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Exploring the use of AI in odontology for paediatric patients : a systematic integrative review.

Diego Alexandre Adam Joda

Dissertação conducente ao **Grau de Mestre** em **Medicina Dentária (Ciclo Integrado)**

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Trabalho realizado sob a Orientação de
Mestre Selma Pascoal

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AGRADECIMENTOS

Gostaria de agradecer à minha família pelo apoio constante durante estes 5 anos, particularmente aos meus pais e minha irmã que confiaram em mim e sem os quais eu não teria podido ir a CESPU, a dez mil km da minha casa.

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RESUMO

Introdução: A inteligência artificial (IA) é a capacidade que um computador tem de reproduzir um determinado raciocínio, planeamento e mesmo a criatividade semelhante à do ser humano. A relevância desta revisão reside na oportunidade de explorar a importância da IA na nossa vida moderna, no futuro fluxo de trabalho dos consultórios dentários, sendo a literatura escassa no âmbito da IA em Odontopediatria.

Objetivo: Determinar de que forma a IA pode ser aplicada em odontologia pediátrica.

Materiais e métodos: Foi realizada uma pesquisa bibliográfica na base de dados PubMed. Os resultados incluem estudos publicados que cumprem os critérios no período de 2013 até 23 de janeiro 2023.

Resultados: Várias pesquisas foram realizadas em pacientes pediátricos em relação à estimativa de idade dentária, posicionamento dentário e diagnóstico de cárie. A maioria desses estudos encontrou conclusões positivas relativamente à precisão dos modelos de aprendizagem profunda aplicados à análise de imagens.

Discussão: Na literatura enfatiza a importância de investigações adicionais com amostras mais significativas. A aplicação desses modelos no fluxo de trabalho odontológico e as preocupações éticas foram também discutidas.

Conclusão: A AI mostra resultados promissores no campo da odontopediatria, mas mais pesquisas são necessárias, a regulamentação ética sobre privacidade de dados precisa ser adotada e aplicada.

ABSTRACT

Introduction: Artificial intelligence (AI) is the ability of a computer to reproduce a certain reasoning, planning and even creativity similar to that of a human being. The relevance of this review lies in the opportunity to explore the importance of AI in our modern life, in the future workflow of dental offices, since literature is scarce in the field of AI in Paediatric Dentistry.

Aim: To determine whether AI can be applied in paediatric dentistry.

Materials and methods: A literature search was conducted in the PubMed database. The results include published studies meeting the criteria in the period from 2013 to January 23, 2023.

Results: Several researches have been conducted in paediatric patients regarding dental age estimation, tooth positioning and caries diagnosis. Most of these studies found positive conclusions regarding the accuracy of deep learning models applied to image analysis.

Discussion: In the literature the importance of further investigations with more significant samples is emphasised. The application of these models in the dental workflow and ethical concerns were also discussed.

Conclusion: AI shows promising results in the field of paediatric dentistry, but more research is needed, ethical regulations on data privacy need to be adopted and enforced.

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AI: Artificial Intelligence

ANN: Artificial Neural Network - a machine learning algorithm modelled after the structure of the human brain.

CNN: Convolutional Neural Network - a deep neural network commonly used in image and video recognition.

DL: Deep Learning - A specific branch of machine learning, known as deep learning, involves the utilization of neural networks that consist of three or more layers.

GDPR: General Data Protection Regulation – Privacy and security law of European Union.

ML: Machine Learning - a field of computer science that uses statistical models and algorithms to enable computers to learn from and make predictions on data.

1. Introduction

In this century, Artificial Intelligence (AI) is already an essential tool in medicine. The last research in AI tries to mimic human intelligence and approximate the power of the human brain. A large dataset is a prerequisite. Once trained with those data, the machine has the capability to enhance the diagnosis and treatment plan in the medical fields(1). In this century, AI is changing and will change society and the world economy at a surely faster pace than the computer revolution of the last century(2).

AI refers to techniques that aim to understand and imitate human intelligence to solve complex problems, such as image recognition. Machine learning (ML) is the set of techniques that allows a computer to learn. There are several types of learning, supervised, unsupervised learning, and reinforcement learning are the mains. Deep learning (DL) is a subgroup of ML. It consists of algorithms composed of several layers of artificial neurons capable of analysing unstructured data, such as dental X-rays. The term "deep" refers to neuron layers. The term "deep" refers to neuron layers(3): each neuron is connected to others in a weighted manner. Each synaptic connection can be strengthened or weakened by adjusting the weight through iterative learning (4).Thanks to Backpropagation during the training of the model. For Imaging diagnosis, Convolutional Neural Network (CNN) models are used. It is a form of a more complex neuron network, designed to be more efficient than a simple neuron network by adding filters called transformers blocs in the hidden layers to segment the image. It helps the model to analyse images more efficiently.

Indeed, the digital revolution has also affected the field of dentistry, thus influencing modern dentistry by disrupting the workflow of dental practices. It began by introducing advanced and less ionising complementary diagnostic tools such as panoramic radiography and cone beam computed tomography. Additionally, there have been significant advancements in prosthodontics, including the CAD/CAM system, digital impression-taking, and 3D scanning for impressions. More recently, there has been a growing use of deep learning-based diagnostic software to aid in diagnosis(3). Current knowledge already proves that AI techniques can aid dentists in infection control, clinical decision-making, oral

diagnosis, restorative dentistry, endodontics, orthodontics, and periodontics(5). Preclinical studies have shown encouraging results in localising root canal orifices, detecting vertical fractures, and dental cavities or evaluating bone loss. Nevertheless, further studies need to be performed to confirm all those information (6). Most of the Research previously quoted was performed on a pull of adult patients.

Advancements in medical imaging research, particularly those involving machine learning implementation. This leads to an interrogation of the quality of the results that could be obtained. Find the accuracy of such tools. Furthermore, the possibility of integrating these innovative technologies into the paediatric dental office workflow will show how such a disruptive instrument is regulated and controlled. The relevance of these review lives in the opportunity to explore the importance of AI in our modern life, in the future workflow of dental practices, due to the lack of literature review on the field of IA in Paediatric dentistry.

2. Objective

This systematic review aims to investigate AI's current clinical application and diagnostic performance in paediatric dentistry.

3. Materiel and Method

This systematic review was performed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines(7).
The electronic database PubMed was searched to find AI's different applications in paediatric odontology. Searches were performed from 2013 to January the 23rd, 2023.

All records were exported to an Excel file (Microsoft® Office), and the software filter removed the duplicates and then manually verified them. Two authors (D.J. and S.P.) independently screened the titles and abstracts of all identified studies. The same authors evaluated the full texts of the most relevant studies to assess their eligibility.

All data related to study characteristics and outcomes from the included studies were extracted to an Excel spreadsheet by one author (D, J) and reviewed by another author (S.P). Data related to the study characteristics were collected (year, study design, measured variables, and outcomes analysis).

3.1 Eligibility criteria

The research question and the selection of studies included in this systematic review were elaborated according to the PICo strategy and the inclusion and exclusion criteria.

Table 1. PICo Strategy

P	Population	Paediatric subjects are susceptible to needs diagnosis with a dental imaging tool.
I	Interest	The events of interest will be measured if AI implementation in dental imaging tools is a proper

		increment in paediatric dentistry workflow in terms of accuracy and reliability.
Co	Context	In many developed countries, the traditional way of performing dental work has been replaced by a digital workflow using electronic tools and processes as imaging acquisition devices. In the past few years, AI researchers have made significant advances, and nowadays, AI models can be implemented in many sectors, and healthcare is a promising one.

3.2 Inclusion criteria

- Articles with a publication date between 2013 and January the 23rd, 2023
- Retrospective studies
- Paediatric population
- Radiology-based clinical studies using AI models for automatic diagnosis of tooth position, tooth recognition decays, age maturation or detection of cleft palate.

3.3 Exclusion criteria

- Articles with a publication date prior to 2013.
- Article with others Imaging methods.
- Full text is not accessible.
- Review or meta-analysis, case studies or conference proceeding
- Articles not in English

3.4 Research strategy

Table with the number of results and combination of keywords

Table 2. Combinations of keywords and articles found.

Platform	**Combination of Mesh Terms**	**Results**	**Results after filters**	**Selected Articles**
PubMed	Keys words: Artificial Intelligence[Mesh] OR Diagnosis, Computer-Assisted[Mesh] OR Neural Networks (Computer)[Mesh] OR AI OR CNN OR Machine learning OR Deep learning OR Convolutional OR Automatic OR Automated AND Diagnostic imaging[Mesh] AND Dentistry[Mesh]	**1998**	**850**	**14**

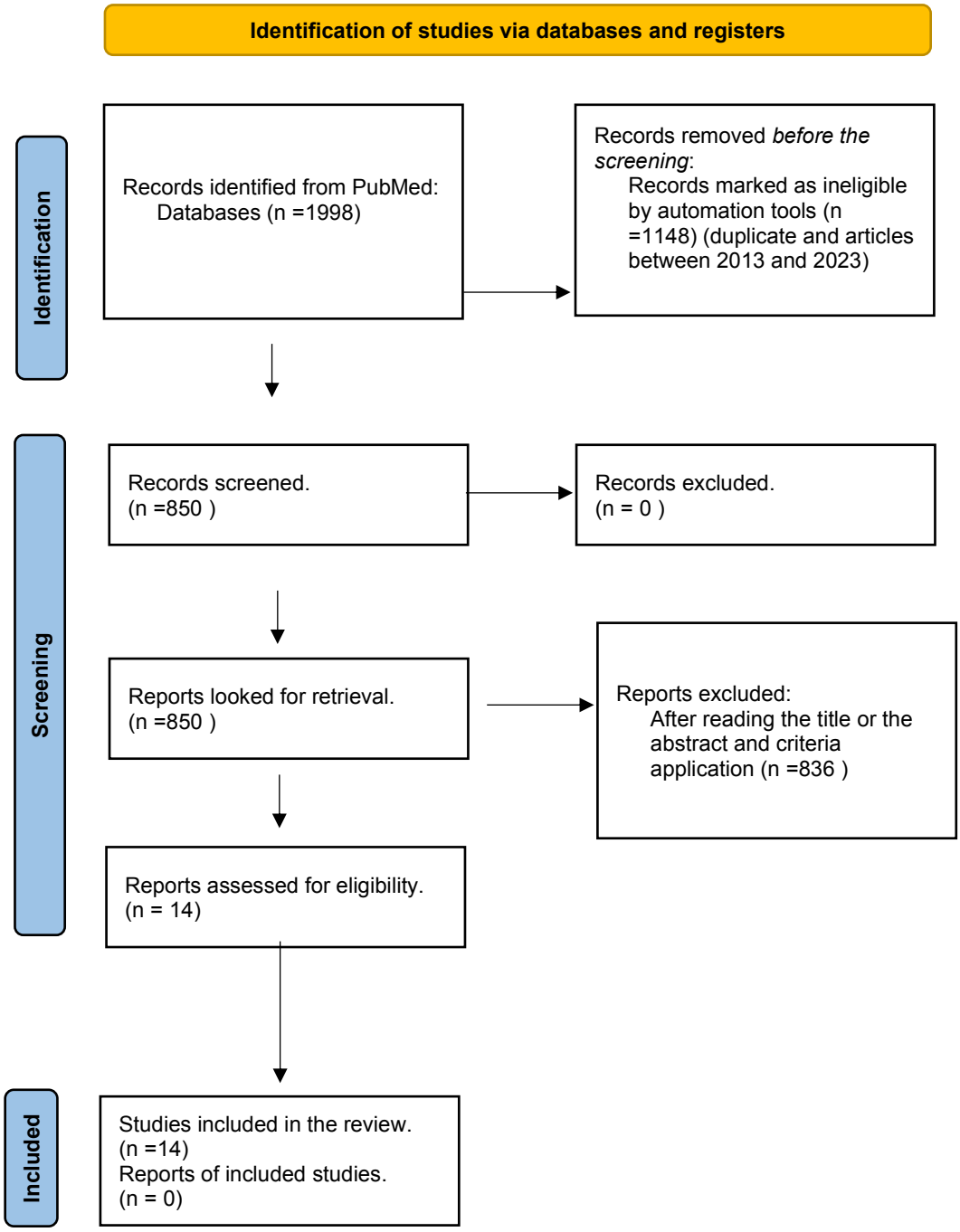

Figure 1. PRISMA 2020 flow diagram for new systematic reviews, which included searches of databases and registers only.

4. **Results**

The search in the PubMed database resulted in 1998 articles. The first analysis phase involved a date removal, and systematic review articles were also removed. During the second phase, titles and abstracts were read following the inclusion and exclusion criteria. After thoroughly reading the remaining articles, fourteen were used to prepare the table out of a total of articles used in this thesis.

In this paper, we review fourteen articles, six of which focused on the implementation of AI in different applications of radiographic diagnosis. four studied tooth positions in the alveolar arch, one detected and enumerated teeth, one focused on cleft alveolus with and without cleft palate detection and classification, one detects mesiodens and one on decay detection. All studies were performed on paediatric patients' panoramic radiographs, except one on cephalometric and hand-wrist X-rays.

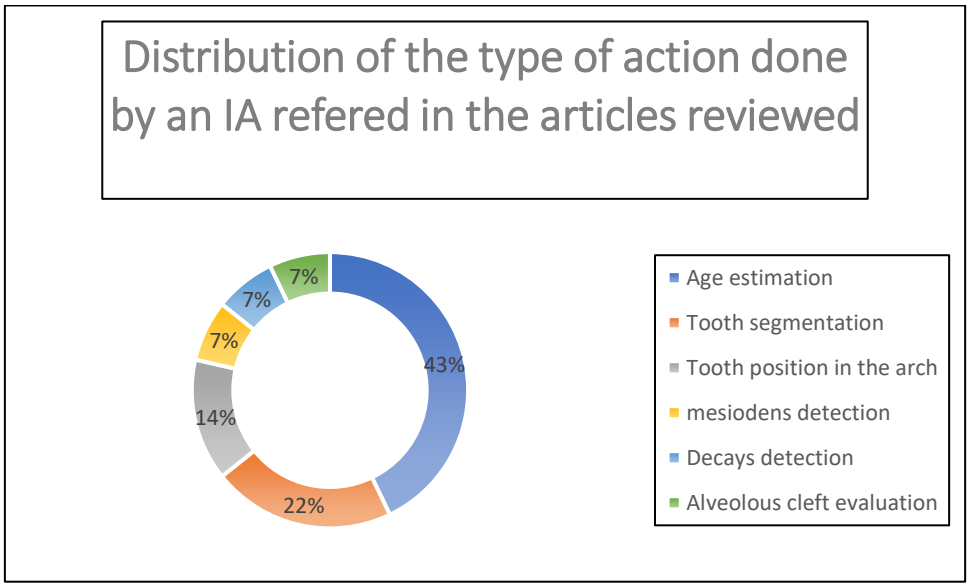

Figure 2 – Circular Diagram

Table 3. Details gathered from the selected studies.

Authors, year	Study design	Objective	Material and methods	AI technique	Function	Outcome
Bunyarit *et al.,* 2022 (8)	Retrospective cross-sectional study	The study aims to set up a population-specific prediction model for accurate dental age estimation in this ethnic group.	Dataset: 1015 Dental panoramic tomographs of Malaysian Indians aged 5.00-17.99 years. Calculation of dental age using Chaillet and Demirjian's eight-tooth method and compared it to a population-specific prediction model using artificial neural networks multilayer perceptron.	ANN-MLP	Determinate age of a specific population base on a dataset composed of panoramic radiography	Chaillet and Demirjian's modified eight-tooth method underestimated the dental age of Malaysian Indian children and adolescents. The study set up a novel Malaysian Indian-specific prediction model using ANN-MLP that resulted in highly correct dental age estimation. The new set of dental maturity scores and prediction formula developed in the study can be used for correct dental age estimation in this ethnic group.
Zhu H *et al.*, 2022 (9)	Retrospective study	Compared performance of an ANN vs dentist in ectopic eruption of	The paper used the nnU-Net algorithm to develop an AI model for automatically detecting and segmenting ectopic eruption of first permanent molars in early mixed	ANN named nnU-Net	detect ectopic eruption of first permanent	model based on nnU-Net algorithm was able to automatically detect and segment ectopic eruption of first permanent molars in early mixed dentition on

		first permanent molars	dentition on panoramic radiographs. The detecting performance of the nnU-Net was compared with that of three dentists with different years of experience		molars in early mixed dentition on panoramic radiographs .	panoramic radiographs with high accuracy and consistency. The model outperformed the detecting performance of dentists with different years of experience. The study confirmed the use of AI in dental radiography for more efficient and accurate detection of first permanent molars.
Kim J *et al.*, 2022 (10)	Retrospective study	The aim of this paper is to develop and evaluate the performance of a deep learning model that can automatically diagnose mesiodens in growing children using only panoramic radiographs	The study used 988 panoramic radiographs of growing children, out of which 489 patients with mesiodens were classified as an experimental group, and 499 patients without mesiodens were classified as a control group.	The study developed two deep learning networks: a segmentation network (DeeplabV3plus) and a classification network (Inception-resnet-v2).	Detect mesiodens in a panoramic radiography	- The segmentation network using the posterior molar space in panoramic radiographs was able to confine the ROI with high accuracy, which led to high classification accuracy of mesiodens - The results of this study confirmed the possibility of a fully automated process for diagnosing mesiodens using only panoramic radiographs. - The study suggests that this DL model could be the basis for automatically finding other

						diseases using only panoramic radiographs.
Liu J *et al.*, 2022 (11)	Comparative study	to develop an automatic model that can aid dentists in this task and allow timelier interventions	- Two paediatric dentists with five years of clinical experience independently evaluated two hundred regions from 100 panoramic radiographs, which contained normal and ectopic eruption cases. - The radiographs were selected to cover a wide range of ectopic eruption manifestations in children aged 4-9. - 1580 images were included in the training set, and 100 images (200 regions) in the testing set.	Convolutional neurone network	Detection of ectopic eruption of the maxillary first molar	- The study developed an automated screening method with high accuracy in detecting ectopic eruption of maxillary primary first molars, comparable to that of experts. - While the AI-assisted image recognition model can slightly enhance the accuracy of manual interpretation, DL alone is not entirely reliable in detecting ectopic eruption. - Regular follow-ups and re-evaluations are necessary to address the potential risk of false negative diagnoses.
Zhao W *et al.*, 2022 (12)	Retrospective study	To compare the accuracy of Demirjian and	Seven hundred forty-eight panoramic images of adolescents aged 5 to 13	ML-supervised regression algorithms: DT,	Dental age estimation	The prediction accuracy of dental age was affected by ML algorithms. MD, MAD, MSE, and

		Cameriere methods for deciding dental age using ML and to evaluate the prediction capabilities of three ML algorithms (DT, BRR, KNN).	years old, including 356 females and 392 males.	BRR, and KNN were used to predict dental age.		RMSE of the dental age predicted by ML significantly decreased. The KNN model based on the Cameriere method had the highest accuracy
Cieślińska K *et al.*, 2022(13)	Retrospective study	To develop neural models for evaluating the placement of the second premolar tooth's bud by analysing tooth-bone markers of other teeth.	Three hundred x-rays of Polish children aged 6 to 10 years old, including 165 males and 135 females.	Two distinct types of ANN: RBF and MLP Multilayer Perceptron.	Evaluation of the second premolar's bud position	The study found that a RBF network was the most right in predicting the position of the second premolar tooth's bud, achieving 91% accuracy. The study suggests that neural modelling techniques can be used to improve the accuracy of dental development assessments and treatment planning for orthodontic or other dental procedures. The method could be incorporated into a computer program to aid

						healthcare professionals in their practice.
Zhou X *et al.,* 2022(14)	Retrospective study	Improve the accuracy of paediatric dental caries diagnosis on panoramic X-rays by enhancing conventional convolutional neural networks.	A reference group of individuals without cavities of similar age. The database included 210 panoramic radiographs with at least one cavity and ninety-four without cavities.	Alexnet, Googlenet, VGG16, VGG19, Resnet18, Resnet50, Resnet101, and Xception networks Context-aware CNN	Carie diagnosis	The context-aware CNN model had a higher accuracy rate than the diagnoses made by two experienced doctors with five years of experience. However, the proposed model relies on manually extracting each tooth from dental panoramic X-rays, making it less practical for clinical use without added human annotation.
Shan W *et al*., 2022 (15)	Retrospective study	The research examines the applicability of traditional estimation methods for populations in southern China and evaluates the	One thousand four hundred seventy-seven panoramic radiographs from southern China, with 644 males and 833 females between the ages of 2 to 17.99 years old.	SVR, BPNN, Random forest AdaBoost, KNN, Light GBM, XGBoost, Extra trees, Decision trees,	Dental age estimation	The study compared different methods for estimating dental age in children aged 7-8. The Demirjian method was more correct than the modified and Willems methods. However, for other age groups, the Willems method was more exact. The study also found that the use of ML methods, such as GBDT,

		effectiveness of various machine learning algorithms when applied to the same data.		GBDT, CatBoost		can effectively improve age estimation accuracy and supply guidance for age assessment in different regions.
Kaya E *et al*., 2022(16)	Retrospective study	Evaluate the performance of a deep learning system in automatically detecting and labelling teeth in panoramic X-rays of children.	4545 panoramic X-ray images of children between the ages of 5 and 13 were used for this study.	CNN algorithm, YOLO V4	Tooth recognition for permanent and primary tooth	The proposed algorithm achieved high accuracy and speed in tooth detection and numbering. By combining the ability of dental professionals with the capabilities of DL models, the proposed algorithm can improve treatment outcomes and ease more accurate and efficient disease diagnoses.

Shen S *et al.*, 2021 (17)	Retrospective study	evaluate the accuracy and reliability of the Cameriere method, using seven lower left permanent teeth, for dental age estimation in children	Seven hundred forty-eight children, 356 females and 392 males aged between 5.00 to 13.99 years.	RF, SVM, and LR	Dental age estimation	ML algorithms can improve the accuracy of dental age estimation compared to traditional methods such as the European or Chinese Cameriere formulas. Specifically, the SVM, LR, and RF models proved higher accuracy in predicting dental age. These results support using ML algorithms as a superior alternative to traditional Cameriere formulas for dental age estimation.
Kuwada C *et al.*, 2021(18)	Retrospective study	Detection and diagnosis of cleft lip and palate using a DL object detection technique. The researchers aimed to assess the model's performance with and without average data in the	Panoramic radiographs of 383 patients with unilateral cleft alveolus, with a mean age of 9.3 years for both male and female patients. Two groups: 174 cleft alveolus only group, and 209 had cleft alveolus and cleft palate. To compare the performance of the DL models with human observers, two radiologists with more than four years of experience in interpreting	The study developed two CNN using DetectNet 1. The first model was trained solely on panoramic radiographs with anomalies, and two. model was trained using a	Detection and classification of unilateral cleft alveolus with and without cleft palate	The DL model has the potential to detect and classify cleft alveolus on panoramic radiographs. The model was trained using a small dataset with a regular group, so the results cannot be generalised. Further research should use larger datasets from multiple hospitals and different panoramic machines to improve the model's performance.

		learning process and find any appearance features related to its performance. Another goal was to compare the DL model's performance with that of human observers to evaluate its usefulness.	panoramic radiographs classified the same testing data used to verify the deep learning models' performance.	dataset of panoramic radiographs both with and without anomalies. In this study, anomalies referred to cleft lip and palate.		The model with a dataset of panoramic without cleft lip and palate performed better than the one with only anomalies. Model 2 had an accuracy of 82.2%, while the two radiologists had an accuracy of 73.3%., Almost a 10 % difference in favour of AI in terms of precision.
Kök H *et al.*, 2021(4)	Retrospective study	Use an ANN to identify growth and development stages and gender based on cervical vertebrae characteristics.	- The study included 419 patients between the ages of 8 and 17. - An ANN was trained on reference points from the radiographs to predict the age group of patients. - The data was split into three sets for training, testing, and validation. - Two ANN models with high accuracy were selected, and their results were reported in the paper.	The researchers employed a supervised learning algorithm called "Scaled Conjugate Gradient Backpropagation."	Determination of growth and development periods in orthodontics	- The ANN algorithm showed promising results : - The 6th Model exhibited the highest accuracy with a score of 0.94. - The study highlights the potential for using ANN in orthodontics for age prediction.

Vranckx M *et al.* , 2020(3)	Retrospective study	Develop an AI tool capable of segmenting mandibular molars on panoramic radiographs and extracting their orientations, which could help predict the probability of third molars erupting.	- The study used 838 panoramic radiographs, with 588 used for training and technical validation and 250 for clinical validation. - In two stages, the fully CNN used a pre-trained Resnet-101 model for molar segmentation and orientation estimation. - Accuracy was evaluated by comparing the network's angle measurements with human reference measurements within a predefined error range.	CNN, Restnet-101	Predict the first molar eruption path.	- The study developed an AI tool that accurately measures the angle of molars in panoramic radiographs. - The tool was validated and shown to predict segmentation maps and orientation lines for third molar eruption prediction. - Dental practitioners can use this tool to improve routine care and increase diagnostic accuracy. - The tool has a high accuracy rate of 98.1% with a 5-degree margin of error.
Banar N *et al.*, 2020(19)	Retrospective study	Fully automate the staging process by maximising CNN and integrating them into every procedure stage.	The study used a dataset of 400 panoramic images selected by three observers. The process involved three stages: localisation, segmentation, and classification. CNN were used in each stage to complete the staging process's automation.	Yolo-like architecture convolutional neural network	Third molar development staging	The study proposed a model that can automate determining third molar stages in less than 3 seconds, outperforming the manual process. Although the dataset was limited, the fully automated method showed promising results compared to the manual determination of third molar stages.

			The localisation stage found the region of interest having the dentition. The segmentation stage delineated the individual teeth in the region of interest. The classification stage used a deep learning model to stage the dental development of each tooth.			

Legend: **AI:** Artificial Intelligence ; **ANN**: Artificial Neural; **BPNN**: Backpropagation Neural Network; **BRR**: Bayesian Ridge Regression; **CNN**: Convolutional Neural Network; **DetectNet**: a deep learning framework developed by NVIDIA for object detection in images and video; **DL:** Deep Learning; **DT**: Decision; **GBDT**: Gradient Boosting Decision Tree; **GBM:** Gradient Boosting Machine; **GBPM**: Gradient Boosting Permutation Method; **KNN**: k-Nearest Neighbors; **LR**: Logistic Regression; **MAE**: Mean Absolute Error **ML:** Machine Learning; **MLP:** Multilayer Perceptron; **OPG**: Orthopantomogram; **RBF**: Radial Basis Function; **RF**: Random; **RMSE**: Root Mean Squared; **ROI**: Region of Interest; **ROI-P**: Region of Interest; **ResNet**: Residual; **SVM**: Support Vector; **SVM-RFE**: Support Vector Machine Recursive Feature Elimination; **SVR**: Support Vector Regression; **YOLO**: You Only Look Once

The Scientific Journal Ranking score was also used to evaluate the scientific influence of academic journals by publication date for each selected study. Their respective rankings are showed in the following table (Table 4). 50% of the article are in the top ranking of the journal, 14,3% are in the second quartile. The 35,7% remaining are in the third quartile of the ranking.

Table 4 - Scientific Journal Ranking quality rating of academic journals

Study	**Journal**	**Rank**
Bunyarit *et al.*, 2022 (8)	Annals of Human Biology	Quartile 3
Zhu H *et al.*, 2022(9)	International Journal of Paediatric Dentistry	Quartile 1
Kim J *et al.*, 2022 (10)	Dentomaxillofacial Radiology	Quartile 1
Liu J *et al.*, 2022 (11)	Journal of Dentistry	Quartile 3
Zhao *et al.*, 2022 (12)		
Cieślińska K *et al.*, 2022(13)	International Journal of Environmental Research and Public Health	Quartile 2
Zhou X *et al.*, 2022(14)	Computational and Mathematical Methods in Medicine	Quartile 3
Shan W *et al.*, 2022 (15)	Nature	Quartile 1
Kaya E *et al.*, 2022(16)	International Journal of Clinical Paediatric Dentistry	Quartile 3
Shen S *et al.*, 2021 (17)	BMC Oral Health	Quartile 1
Kuwada C *et al.*, 2021(18)	Nature	Quartile 1
Kök H *et al.*, 2021(4)	Orthodontics and Craniofacial Research	Quartile 1
Vranckx M *et al.*, 2020(3)	International Journal of Environmental Research and Public Health	Quartile 2
Banar N *et al.*, 2020(19)	International Journal of Legal Medicine	Quartile 1

5. Discussion

Zhou X *et al.* (2022) (14) compared the ability to diagnose a cavity on a dataset of dental radiographies of patients from the Beijing children´s hospital. The results showed a significantly diminution of the time needed between two five-year attending doctors and the CNN context aware. The machine needed sixty-four fewer times to make a diagnosis. The CNN context aware were also compared to mainstream models as Alexnet Googlenet or Resnet18 for example. All the evaluation metrics demonstrate the superiority of the professionals versus the CNN context aware model of this study but, this paper advances the possibility for CNN to be an Aid-Diagnosis for practicians, and the limitation was that the model in this research could only give a binary answer to the presence of decay, while in dentistry, we use classifications to diagnose cavities stages (13). A study by Devlin H *et al. (*2021) (20) published in the journal of the British Dental Association showed that a dentist assisted by a CNN context aware named "AssistDent" had better sensitivity to assessing proximal caries, but less sensibility compared to an unassisted dentist. Indeed, the use of AssistDent increased the detection of enamel-only proximal caries by 71%, assisted participants were 11% less likely to correctly find healthy proximal surfaces as non-carious. Notably, the use of an aid diagnosis software here allows an increase in the percentage of detection of carious lesions, but at the same time, also an augmentation of false positives. In other terms, a sensibility augmentation with a specificity diminution.

Also, other studies on Paediatric patient's panoramic radiography have been conducted and shown promising results. For example, a precision of 85% in the detection and enumeration of primary and permanent teeth would be suggested in the conclusion of the research conducted by Kaya E *et al.* (2022) (16) They concluded that combination of deep learning-based models with the practice of dental experts may provide better treatment outcomes and accurate diagnoses of diseases in less time. In the field of detection and enumeration, some investigators trained models on their ability to detect the angulation of a tooth in the arch (13,19) or to predict the eruption area as Vranckx *et al.*(2020) (3) showed

after demonstrate that the model were two to four times more quicker than the manual orientation method, conclude that the CNNs that they trained can assist dentist in the adolescents' third molar eruption of and angulation prediction in a fast, consistent and accurate way. Liu J *et al.* (2021) (11) showed that ectopic eruption of primary first molar detection diagnosis and interpretation can be as correct as experts' level of performance. Additionally, they concluded in this paper that it should also be study the effect of possible false negative diagnosis and follow-ups and revaluation is needed(10). Also, in 2022 Cieślińska *et al.* (13) published a method to determine with a machine learning model based on 21 tooth and bone parameters the second premolars' bud position, the results demonstrated that this methodology can be used as an algorithm for implementation in a computer application that will automatically determine the position of bud on panoramic radiographs of children and adolescents aged 6 to 10 years, and concluded that it is a promising tool to help practitioners in their clinical work (12). But as mentioned Kök H *et al.* (4) in their study on the determination of growth development stage, further studies need to be performed to obtain fully automated systems or aid-system that doctors could rely on. But, on the other hand Kim J *et al*. (2022) conclude that a fully automated process for diagnosing mesiodens is already possible (9).

In our review most of the research articles were on implementing an ML model in software that decided tooth maturation, some of them compared the Demirjian method *versus* the Cameriere method (8,17,21,22). One limitation was that the dataset was too narrow on a specific geographical zone and had few images. Willem's method also has been studied by Shan W *et al.* (2021) (14). All articles reviewed conclude that the ML model trained to estimate age was significantly more exact than other methods studied.

Kuwada C *et al.* (2021) (18) studied the capacity of CNN to detect a Clef alveolus and classify it into two categories, with or without palate involvement. The result is encouraging despite the limitation of the size of the data sample, indeed, to obtain trustful tools powered by DL technology, Large and best-quality data samples are required (17).

The use of machine learning in medical imaging has the potential to improve healthcare, but it is also raise important ethical and legal questions. Algorithms may perpetuate bias in the diagnosis and treatment of dental diseases. Additionally, there are questions about patient privacy and the security of medical data collection to train AI systems. Clear guidelines on the use of AI are needed to ensure that these technologies are used safely and effectively. That is why in Europe, the General Data Protection Regulation (GDPR) is an essential regulation tool, effective since 2018 in the European Union and in the European Economic Area. Its first aim is to protect privacy and persona data of citizen of the EU/EEA. Medical images are considerate as sensitive personal data under the GDPR. This mean added safeguards must be put in place to protect the data: explicit consent from the patient, in a way that ensures its confidentiality and integrity. It also gives patients the right to access their data and request that it be corrected or removed if it is inaccurate or no longer necessary for its intended purpose(23).

After, reviewing these studies, its seems that promising results are describe in the domain of tooth enumeration, age estimation/angulation, cleft alveolus detection, or simple decay detection for paediatric patients. Nevertheless, exciting outcomes in research led to dentistry on adults subjects, for example, root canal detection, study of anatomy, disease prediction, treatment plan, implant planning and tumour detection, with high accuracy and precision results (21).

It is important to note that large-quality datasets are needed to train a trustful model. In the AI field, bias in the algorithm construction can lead to outperformance during the clinical application, for this reason, ethical concerns about the use of AI in medicine are essential.

In the near future, it will be possible for patients to fill out their medical history online, it would be available digital aid assistant to analyse every type of medical imaging that could give a diagnosis and treatment plan and after validation, the DL-powered assistant could send by email all the information about the treatment. Then, after treatment, the patient will be able to dialogue with chatbots pre-trained about how to behave and calm anxieties. Even further, saliva

could be analysed in real-time thanks to small chips, or the clinician could also evaluate the quality of brushing with a "Smart toothbrush".

Gordon Moore, one of the co-founders of Intel Corporation, saw in 1965 that the number of transistors on a microchip doubled approximately every two years while the cost per transistor decreased, which allowed it to run on more powerful hardware every two years DL algorithm. Technical limits in 1989, when Yann Lecun, a pioneer in AI, demonstrated the feasibility of imaging recognition with the help of CNN (24), do not exist today. Yann Lecun describes that in 2025 processors will be able to have the same computing capacity as a human brain. Also, the increasing number of papers published in dentistry in this domain shows a growing interest in those solutions.

Dental practitioners are susceptible to embrace those tools in the digital workflow of their practice because they have the moral and ethical obligation to implement the best means and technologies. IA is efficient in extensive data analysis, recognising all shades of grey where a human can distinguish just a few. How Dentists might adapt the best to those innovative technologies could be the subject of a new systematic review.

6. Conclusion

AI shows promising results in various aspect of paediatric dentistry, such as decays detection, orthodontic treatment plan, age estimation, detection of anatomical areas in panoramic. However, more research in the field of paediatric dentistry is needed with wider and qualitative dataset. Different model architectures needed to be done to evaluate the long-tern efficacy and reliability of AI in clinical settings. Moreover, ethical, and legal implication must be taken seriously by authorities to develop a regulation in digital tools powered by AI that dentists can use. Overall, the integration of AI in paediatric dentistry has the potential to improve the quality of care and improve patient outcomes.

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