DMF trauma range from conventional radiography to advanced imaging modalities such as computed tomography.
as computed tomography (CT), cone beam CT (CBCT) and magnetic resonance imaging (MRI). Plain radiography for maxillofacial trauma includes panoramic and skull radiographs (eg, posteroanterior, reverse towne and submentovertex); however, periapical radiographs are more effective in diagnosing dental fractures. Plain films are widely accessible and affordable; however, superimposition between bone images can reduce the accuracy. CT and CBCT, including advanced imaging, can image hard tissue in the coronal, sagittal and axial planes without superimposition. CT is currently the diagnostic gold standard owing to its accuracy, although it has some disadvantages, including higher cost and radiation exposure compared with plain radiographs. In contrast, MRI is used for soft tissue imaging and is rarely indicated in the diagnostic workup of patients with maxillofacial trauma. Facial trauma is frequently encountered in emergency departments and requires imaging studies to determine the fracture patterns and anatomical structures involved. Human factors, specifically fatigue during night shifts while interpreting radiographic studies, can lead to fracture diagnostic mistakes; up to 3.1% of fractures are not diagnosed during the initial visit to the emergency department. The delayed diagnosis of fractures can adversely affect the long-term efficacy of the treatment administered and increase pain and suffering. Therefore, an organisational management system, specifically the application of equipment that can help prevent errors, may decrease the frequency of fracture misdiagnosis. Thus, an advanced computer-system technology is currently being developed to aid clinicians in detecting fractures on radiographs and CT scans.

Artificial intelligence (AI) is a branch of computer science and a term used to describe a machine that can imitate human intelligence in performing certain tasks. Machine learning is one of its fields in which computers learn a pattern without being explicitly programmed. Regarding medical imaging, we need a programme that can process complex radiographic images; deep learning, which is a subset of machine learning, has been selected as the most popular technique. It comprises multiple interconnected layers forming a large artificial neural network through which the prediction algorithm can be constructed directly from the input data. Convolutional neural network (CNN) is a subset of artificial neural network that is frequently applied in image analysis, including medical imaging, to detect, segment and classify tasks. The detection task determines the location of the targeted object on the image by generating a bounding box and an object label. AlexNet, U-Net, DenseNet and ResNet are examples of the pretrained CNN models that have been established to detect mandibular fractures on panoramic radiographs and CT. The use of AI in diagnostic imaging is promising with the increase of the number of images that require interpretation since an automated programme is required to assist medical professionals in accelerating diagnoses.

The number of studies on diagnostic accuracy related to AI has increased sharply since 2017, of which, 25% discuss the AI algorithm. Many reviews were conducted on the clinical application of AI in DMF imaging according to cases and imaging techniques. Nagn et al and Hung et al reviewed the performance and clinical applications of AI in DMF radiology including anatomical landmarks automation in cephalometry and abnormalities detection, such as dental caries, periapical and periodontal disease, cysts and tumours. The scoping review conducted by Schweindicke et al described the use of AI, especially in the field of dental diagnostic imaging; however, no studies on tooth fractures were identified. In addition to conducting a systematic review, Rainey et al discussed fracture detection using AI on plain radiographs, whereas Kuo et al compared the diagnostic performance between AI and clinicians in fracture detection on various radiographic techniques. In summary, although prior reviews have discussed the use of AI in various diagnostic imaging techniques, fractures in other body parts rather than the DMF area were included.

As research on the application of AI in diagnostic imaging is ongoing and there are no literature reviews on the detection of DMF fractures using AI, we hope this upcoming scoping review will serve as a springboard for further research. This protocol aims to develop guidelines for conducting a scoping review that maps the academic literature and determines the extent to which research has been conducted on the use of AI in the detection of DMF fractures on diagnostic images.

METHODS AND ANALYSIS

A scoping review will be conducted using the Arksey and O’Malley approach, which entails five steps: (1) identifying the research question; (2) identifying relevant studies; (3) study selection; (4) charting data; (5) collating, summarising and reporting results. We will apply Levac et al recommendations at each of the five steps. Consultation, the sixth step, is optional in the Arksey and O’Malley technique, whereas it is a mandatory step in the Levac et al methods. Consultation aims to encourage knowledge transfer and research evidence exchange that bring value to the scoping review. This protocol does not include a consultation stage because of the required time and the limited use of AI among healthcare stakeholders including clinicians or in routine clinical practice. Most AI software developers create technologies for specific organisations and specialised goals that cannot be used widely across populations. The absence of a consultation stage in this protocol is anticipated with the diversity of the authors’ expertise background, which include physicians and radiologists, as well as a computer scientist to provide input on knowledge dissemination and the possibility of AI development in DMF diagnostic imaging.

Review protocols are relevant to both readers and authors as they provide transparency, clarity and future
reproducibility for the review process implementation and minimise duplication. Particularly, no guidelines were established for developing a protocol for a scoping review; thus, we used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews checklist, which provides reporting recommendations to develop deeper knowledge of the conceptual, methodological and reporting quality of scoping reviews (online supplemental files available). The steps of the scoping review process that will be implemented are as follows.

**Step 1: identifying the research question**

The first stage includes two tasks that should be completed: identifying a broad research question and determining the scope of the key concepts, target populations and results. Table 1 displays the research questions that will be discussed in the next scoping review.

The three concepts that summarise the research question are the AI model, location of the DMF fracture and diagnostic imaging technique used. First, the AI concept, which comprises four research questions (table 1), is established to determine the extent to which the AI model development components have been applied to detect DMF fractures on radiographs. Second, any DMF fracture sites detected in AI research should be identified. Furthermore, we should identify the medical imaging techniques that have been used in conjunction with AI to detect DMF fractures. The three concepts are likely to reveal research gaps to develop further studies. In general, the process of developing AI algorithms, especially deep learning, requires radiographical imaging data that have been labelled by experts, followed by a training to enable the AI model to recognise and detect pathological abnormalities. In addition, the effectiveness of AI in detecting abnormalities should be measured using outcome parameters, whose terminology is distinct in both medical and AI applications, and AI performance, which should then be compared with the experts’ diagnostic accuracy. In the medical field, diagnostic accuracy is reported in terms of sensitivity, specificity and area under the curve, whereas AI accuracy is reported in terms of F1-score, recall and precision.

Maxillofacial trauma includes frontal, nasal, orbital, zygomatic, maxillary and mandibular fractures. In addition to location, fractures can be classified according to their severity: simple fractures if the bone is broken into two pieces and comminuted fractures if the bone is broken into several small fragments. Moreover, this scoping review will cover dental fractures. In cases of mild or extensive maxillofacial trauma, the alveolar process and dental structures are typically involved.

The goal of diagnostic imaging is to locate DMF fractures to help in determining the diagnosis, treatment planning and clinical outcomes in terms of both physiological and aesthetic functions. Plain radiographs, including skull projection, panoramic and periapical radiograph, as well as advanced diagnostic imaging, including CT and CBCT, are the radiographic techniques commonly used to depict the DMF region. Articles on DMF fracture

### Table 1 Research questions of the scoping review

<table>
<thead>
<tr>
<th>Concept</th>
<th>Research questions</th>
</tr>
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<tbody>
<tr>
<td>Artificial intelligence</td>
<td>1. What types of AI architecture have been studied?</td>
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<tr>
<td></td>
<td>2. Who is the annotator that defines to the ground truth data, if any?</td>
</tr>
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<td></td>
<td>3. What kind of outcome model and parameter are used to evaluate the AI performance in terms of diagnostic accuracy?</td>
</tr>
<tr>
<td></td>
<td>4. Who is the comparison group to test the AI performance, if any?</td>
</tr>
<tr>
<td>Dentomaxillofacial fracture</td>
<td>Which dentomaxillofacial fractures have been studied for fracture detection using AI in diagnostic imaging?</td>
</tr>
<tr>
<td>Diagnostic imaging</td>
<td>What kinds of diagnostic imaging techniques have been studied?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Concept</th>
<th>Item found</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artificial intelligence</td>
<td>...</td>
</tr>
<tr>
<td>Dentomaxillofacial fracture</td>
<td>...</td>
</tr>
<tr>
<td>Diagnostic imaging</td>
<td>...</td>
</tr>
</tbody>
</table>

### Table 2 Sample of keywords and search queries for artificial intelligence and dentomaxillofacial fracture radiography

<table>
<thead>
<tr>
<th>No.</th>
<th>Keywords and queries</th>
<th>Item found</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(((((&quot;Artificial intelligence&quot;[MeSH Terms]) OR (&quot;AI (Artificial Intelligence)&quot;[Title/Abstract])) OR (&quot;Machine learning&quot;[MeSH Terms] OR (&quot;Deep learning&quot;[MeSH Terms])) OR (&quot;Supervised Machine Learning&quot;[MeSH Terms]) OR (&quot;Computer neural network&quot;[Title/Abstract])) OR (&quot;Convolutional neural network&quot;[Title/Abstract]) OR (&quot;CNN&quot;[Title/Abstract])</td>
<td>...</td>
</tr>
<tr>
<td>2</td>
<td>(&quot;fracture&quot;[Title/Abstract] AND &quot;maxillary&quot;[Title/Abstract]) OR &quot;maxilla&quot;[Title/Abstract] OR &quot;mandibular&quot;[Title/Abstract] OR &quot;mandible&quot;[Title/Abstract] OR &quot;jaw&quot;[Title/Abstract] OR &quot;tooth&quot;[Title/Abstract] OR &quot;dental&quot;[Title/Abstract] OR &quot;root&quot;[Title/Abstract] OR &quot;zygomat&quot;[Title/Abstract] OR &quot;midfacial&quot;[Title/Abstract] OR &quot;orbital&quot;[Title/Abstract] OR &quot;frontal&quot;[Title/Abstract]</td>
<td>...</td>
</tr>
<tr>
<td>3</td>
<td>(Radiography) OR (Radiography, Dental) OR (Radiography, Panoramic) OR (Panoramic radiograph) OR (Orthopantomograph) OR (Orthopantomogram) OR (Orthopantomograph)</td>
<td>...</td>
</tr>
<tr>
<td>4</td>
<td>#1 AND #2 AND #3</td>
<td>...</td>
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Open access

Table 3  Inclusion and exclusion criteria form

<table>
<thead>
<tr>
<th>Inclusion criteria</th>
<th>Exclusion criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original articles relevant to DMF fracture detection using deep learning models, including parameter outcome results</td>
<td>AI models used for reasons other than DMF fractures detection</td>
</tr>
<tr>
<td>Using any conventional (skull, panoramic or periapical radiography) or advanced radiographic techniques (CT or CBCT)</td>
<td>Review articles, case reports, letters to the editor or conference papers</td>
</tr>
<tr>
<td>Articles published since 2000 and afterwards</td>
<td></td>
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<tr>
<td>Articles published in English language</td>
<td></td>
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</tbody>
</table>

AI, artificial intelligence; CBCT, Cone beam computed tomography; CT, Computed tomography; DMF, dentomaxillofacial.

diagnosis using both conventional and advanced imaging will be included.

As an intervention, AI models encompass a broad range of architectures. The performance of diagnostic tests using AI will be compared with that of experts, including physicians, surgeons and radiologists. The research questions derived from the key concepts will serve as the basis for developing queries, choosing the inclusion and exclusion criteria, and selecting variables for data description.

Step 2: identifying relevant studies

At this stage, we will identify suitable primary studies to answer the research questions without compromising the breadth and comprehensiveness of the subsequent scoping reviews. To develop the search strategy, we will use a three-step process that corresponds to the Joanna Briggs Institute (JBI) systematic review standard.35

First, a preliminary limited search was performed on the MEDLINE database using the Medical Subject Headings (MeSH) keywords by entering three concept keywords which are “Artificial Intelligence” (MeSH), “fracture” and “radiography” (MeSH). The text words obtained from the title and abstract in the initial search will then be analysed to find the synonyms used to compose the query. Moreover, we will consult librarians to ensure that the search strategy structure is sufficiently comprehensive to capture relevant studies. The query structure based on the predetermined concepts is presented in table 2. Words associated with AI are included in the first group;

Figure 1  A flow chart diagram of study selection.28
different DMF fracture types are covered in the second group based on their location; and different radiographic examination synonyms are included in the third group. The Boolean operator ‘OR’ is used within the same concept group while ‘AND’ is used to combine concepts. Based on the initial search, relevant studies first appeared in 2009, although research on the diagnostic accuracy of AI in radiology appeared in 2000 and has shown a significant increase in 2020.20 36 37

Second, the databases that will be used in this study (eg, PubMed, Scopus, Science Direct, Cochrane Library, SpringerLink, Institute of Electrical and Electronics Engineers, and ProQuest), will be searched using all the identified keywords and index phrases. To meet the interdisciplinary nature of the research questions, the data used will be drawn from both the health field and informatics domain

<table>
<thead>
<tr>
<th>Table 4 Preliminary data charting</th>
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</thead>
<tbody>
<tr>
<td>Research study characteristics</td>
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<tr>
<td>Author(s)</td>
</tr>
<tr>
<td>Title</td>
</tr>
<tr>
<td>Year and country</td>
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<tr>
<td>Study objective</td>
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<tr>
<td>Study design</td>
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<tr>
<td>Fracture location</td>
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<tr>
<td>Diagnostic imaging technique</td>
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<tr>
<td>Comparator</td>
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<tr>
<td>Comparison group</td>
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<tr>
<td>Artificial intelligence</td>
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<tr>
<td>characteristics</td>
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<tr>
<td>AI architecture</td>
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<tr>
<td>Annotator</td>
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<tr>
<td>Workflow</td>
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<tr>
<td>Training set demographics</td>
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<tr>
<td>Validation technique</td>
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<tr>
<td>Model output</td>
</tr>
<tr>
<td>Outcome parameter</td>
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<tr>
<td>AI, artificial intelligence</td>
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</tbody>
</table>

Third, the references from the identified papers will be used to search for additional studies. Once all the articles are acquired from multiple databases, duplicates will be excluded using the Reference Manager tool (Endnote20 Clarivate Analytics).

**Step 3: study selection**

At this stage, screening is required to ensure consistency among reviewers in deciding whether to include articles covering the topic of this study.38 Because of the differences in knowledge and experience among the reviewers participating in the process of scoping review preparation, the potential for errors and disagreements might exist. To anticipate this, Tricco et al recommended a calibration exercise in which all reviewers screen 50 articles before screening the titles and abstracts. After the screening completion, the results are compared. A predetermined level of agreement of 75% must be reached.28

Levac et al suggested that the title, abstract and full text be reviewed separately by at least two reviewers.25 In this study, the initial screening of titles and abstracts after duplication removal will be conducted independently by two reviewers according to the inclusion and exclusion criteria outlined in table 3. This selection procedure helps in excluding numerous irrelevant articles.38 According to the protocol recommended by Granheim et al, one reviewer will screen the entire articles, while the remaining four will serve as independent second reviewers.39 Each second reviewer will receive an equal number of articles and identify the reason behind the article exclusion. If the two main reviewers disagree, a third reviewer, who is one of the three other than the two primary reviewers, will be involved. Articles that pass the screening will undergo data extraction at a later stage (figure 1).

**Step 4: data charting process**

At this stage, a logical and descriptive summary, adjusted to the objectives and scope of the research question, will be presented.35 The two reviewers will complete a preliminary data charting form, as shown in table 4. The other reviewers will independently conduct a pilot test data extraction on two random included articles to ensure consistency. The results will be compared and discussed, and any inconsistencies will undergo a revision of charting data if necessary as this is an iterative process.28 After all reviewers agree on the data charting format, data extraction will be conducted independently following the pattern of the previous step. The first reviewer will perform data charting on all included articles, and the second reviewer will extract them with an equal distribution of amounts. Disagreements will be
resolved by involving a third reviewer, in a process similar to the method used in the study selection. Some of the key information gathered in the data charting form will be updated in accordance with the JBI’s recommendations in response to the questions and will be addressed in the upcoming scoping review. The variables that will be collected include general information such as author(s), publication year, country of origin and research type, as well as key concept groups such as fracture location and the used diagnostic imaging technique. Some essential information on AI interference will be grouped separately as it should be thoroughly discussed.

**Step 5: collating, summarising and reporting the results**

At this stage, major findings from the included articles will be analysed and summarised to collect all the information from the previously obtained charting data. The data analysis will yield a descriptive summary, numerical counts and a thematic analysis. The results will provide information on the status of the current research on the use of AI in diagnostic imaging to detect DMF fractures. In general, the results will include three concepts: the research study, comparator and AI characteristics. The results should describe the identified research gaps, as well as the strengths and limitations of the existing literature. This can serve as a precursor to a more specific research question for future systematic reviews.

**Patient and public involvement**

No patients or participants were involved in this study.

**Ethics and dissemination**

The article review that will be conducted does not involve human research subjects or other personal information; therefore, ethical approval is not required. New researchers interested in conducting scoping reviews may find the methods outlined in this protocol helpful.

The research results will be formatted into publications, submitted to an international peer-reviewed journal, and presented at conferences.

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SFD compiled the research concept, designed a search strategy for database articles and drafted the manuscript. DCRS, VS, YA supported conceptualisation by providing feedback based on expertise in each area as well as assisting with the compilation of preliminary charting. BSB assisted in the development of research questions, including compilation of search queries and finalisation of manuscripts. All authors gave final approval to the manuscript.

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**Competing interests**

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**Patient and public involvement**

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**Patient consent for publication**

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**Provenance and peer review**

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**Supplemental material**

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