



**Maîtriser l'IA pour générer un jumeau numérique**  
**Master RB 14 -Dr Raphaël Richert**



**Je ne déclare aucun conflit d'intérêt**

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**INSA** | INSTITUT NATIONAL  
DES SCIENCES  
APPLIQUÉES  
LYON





**Siri**

*Sortie initiale 2011*



# Siri

Kumar et al. *J Big Data* (2019) 6:111  
<https://doi.org/10.1186/s40537-019-0268-2>

Journal of Big Data

**SURVEY PAPER**

**Open Access**



## Internet of Things is a revolutionary approach for future technology enhancement: a review

Sachin Kumar<sup>1\*</sup> , Prayag Tiwari<sup>2</sup> and Mikhail Zymbler<sup>1</sup>

\*Correspondence:  
sachinagnihotri16@gmail.com

<sup>1</sup> Department of Computer Science, South Ural State University, Chelyabinsk, Russian Federation  
Full list of author information is available at the end of the article

### Abstract

Internet of Things (IoT) is a new paradigm that has changed the traditional way of living into a high tech life style. Smart city, smart homes, pollution control, energy saving, smart transportation, smart industries are such transformations due to IoT. A lot of crucial research studies and investigations have been done in order to enhance the technology through IoT. However, there are still a lot of challenges and issues that need to be addressed to achieve the full potential of IoT. These challenges and issues must be considered from various aspects of IoT such as applications, challenges, enabling





Journal of Manufacturing Systems 58 (2021) 346–361

Contents lists available at [ScienceDirect](https://www.sciencedirect.com)



ELSEVIER

Journal of Manufacturing Systems

journal homepage: [www.elsevier.com/locate/jmansys](http://www.elsevier.com/locate/jmansys)

## Review of digital twin about concepts, technologies, and industrial applications

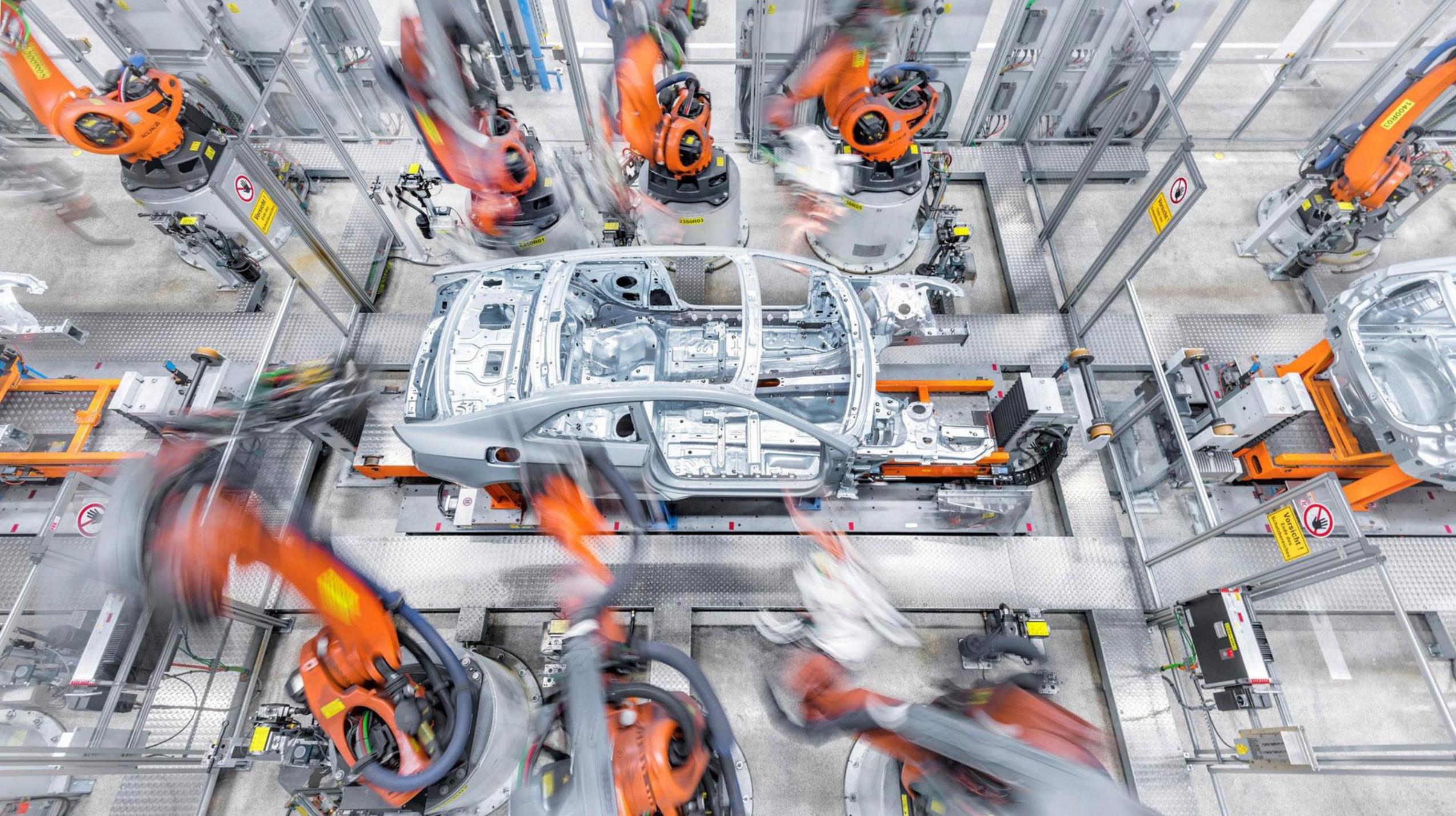
Mengnan Liu <sup>a,b</sup>, Shuiliang Fang <sup>a,b,\*</sup>, Huiyue Dong <sup>a,b</sup>, Cunzhi Xu <sup>a,b</sup>

<sup>a</sup> State Key Laboratory of Fluid Power and Mechatronic System, College of Mechanical Engineering, Zhejiang University, Hangzhou, 310027, China

<sup>b</sup> Key Laboratory of Advanced Manufacturing Technology of Zhejiang Province, College of Mechanical Engineering, Zhejiang University, Hangzhou, 310027, China

ARTICLE INFO

ABSTRACT





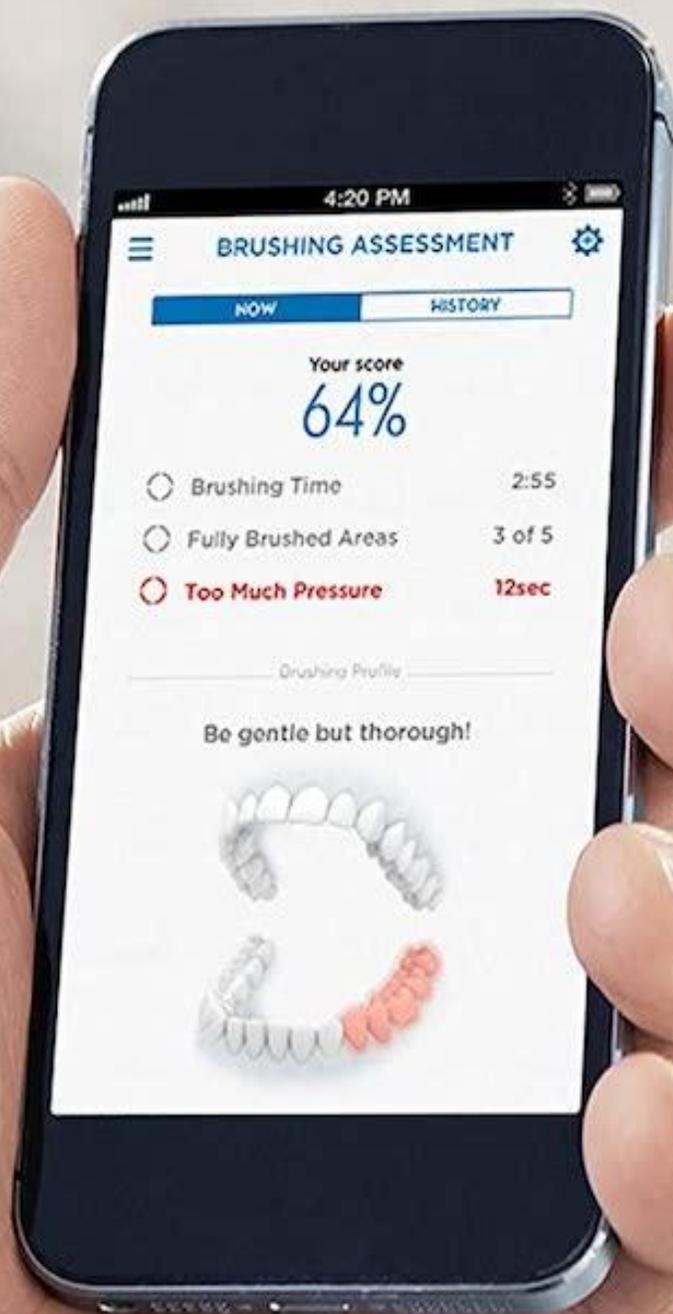


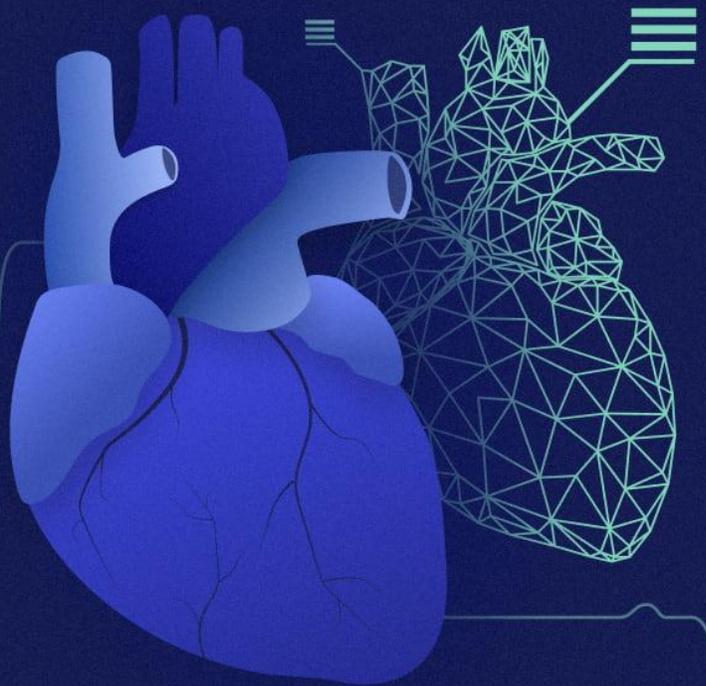
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the crown.





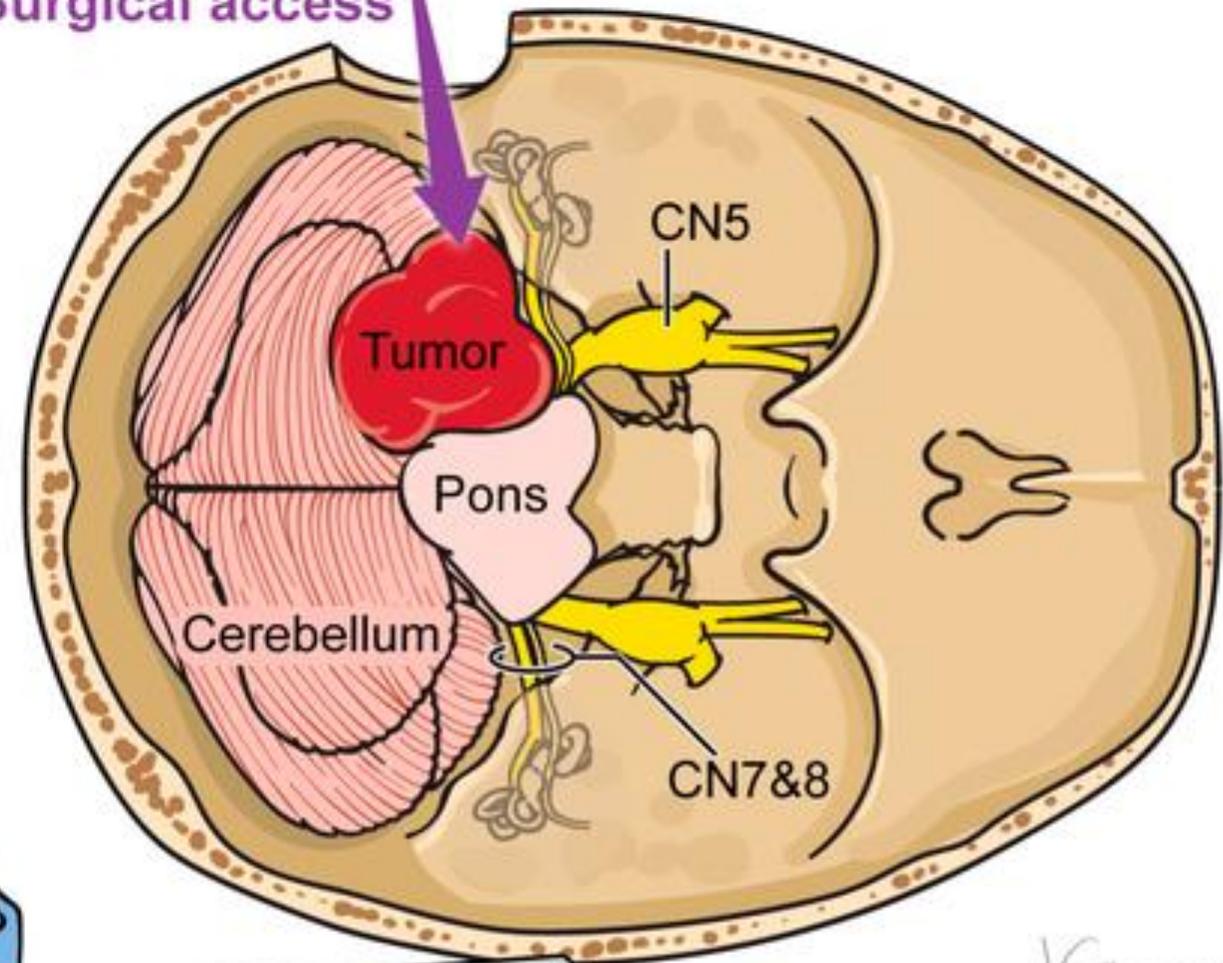
## Digital twins for health: a scoping review

Evangelia Katsoulakis<sup>1,2</sup>, Qi Wang<sup>3</sup>, Huanmei Wu<sup>4</sup>, Leili Shahriyari<sup>5</sup>, Richard Fletcher<sup>6,7</sup>, Jinwei Liu<sup>8</sup>, Luke Achenie<sup>9</sup>, Hongfang Liu<sup>10</sup>, Pamela Jackson<sup>11</sup>, Ying Xiao<sup>12</sup>, Tanveer Syeda-Mahmood<sup>13</sup>, Richard Tuli<sup>2</sup> & Jun Deng<sup>14</sup> ✉

The use of digital twins (DTs) has proliferated across various fields and industries, with a recent surge in the healthcare sector. The concept of digital twin for health (DT4H) holds great promise to revolutionize the entire healthcare system, including management and delivery, disease treatment and prevention



Surgical access



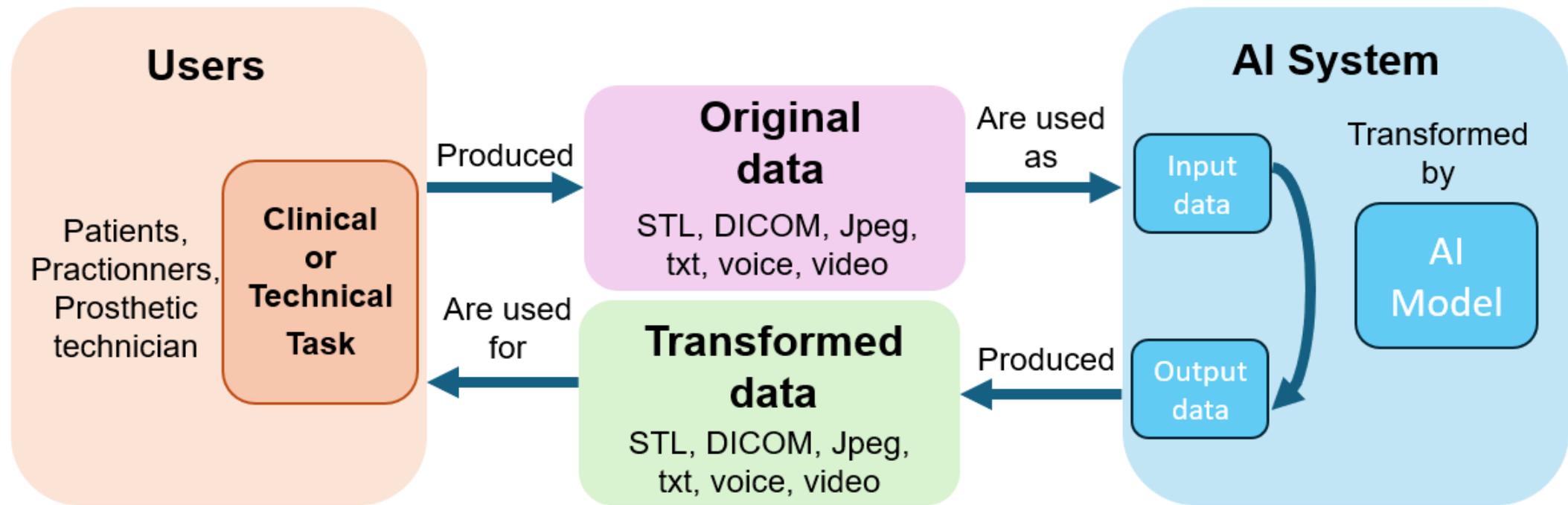
J. Gregory

# Un exoscope utilisé pour la première fois en France en neurochirurgie pédiatrique

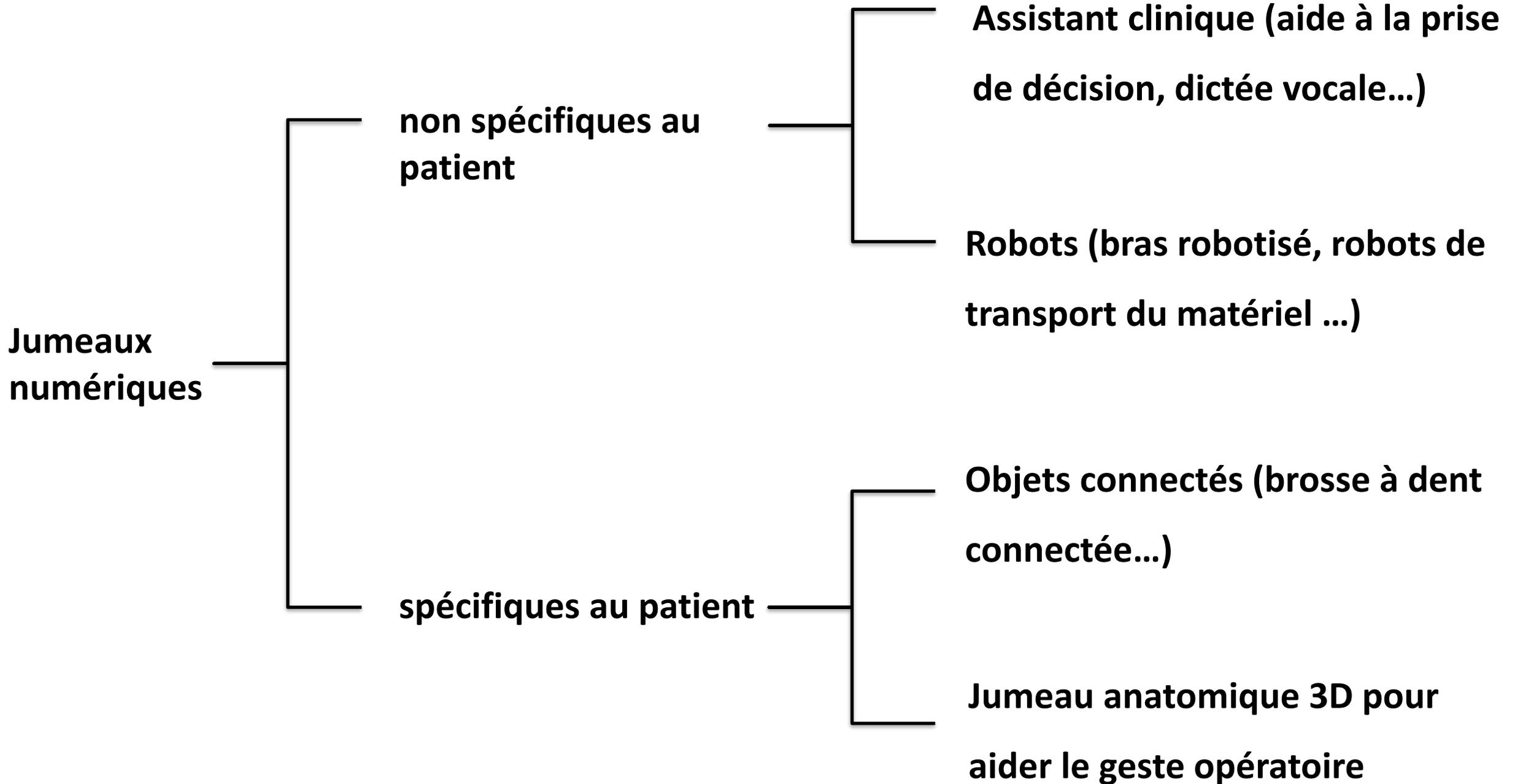


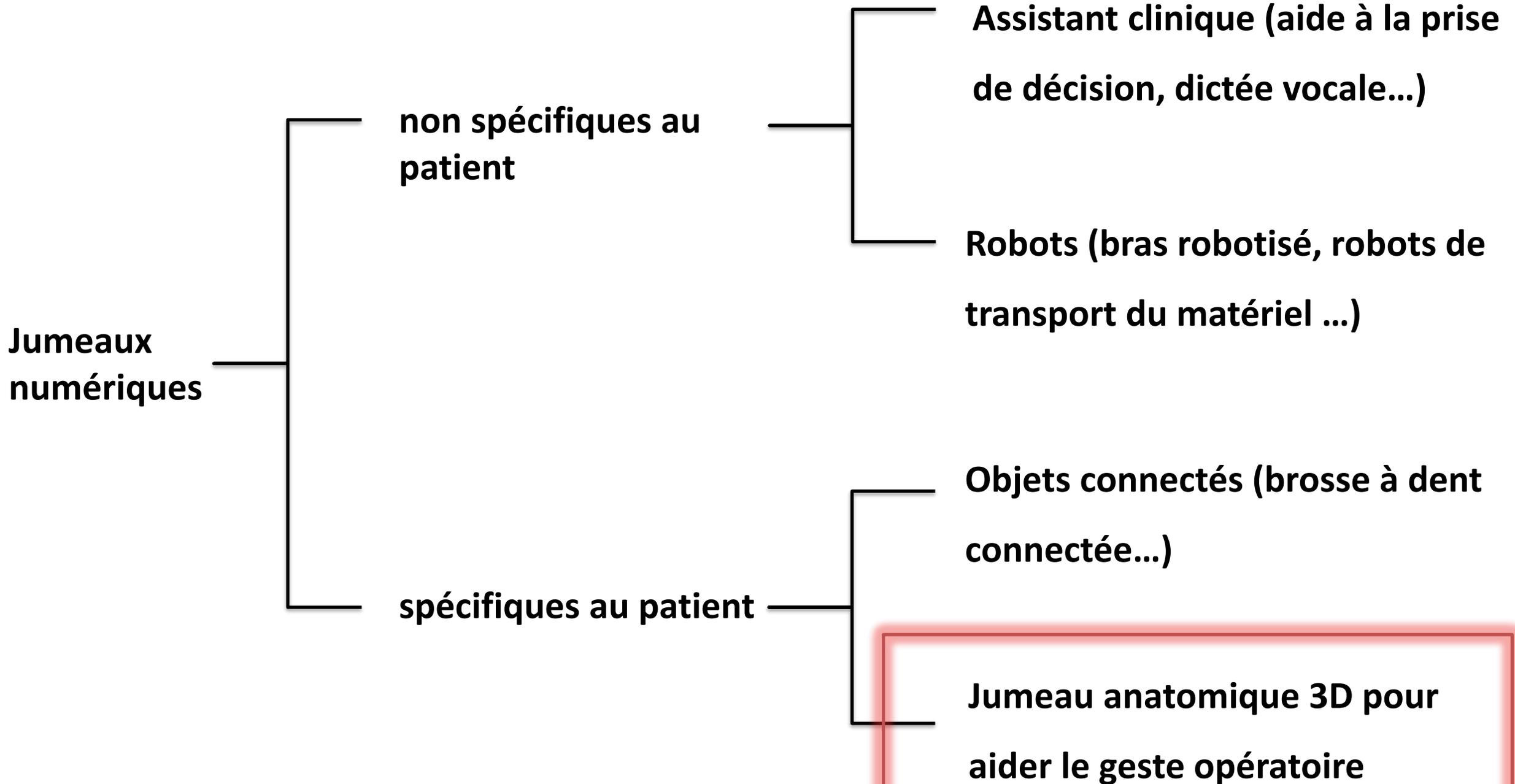






*[Faure et al. 2026] updated from OECD definition of AI*





# *Evolution of our practice*



# Evolution of our practice



**United States Patent** [19] [11] **Patent Number:** 4,611,288  
Duret et al. [45] **Date of Patent:** Sep. 9, 1986

[54] APPARATUS FOR TAKING ODONTOLOGICAL OR MEDICAL IMPRESSIONS [56] References Cited  
U.S. PATENT DOCUMENTS

 **ELSEVIER SAUNDERS**

Dent Clin N Am 52 (2008) 707–730

**THE DENTAL CLINICS OF NORTH AMERICA**

### What is Cone-Beam CT and How Does it Work?

William C. Scarfe, BDS, FRACDS, MS<sup>a,\*</sup>,  
Allan G. Farman, BDS, PhD, DSc, MBA<sup>b</sup>

<sup>a</sup>Department of Surgical/Hospital Dentistry, University of Louisville School of Dentistry, Room 222G, 501 South Preston Street, Louisville, KY 40292, USA  
<sup>b</sup>Department of Surgical/Hospital Dentistry, University of Louisville School of Dentistry, Room 222C, 501 South Preston Street, Louisville, KY 40292, USA

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pon an optical im-  
with nontraumatic  
transformed into  
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brication process.  
cal applications as

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# Evolution of our practice



**United States Patent** [19] [11] Patent Number: 4,611,288  
Duret et al. [45] Date of Patent: Sep. 9, 1986

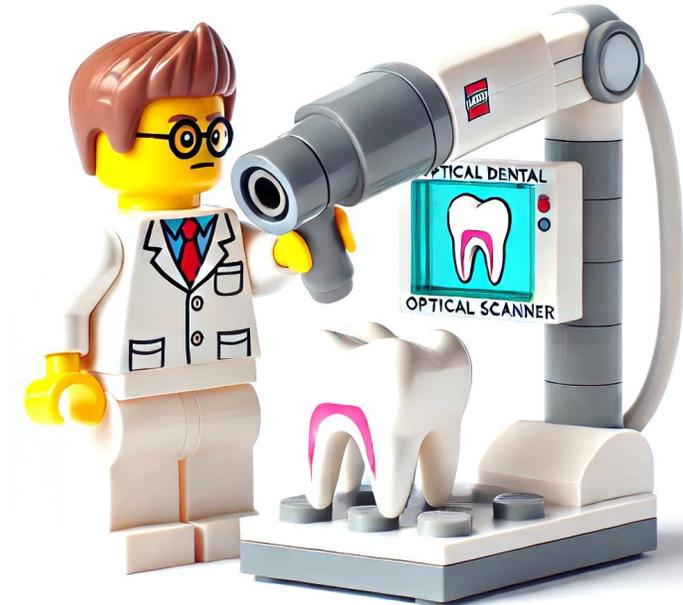
[54] APPARATUS FOR TAKING ODONTOLOGICAL OR MEDICAL IMPRESSIONS [56] References Cited U.S. PATENT DOCUMENTS

 THE DENTAL CLINICS OF NORTH AMERICA  
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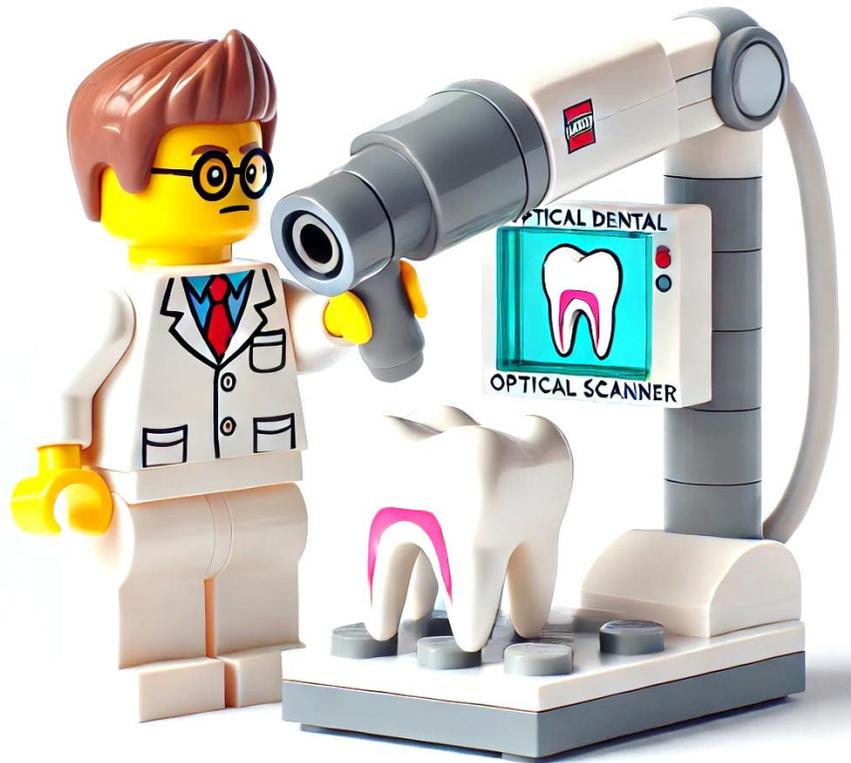
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<sup>b</sup>Department of Surgical/Hospital Dentistry, University of Louisville School of Dentistry, Room 222C, 501 South Preston Street, Louisville, KY 40292, USA

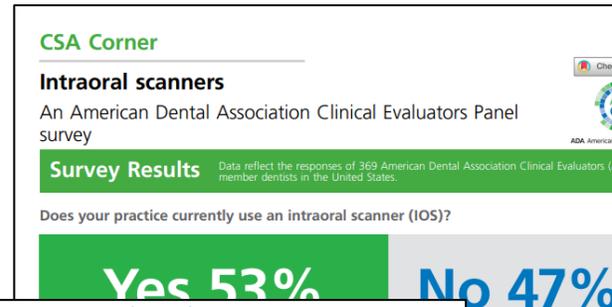


# *Evolution of our practice*



# Evolution of our practice

- 80% have access to CBCT, 50% own one
- 53% possess intraoral scanners, 78% use them daily



INTERNATIONAL DENTAL JOURNAL 73 (2023) 754-759

Scientific Research Report

### User Experience of Intraoral Scanners in Dentistry: Transnational Questionnaire Study

**Clinical Research**

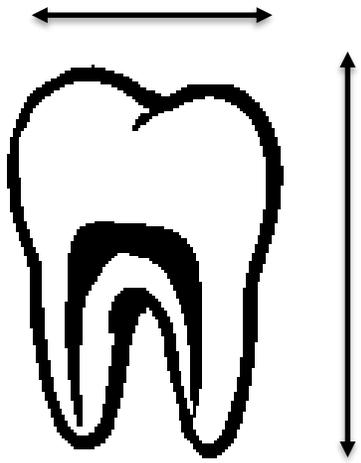
### A Survey of Cone-beam Computed Tomographic Use among Endodontic Practitioners in the United States

Frank C. Setzer, DMD, PbD, MS,\* Nathan Hinckley, DDS,† Meetu R. Kobli, BS, DMD,\* and Bekir Karabucak, DMD, MS\*

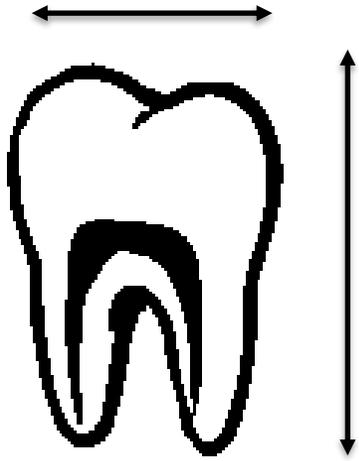
**Abstract**



# *Evolution of our practice*



# Evolution of our practice



**HAS**  
HAUTE AUTORITÉ DE SANTÉ

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**ASSESSING**  
HEALTH TECHNOLOGIES

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**PREPARATORY**  
REPORT

Integration of digital  
medical devices for  
professional use  
into clinical practice

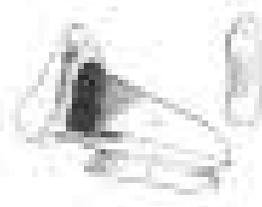
State of the art and decision

# Evolution of our practice



A practice of :

- Precision Measurements



Journal of Oral Biology and Craniofacial Research 12 (2022) 208–215

Contents lists available at ScienceDirect

**Journal of Oral Biology and Craniofacial Research**

journal homepage: [www.elsevier.com/locate/jobcr](http://www.elsevier.com/locate/jobcr)

ELSEVIER

Effectiveness of digital data acquisition technologies in the fabrication of maxillofacial prostheses – A systematic review

Nandita Suresh<sup>a</sup>, Chandrashekar Janakiram<sup>b,\*</sup>, Suresh Nayar<sup>c</sup>, V.N. Krishnapriya<sup>a</sup>, Anil Mathew<sup>a</sup>

<sup>a</sup> Department of Prosthodontics and Implantology, Amrita Vishwa Vidyapeetham, Amrita School of Dentistry, Kochi, Kerala, 682041, India  
<sup>b</sup> Department of Public Health Dentistry, Amrita School of Dentistry, Amrita Vishwa Vidyapeetham, Kerala, 682041, India  
<sup>c</sup> Institute for Reconstructive Sciences in Medicine, Division of Otolaryngology Head and Neck Surgery, Department of Surgery, Faculty of Medicine and Dentistry, University of Alberta, Institute for Reconstructive Sciences in Medicine (IRSM), Alberta Health Services/Covenant Health/University of Alberta, Canada

**ARTICLE INFO**

**Keywords:**  
Maxillofacial prostheses  
Digital workflow  
Computer-aided designing  
Rapid prototyping  
Facial defects  
Computerized tomography  
LASER scanning

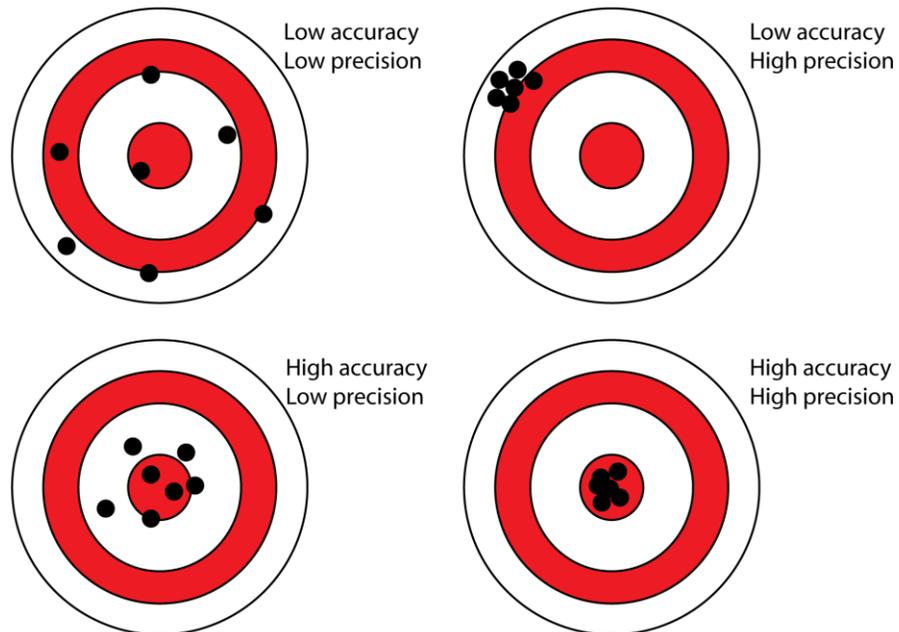
**ABSTRACT**

**Objective:** The systematic review was designed to review and analyze the outcomes of various digital data acquisition technologies used for treatment planning in the prosthetic rehabilitation of maxillofacial defects.

**Methods:** The review protocol was registered in PROSPERO data with registration number: CRD42020188415. The PICOS inclusion criteria was employed in the systematic review. An electronic search (PubMed, databases) yielded twenty-eight eligible case reports. The qualitative methodological assessment was done according to an article that provided criteria for special considerations in evaluating case reports. It consisted of four questions each carrying grading of 0, 1, and 2. During the full-text screening, the reviewers shortlisted six questions (time, aesthetics, cost, dimensional accuracy, patient satisfaction, and fabrication process) and graded (0, 1, 3) each

# Evolution of our practice

## Plus reproducible



The screenshot shows the front page of an article in the *Journal of Prosthodontic Research*. The page includes the journal title, Elsevier logo, and article information.

Journal of Oral Biology and Craniofacial Research 12 (2022) 208–215

Contents lists available at ScienceDirect

journal of prosthodontic research 62 (2018) 347–352

Contents lists available at ScienceDirect

**Journal of Prosthodontic Research**

journal homepage: [www.elsevier.com/locate/jpor](http://www.elsevier.com/locate/jpor)

Original article

**Trueness and precision of digital impressions obtained using an intraoral scanner with different head size in the partially edentulous mandible**

Hironari Hayama, Kenji Fueki\*, Juro Wadachi, Noriyuki Wakabayashi

Removable Partial Prosthodontics, Oral Health Sciences, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University, Tokyo, Japan

ARTICLE INFO

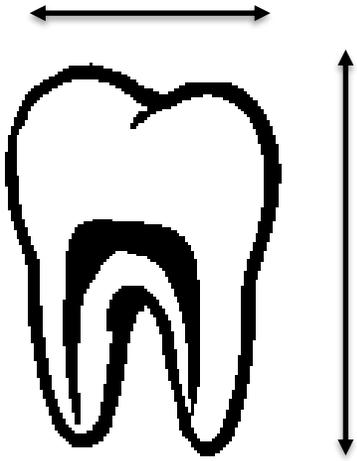
ABSTRACT

Article history:

Purpose: It remains unclear whether digital impressions obtained using an intraoral scanner are

various digital data for orofacial defects. CRD42020188415 PubMed, databases one according to a ed of four questions six outcomes (time graded (0, 1, 3) ac

# *Evolution of our practice*



**A practice of :**

- Precision Measurements
- **Data Collection**

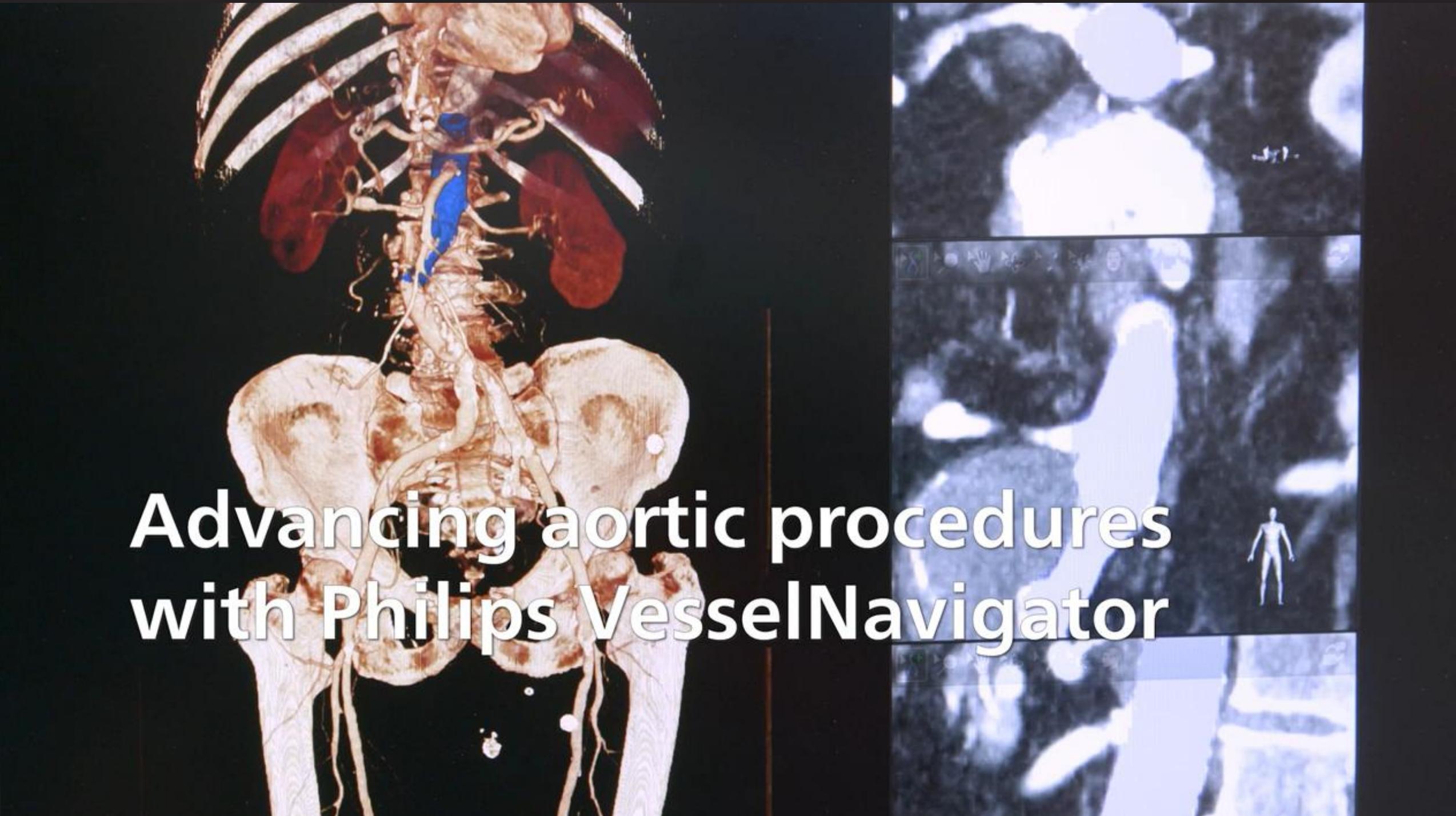
**80% des praticiens et 90 % des laboratoires de prothèse ont accès ou utilisent un système d'acquisition 3D**

**[Setzer et al. 2018]**

Lower Jaw

00:00:04





**Advancing aortic procedures  
with Philips VesselNavigator**

# Evolution of our practice

## Precision

Ultrasonics 141 (2024) 107332

Contents lists available at [ScienceDirect](#)



Ultrasonics

journal homepage: [www.elsevier.com/locate/ultras](http://www.elsevier.com/locate/ultras)



Investigation of 3D vessel reconstruction under Doppler imaging with phantoms: Towards reconstruction of the Circle of Willis

Shuai Li<sup>a</sup>, Queenie Tsung Kwan Shea<sup>a</sup>, Yan To Ling<sup>a,c</sup>, Yong-Ping Zheng<sup>a,b,\*</sup>

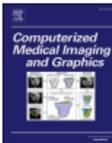
Computerized Medical Imaging and Graphics 92 (2021) 101956

Contents lists available at [ScienceDirect](#)



Computerized Medical Imaging and Graphics

journal homepage: [www.elsevier.com/locate/compmedimag](http://www.elsevier.com/locate/compmedimag)



Automated three-dimensional vessel reconstruction based on deep segmentation and bi-plane angiographic projections

D.M. Bappy<sup>a</sup>, Ayoung Hong<sup>a,c</sup>, Eunpyo Choi<sup>b</sup>, Jong-Oh Park<sup>a,b,\*\*</sup>, Chang-Sei Kim<sup>a,b,\*</sup>

<sup>a</sup> Korea Institute of Medical Microrobotics, Gwangju, 61011, South Korea  
<sup>b</sup> School of Mechanical Engineering, Chonnam National University, Gwangju, 61186, South Korea  
<sup>c</sup> Robotics Engineering Convergence, Chonnam National University, Gwangju, 61186, South Korea

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ARTICLE INFO

Keywords:  
Automated medical image reconstruction  
Vessel segmentation  
3-D reconstruction

ABSTRACT

Automated three-dimensional (3D) blood vessel reconstruction to improve vascular diagnosis and therapeutics is a challenging task in which the real-time implementation of automatic segmentation and specific vessel tracking for matching artery sequences is essential. Recently, a deep learning-based segmentation technique has been proposed; however, existing state-of-the-art deep architectures exhibit reduced performance when they are

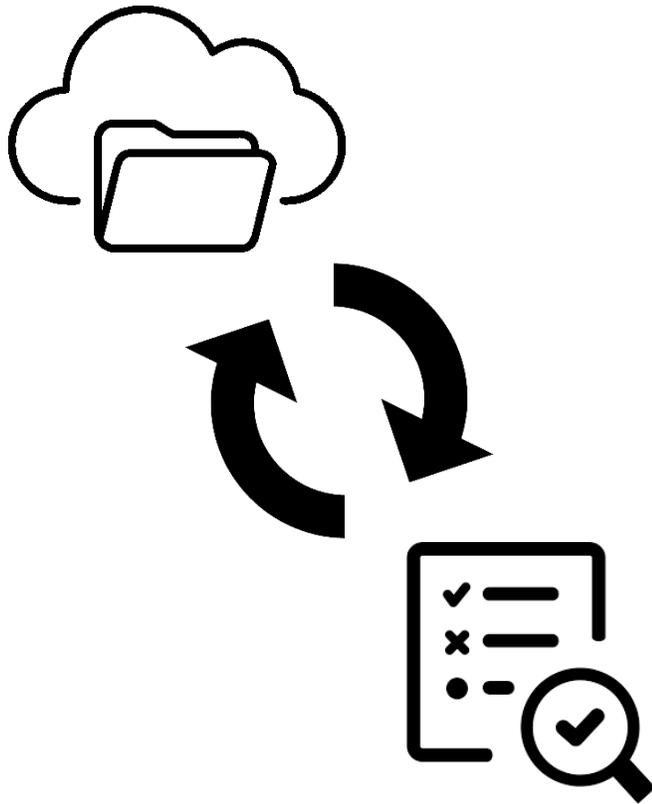
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t disease, and diabetes e cerebral arteries [5]. mical structure called

# Evolution of our practice

## Precision



Ultrasonics 141 (2024) 107332

Contents lists available at [ScienceDirect](#)

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**ABSTRACT**

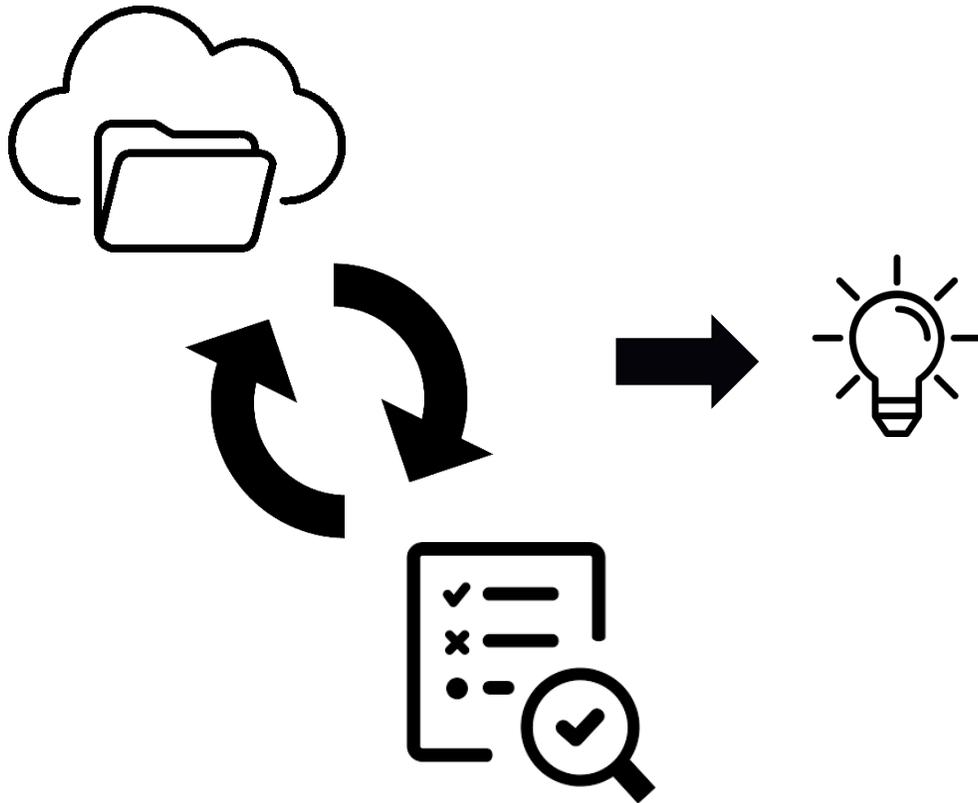
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# Evolution of our practice

## Precision



Ultrasonics 141 (2024) 107332

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Investigation of 3D vessel reconstruction under Doppler imaging with phantoms: Towards reconstruction of the Circle of Willis

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Computerized Medical Imaging and Graphics 92 (2021) 101956

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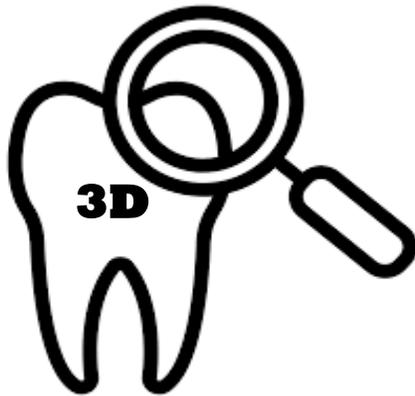
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# Evolution of our practice

## New capabilities of diagnosis

change in the apical category. The selections changed in 55% of the cases when determining etiology and in 49% of the cases when making recommendations. CBCT imaging was



### Clinical Research

## A New Periapical Index Based on Cone Beam Computed Tomography

*Carlos Estrela, DDS, MSc, PhD,\* Mike Reis Bueno, DDS, MSc,<sup>†</sup> Bruno Correa Azevedo, DDS, MSc,<sup>‡</sup> José Ribamar Azevedo, DDS,<sup>§</sup> and Jesus Djalma Pécora, DDS, MSc, PhD<sup>||</sup>*

### Abstract

The purpose of this study was to evaluate a new | Periapical radiography is an essential resource in endodontic diagnosis, because it

### CLINICAL RESEARCH

## The Recommendation of Cone-beam Computed Tomography and Its Effect on Endodontic Diagnosis and Treatment Planning

### ABSTRACT

**Introduction:** Although intraoral radiographs are foundational for diagnosis and planning treatment in dentistry, the resulting 2-dimensional image varies in interpretation requiring judgment. Cone-beam computed tomographic imaging provides a more detailed 3-dimensional image that may affect treatment recommendations. This study aimed to determine the basis for CBCT recommendations and the effect on diagnosis and treatment planning. **Methods:** The study involved a sample of 45 cases that presented for endodontic treatment, 30 with a CBCT scan on record and 15 without. For phase 1, all 45 cases were reviewed by 3 examiners without access to the CBCT scans. For phase 2, 4 months later, the

*Sami Chogle, DMD, MSD  
Maan Zuaitar, DDS,  
Ramzi Sarkis, DMD, MSD  
Manal Saadoun, BDS, MSD  
Anthony Mecham, DMD and  
Yihong Zhao, PhD*

### SIGNIFICANCE

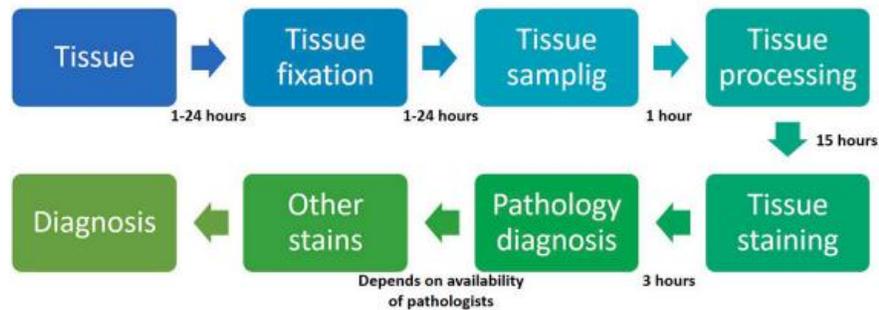
This study's goals were to determine whether or not CBCT imaging can provide additional useful information, and whether that information can be used to improve treatment planning when

istence of apical  
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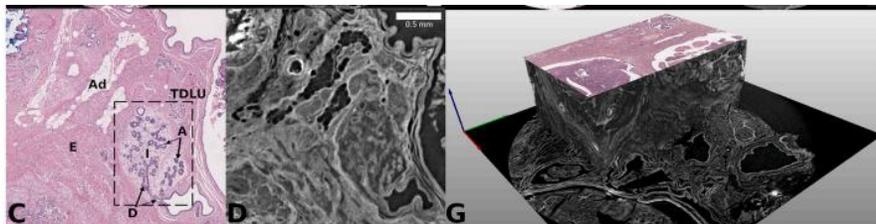
# Evolution of our practice

## New capabilities of diagnosis

### Workflow traditionnel



### Virtual Histology



Ultrasonics 141 (2024) 107332

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journal homepage: [www.elsevier.com/locate/ultras](http://www.elsevier.com/locate/ultras)

Investigation of 3D vessel reconstruction under Doppler imaging with phantoms: Towards reconstruction of the Circle of Willis

Trends in Analytical Chemistry 180 (2024) 117943

Contents lists available at ScienceDirect

**Trends in Analytical Chemistry**

journal homepage: [www.elsevier.com/locate/trac](http://www.elsevier.com/locate/trac)

Advancing breast cancer diagnosis in 3D: The transformative power of X-ray phase-contrast microtomography for virtual histology

S. Donato <sup>a,b,\*</sup>, D. Bonazza <sup>c</sup>

<sup>a</sup> Department of Physics, University of Calabria, via P. Bucci, 31C, Rende, 87036, CS, Italy  
<sup>b</sup> INFN Division of Frascati, via Enrico Fermi, 54, Frascati, 00044, RM, Italy  
<sup>c</sup> Unit of surgical Pathology, Cattinara Hospital, Azienda Sanitaria Universitaria Giuliana Isontina (ASUGI), Strada di Fiume, 447, Trieste, 34149, TS, Italy

risk detection could  
 using 1D-Transcranial  
 provide low spatial  
 CT have high rad-  
 devices. This study  
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 r blood vessels using

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#### ARTICLE INFO

Keywords:  
 Breast cancer

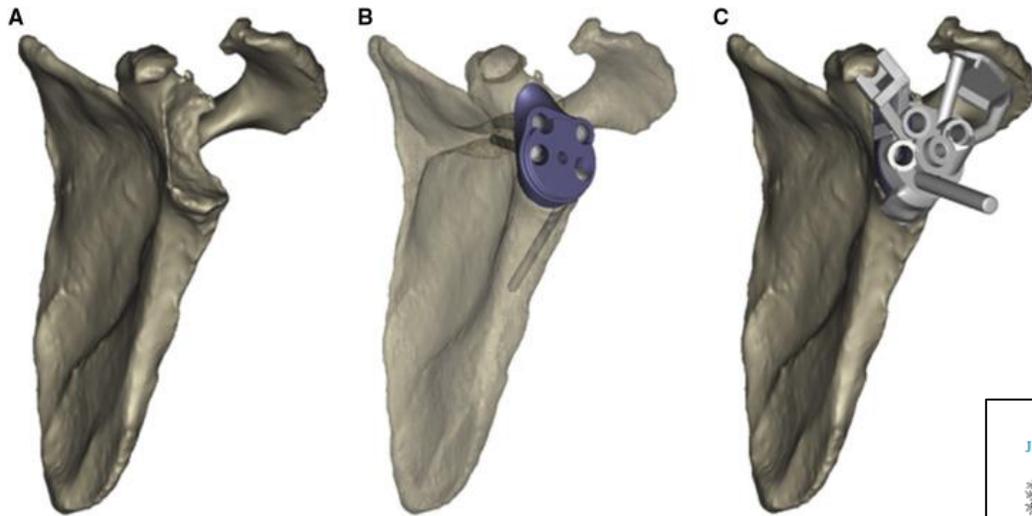
#### ABSTRACT

Breast cancer, a prevalent global malignancy in women, demands accurate tissue alteration detection for



# Evolution of our practice

## Surgical planning



J Shoulder Elbow Surg (2014) 23, 1563-1567



ELSEVIER

JOURNAL OF SHOULDER AND ELBOW SURGERY

www.elsevier.com/locate/jyse

Accuracy of patient-specific guided glenoid baseplate positioning for reverse shoulder arthroplasty



J Shoulder Elbow Surg (2015) 24, 965-971



ELSEVIER

JOURNAL OF SHOULDER AND ELBOW SURGERY

www.elsevier.com/locate/jyse

Patient-specific targeting guides compared with traditional instrumentation for glenoid component placement in shoulder arthroplasty: a multi-surgeon study in 70 arthritic cadaver specimens

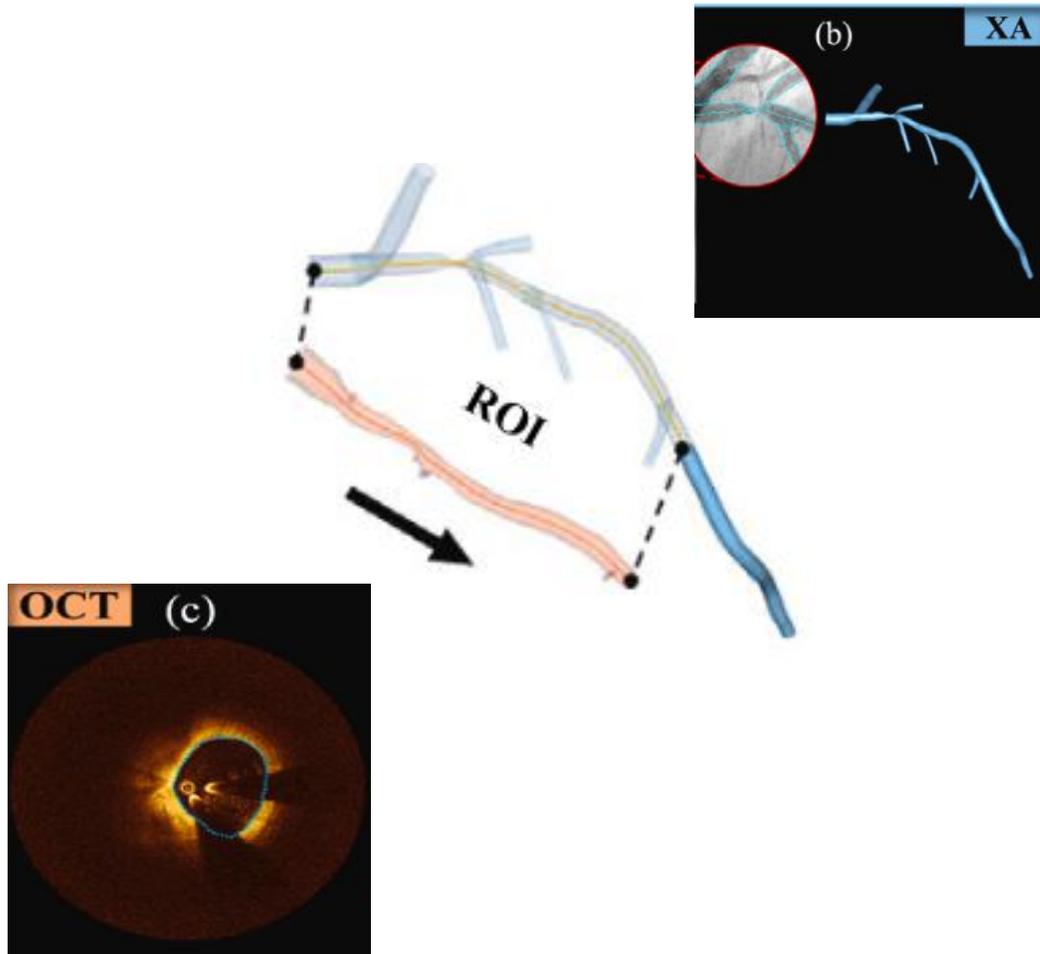


Frankle, MD<sup>b</sup>,

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# Evolution of our practice

## A streamlined Workflow



Medical Image Analysis 101 (2025) 103432

Contents lists available at ScienceDirect

Medical Image Analysis

journal homepage: [www.elsevier.com/locate/media](http://www.elsevier.com/locate/media)



### AutoFOX: An automated cross-modal 3D fusion framework of coronary X-ray angiography and OCT

Chunming Li<sup>a, b</sup>, Yuchuan Qiao<sup>b</sup>, Wei Yu<sup>a, b</sup>, Yingguang Li<sup>c, b</sup>, Yankai Chen<sup>a</sup>, Zehao Fan<sup>a</sup>, Runguo Wei<sup>a</sup>, Botao Yang<sup>a</sup>, Zhiqing Wang<sup>d</sup>, Xuesong Lu<sup>e</sup>, Lianglong Chen<sup>d</sup>, Carlos Collet<sup>f</sup>, Miao Chu<sup>a, g, \*</sup>, Shengxian Tu<sup>a, g, b, \*</sup>

<sup>a</sup> School of Biomedical Engineering, Shanghai Jiao Tong University, Shanghai 200030, China

<sup>b</sup> Institute of Science and Technology for Brain-Inspired Intelligence, Fudan University, Shanghai 201200, China

<sup>c</sup> International Smart Medical Devices Innovation Center, Kunshan Industrial Technology Research Institute, Suzhou, China

<sup>d</sup> Department of Cardiology, Fujian Medical University Union Hospital, Fuzhou, China

<sup>e</sup> School of Biomedical Engineering, South-Central Minzu University, Wuhan 430074, Hubei, China

<sup>f</sup> Cardiovascular Center Aalst, OLV Clinic, Aalst, Belgium

<sup>g</sup> Department of Cardiovascular Medicine, University of Oxford, OX39DU, UK

#### ARTICLE INFO

##### Keywords:

Coronary artery disease

X-ray angiography

OCT

Deep learning-based alignment

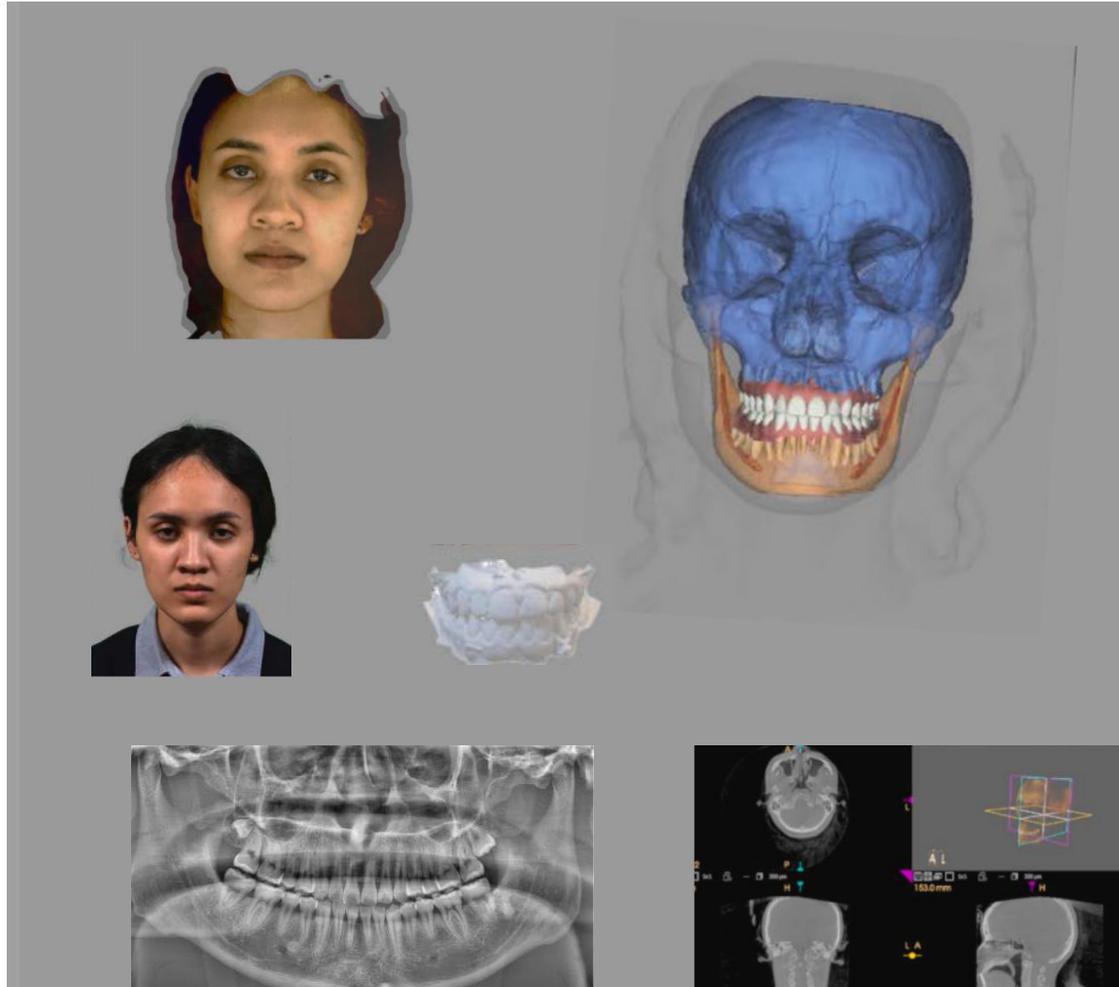
3D fusion

#### ABSTRACT

Coronary artery disease (CAD) is the leading cause of death globally. The 3D fusion of coronary X-ray angiography (XA) and optical coherence tomography (OCT) provides complementary information to appreciate coronary anatomy and plaque morphology. This significantly improve CAD diagnosis and prognosis by enabling precise hemodynamic and computational physiology assessments. The challenges of fusion lie in the potential misalignment caused by the foreshortening effect in XA and non-uniform acquisition of OCT pullback. Moreover, the need for reconstructions of major bifurcations is technically demanding. This paper proposed an automated 3D fusion framework AutoFOX, which consists of deep learning model TransCAN for 3D vessel alignment. The 3D vessel contours are processed as sequential data, whose features are extracted and integrated with bifurcation information to enhance alignment via a multi-task fashion. TransCAN shows the highest alignment accuracy among all methods with a mean alignment error of  $0.99 \pm 0.81$  mm along the vascular sequence, and only  $0.82 \pm 0.69$  mm at key anatomical positions. The proposed AutoFOX framework uniquely employs an advanced side branch lumen reconstruction algorithm to enhance the assessment of

# Evolution of our practice

## A streamlined Workflow



### Automated orofacial virtual patient creation: A proof of concept

Thanatchaporn Jindanil<sup>a,b,c</sup>, Oana-Elena Burlacu-Vatamanu<sup>a,d</sup>, Joeri Meyns<sup>a,e</sup>,  
 Jeroen Meewis<sup>e</sup>, Rocharles Cavalcante Fontenele<sup>a,b</sup>, Maria Cadenas de Llano Perula<sup>f</sup>,  
 Reinhilde Jacobs<sup>a,g,\*</sup>

<sup>a</sup> OMFS-IMPATh Research Group, Department of Imaging and Pathology, Faculty of Medicine, KU Leuven, Leuven, Belgium

<sup>b</sup> Department of Oral and Maxillofacial Surgery, University Hospitals Leuven, Leuven, Belgium

<sup>c</sup> Department of Radiology, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand

<sup>d</sup> Doctoral School, Carol Davila University of Medicine and Pharmacy, Bucharest, Romania

<sup>e</sup> Department of Oral and Maxillofacial Surgery, Ziekenhuis Oost Limburg, Genk-Maaseik, Belgium

<sup>f</sup> Department of Oral Health Sciences - Orthodontics, KU Leuven and Dentistry, University Hospitals Leuven, Leuven, Belgium

<sup>g</sup> Department of Dental Medicine, Karolinska Institute, Stockholm, Sweden

#### ARTICLE INFO

**Keywords:**  
 Virtual patient  
 Multimodal registration  
 Digital dentistry

#### ABSTRACT

**Objectives:** To (1) construct a virtual patient (VP) using facial scan, intraoral scan, and low-dose computed tomography (CT) based on an Artificial intelligence (AI)-approach, (2) quantitatively compare it with AI-refined and semi-automatic registration, and (3) qualitatively evaluate user satisfaction when using virtual patient as a communication tool in clinical practice.

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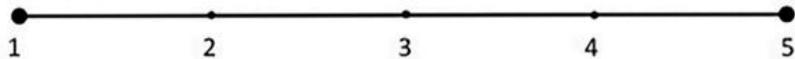
# Evolution of our practice

## Communication avec les patients

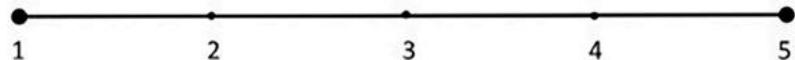
### Patient survey for pre-op anatomical models

(1 - strongly disagree, 2 - disagree, 3 - neutral, 4 - agree, 5 - strongly agree)

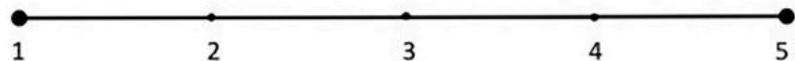
The model improved my understanding of my condition.



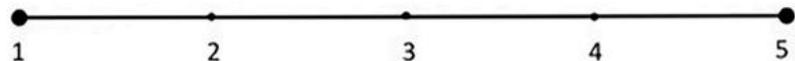
The model helped me in coping with this condition.



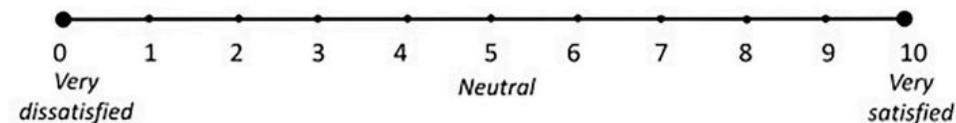
The model improved my confidence in the treatment provided for me.



The model improved my confidence in the doctor treating me.



Overall satisfaction





Contents lists available at [ScienceDirect](#)

## Annals of 3D Printed Medicine

journal homepage: [www.elsevier.com](http://www.elsevier.com)



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Research paper

### Patient comprehension of oncologic surgical procedures using 3D printed surgical planning prototypes

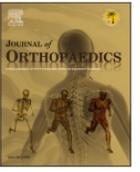




Contents lists available at [ScienceDirect](#)

## Journal of Orthopaedics

journal homepage: [www.elsevier.com/locate/jor](http://www.elsevier.com/locate/jor)



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### Role of patient specific 3D printed models in patient confidence, understanding and satisfaction of care in Singapore

Carol Xiaoshu Zhao <sup>a,\*</sup>, Michael Yam <sup>b</sup>

<sup>a</sup> Lee Kong Chian School of Medicine, Nanyang Technological University, Singapore  
<sup>b</sup> Orthopaedic Department, Tan Tock Seng Hospital, 308433, Singapore

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**ARTICLE INFO**

**Keywords:**  
 Patient specific 3D models  
 Customised 3D models  
 Preoperative counselling  
 Improve understanding of patients' condition  
 Boost patients' confidence in the procedure

**ABSTRACT**

**Introduction:** Patient specific 3D models have been widely used for pre-op planning and intra-op guidance in orthopaedic surgery. These models however are not often used in pre-operative doctor-patient communication. This study evaluates the roles of customized 3D models in improving patient understanding, confidence, and satisfaction of patient care when they were used during preoperative counselling.

**Materials and methods:** A prospective survey was conducted on 33 orthopaedic trauma patients who were required to rate on a scale of 1–5, the effectiveness of patient specific 3D models in: 1) improving patient's

# Evolution of our practice

## Enseignement



Multi-color and multi-material bio-model.  
Technology: PolyJet

RESEARCH ARTICLE

Open Access

The role of 3D printed models in the teaching of human anatomy: a systematic



HAS

HAUTE AUTORITÉ DE SANTÉ

SoFraSimS

MESURER  
& AMÉLIORER LA QUALITÉ

GUIDE

Bonnes pratiques

# AlphaFold

An overview

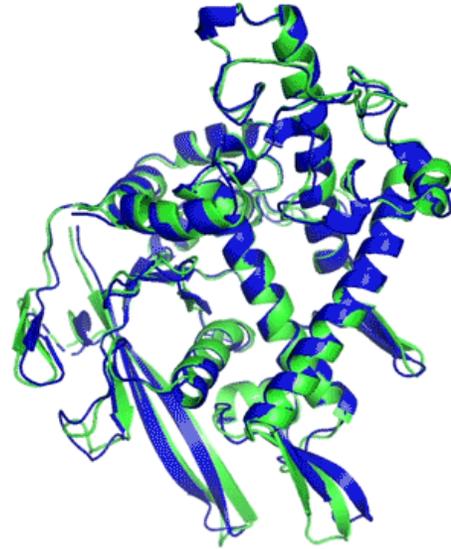


DeepMind

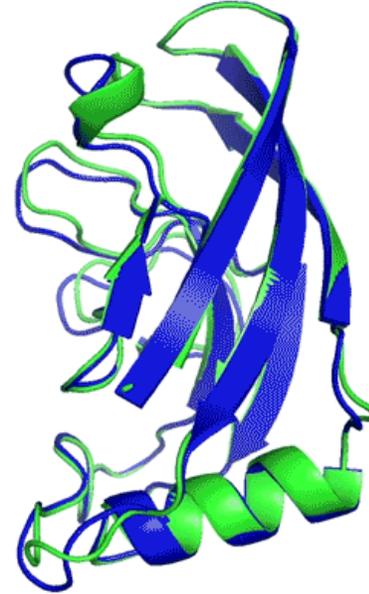
Google

# Evolution of our practice

Clinical Assessment of protein structure



**T1037 / 6vr4**  
90.7 GDT  
(RNA polymerase domain)



**T1049 / 6y4f**  
93.3 GDT  
(adhesin tip)

- Experimental result
- Computational prediction

*Comment votre  
pratique peut/  
pourrait intégrer la  
3D ?*



*Comment votre pratique  
pourrait intégrer  
l'utilisation d'un jumeau  
numérique ?*



<b>Catégorie</b>	<b>Critères d'évaluation</b>
<b>Objectifs cliniques</b>	- But principal de l'outil 3D ? (diagnostic, planification chirurgicale, communication patient...)
<b>Type d'outils et sources de données</b>	- Type d'acquisition (IRM, CBCT, scanner, empreinte optique, ou simulation...)
<b>Précision et reproductibilité</b>	- La résolution des données est-elle adaptée à l'usage prévu (chirurgie guidée) ou une approximation suffit-elle (ex. communication patient) ? - L'outil est-il reproductible et fiable sur plusieurs essais ?
<b>Risque de biais et</b>	- Sensibilité/ bruit dans les données ou l'acquisition

<b>Risque de biais et qualité des données</b>	<ul style="list-style-type: none"><li>- Sensibilité/ bruit dans les données ou l'acquisition qui pourrait fausser le modèle 3D ?</li><li>- Comment s'assurer de la fiabilité des acquisitions ? (recalibrage scanner, réduction artefacts)</li></ul>
<b>Intervention de l'opérateur</b>	<ul style="list-style-type: none"><li>- Une correction manuelle ou un post-traitement est-il nécessaire (ex : segmentation post CBCT)?</li><li>- Faut-il une intervention humaine pour valider les résultats ?</li></ul>
<b>Formation et logiciels</b>	<ul style="list-style-type: none"><li>- Les utilisateurs doivent-ils être formés /experts ? -</li><li>Quels logiciels sont utilisés pour visualiser ou modifier les modèles 3D ? S'intègrent-ils dans le circuit actuel de soins ?</li></ul>
<b>Maintenance et</b>	<ul style="list-style-type: none"><li>- L'équipement ou le logiciel nécessite-t-il une</li></ul>

<b>logiciels</b>	Quels logiciels sont utilisés pour visualiser ou modifier les modèles 3D ? S'intègrent-ils dans le circuit actuel de soins ?
<b>Maintenance et durabilité</b>	- L'équipement ou le logiciel nécessite-t-il une maintenance régulière ? - Qui est responsable de son entretien et de son suivi ?
<b>Réglementation et statut médical</b>	- Le système est-il considéré comme un <b>dispositif médical</b> et doit-il être certifié (ex. marquage CE, FDA) ? - Y a-t-il des normes ISO à respecter ?

*A vous de jouer*

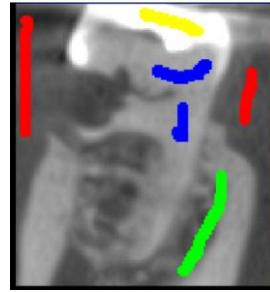
# Création d'un jumeau numérique

Situation clinique

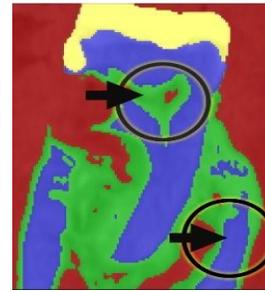


[Richert et al. 2022]

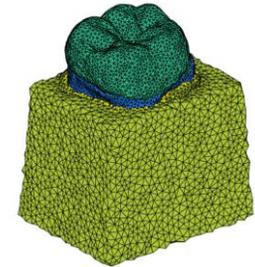
Enregistrer l'anatomie



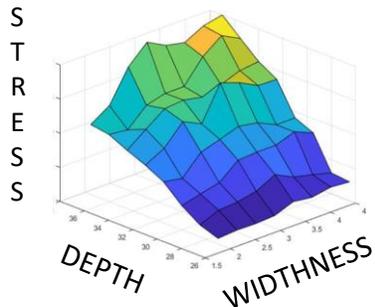
Segmenter l'image



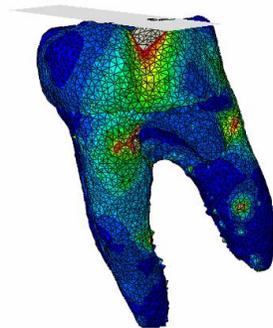
Mailler le volume



Analyse et optimisation



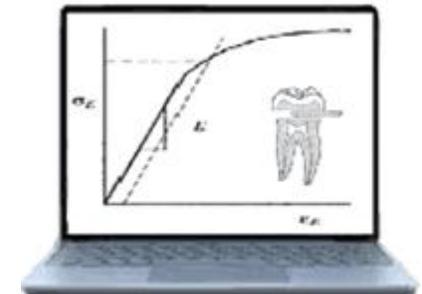
Effectuer le calcul numérique



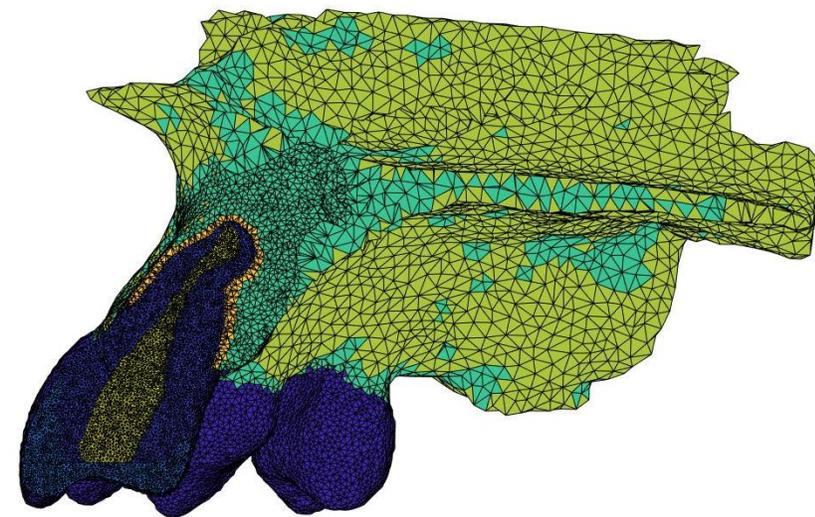
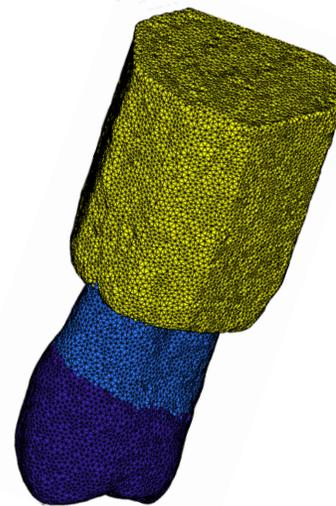
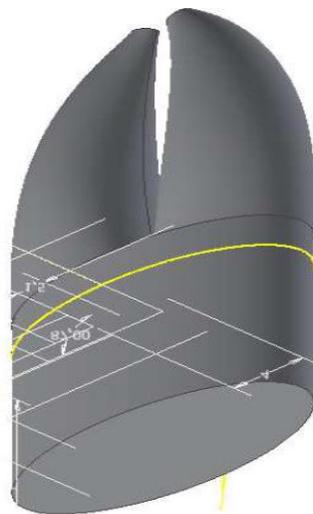
Intégrer le chargement



Intégrer les lois matériaux



# Evolution des approches



2018



# Chapitre 1

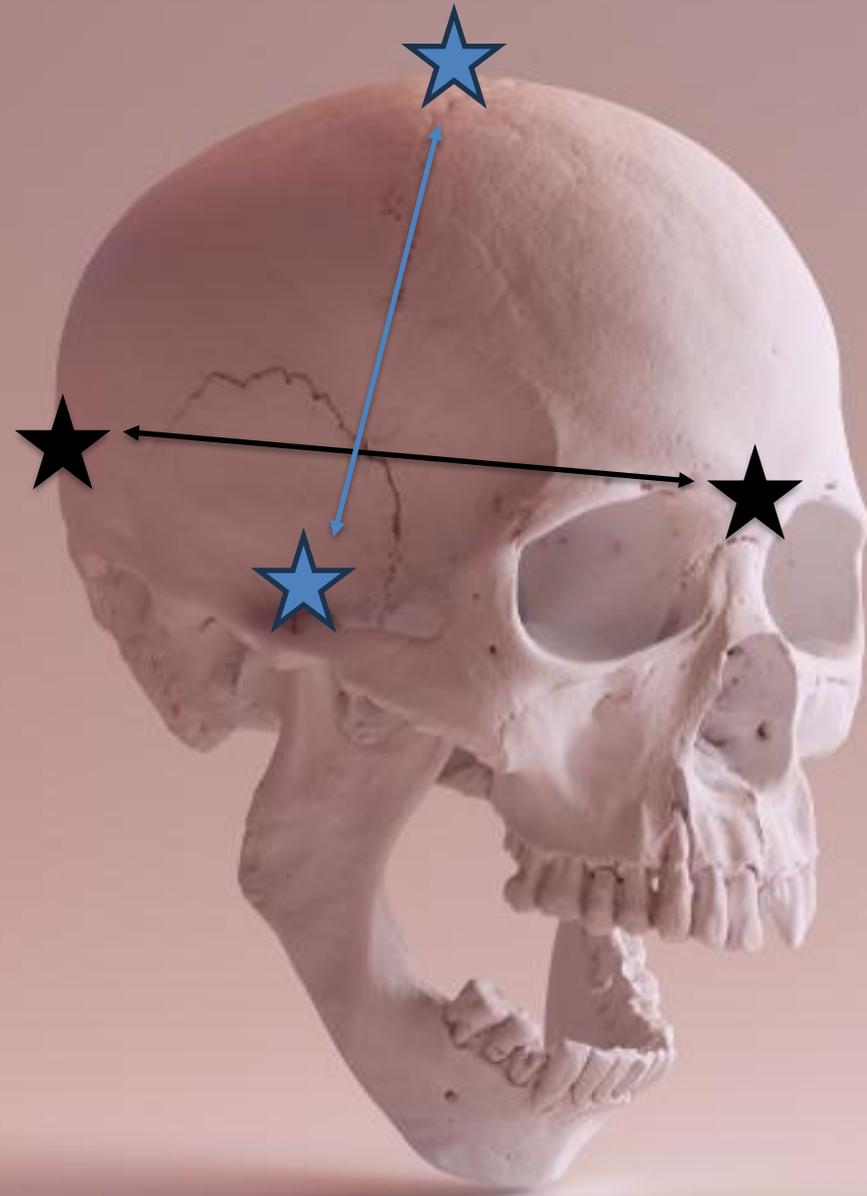


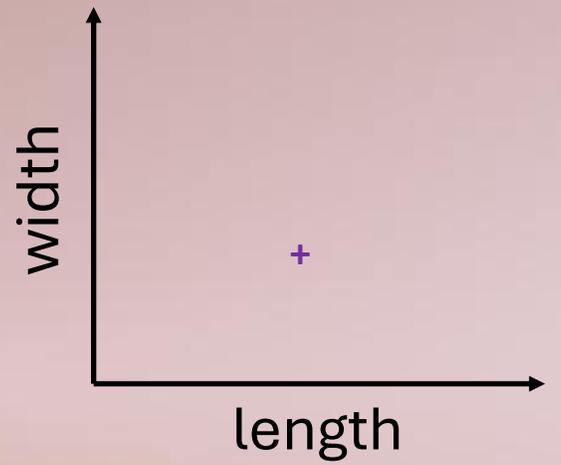
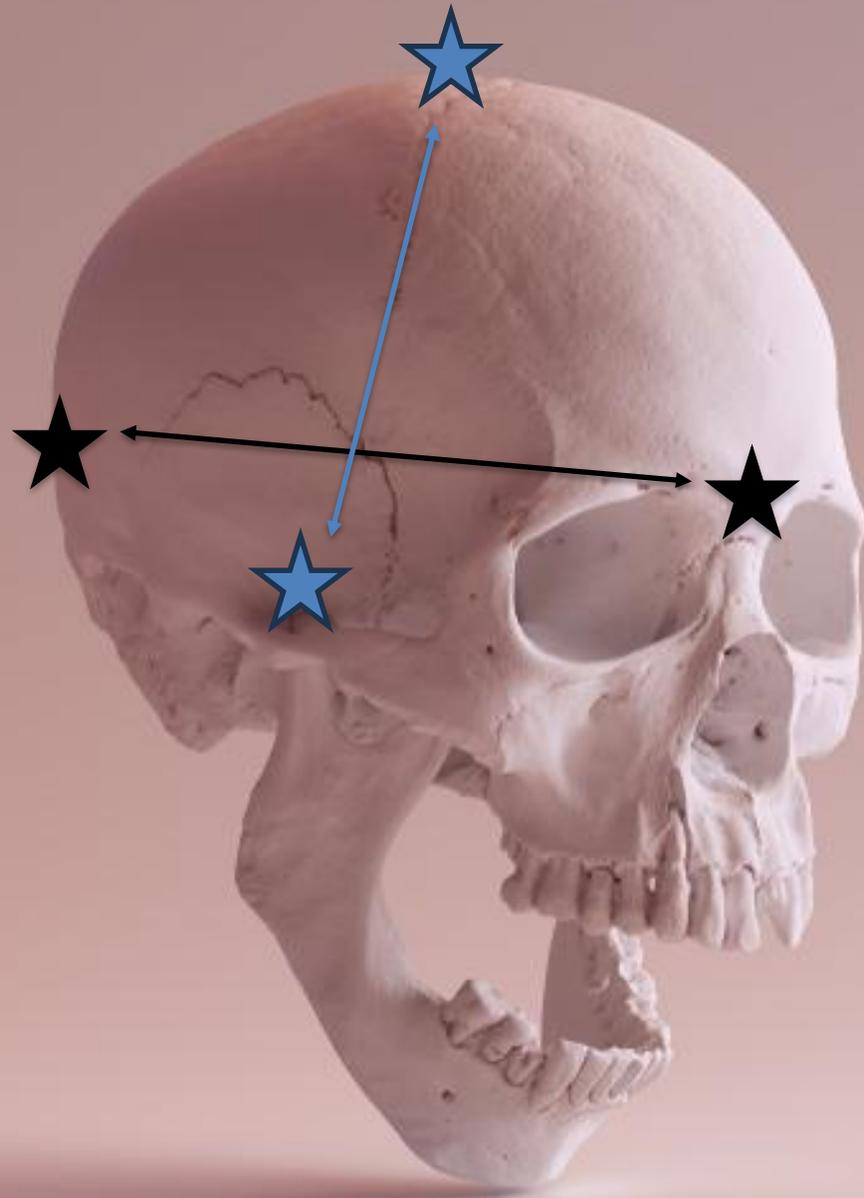
Chapitre 1

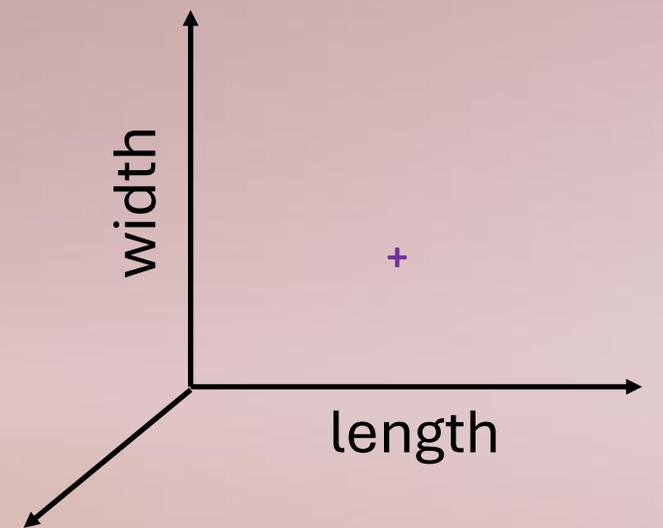
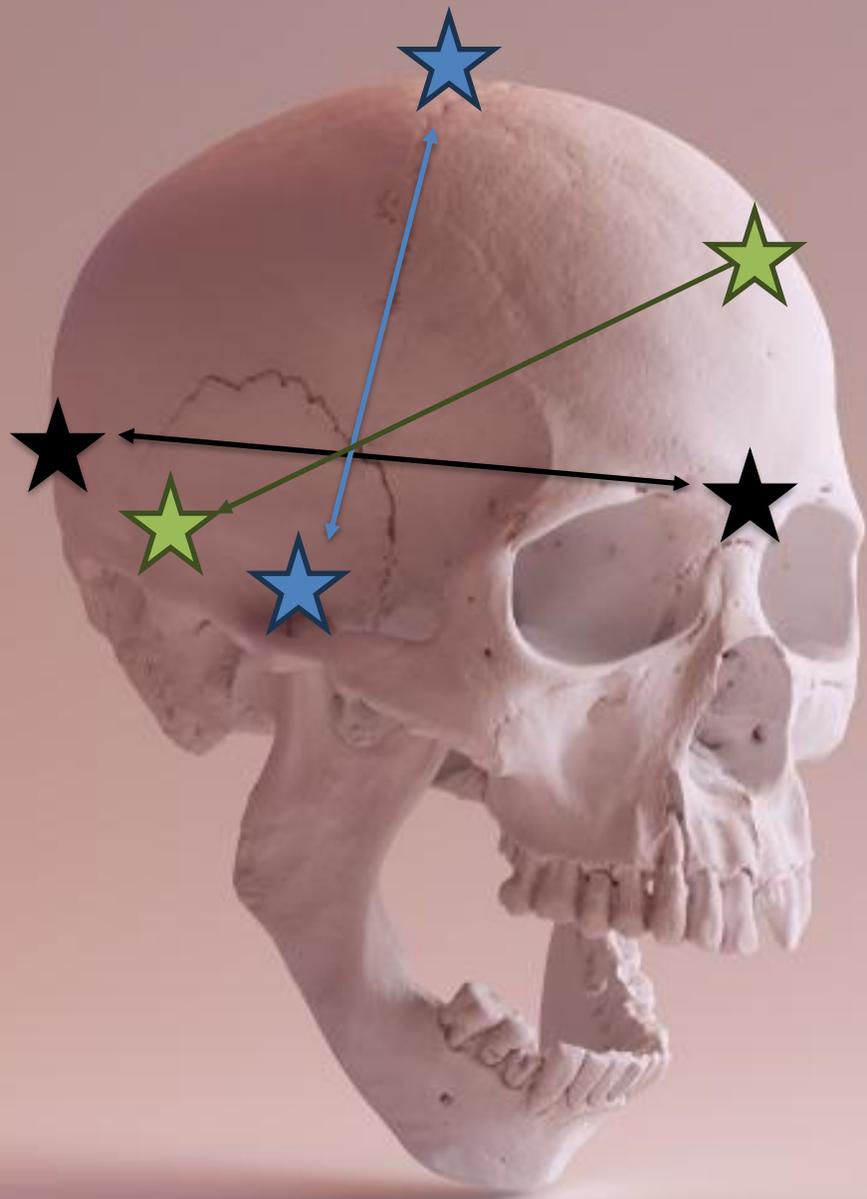
Apprendre la forme



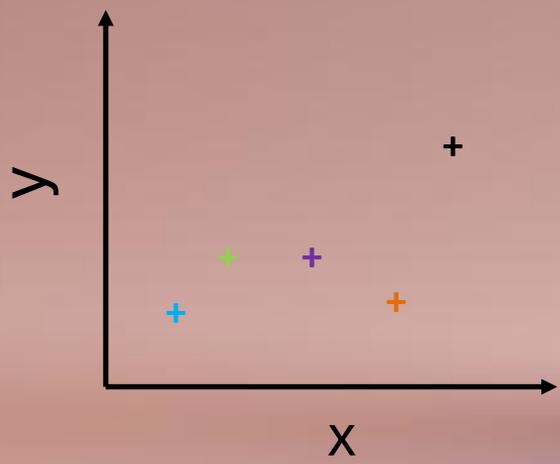


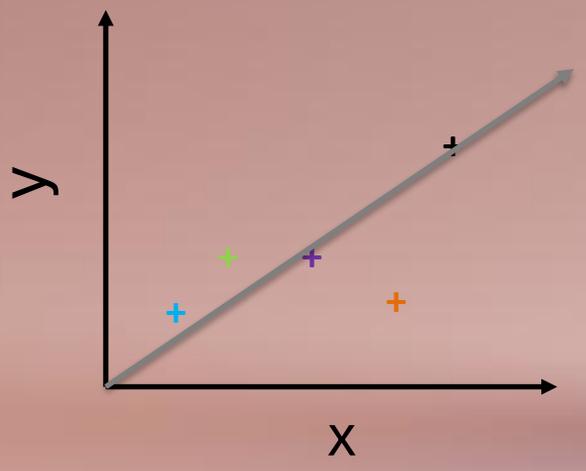


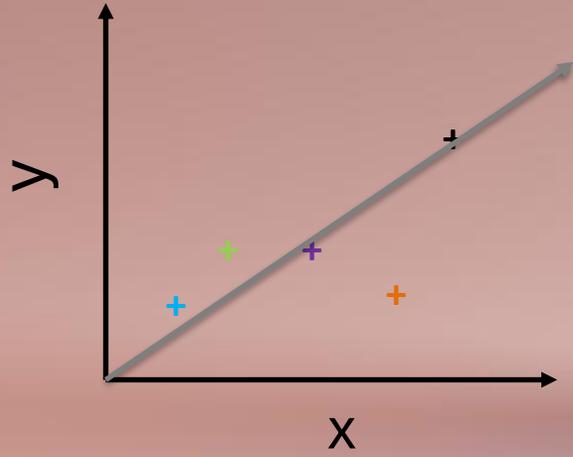
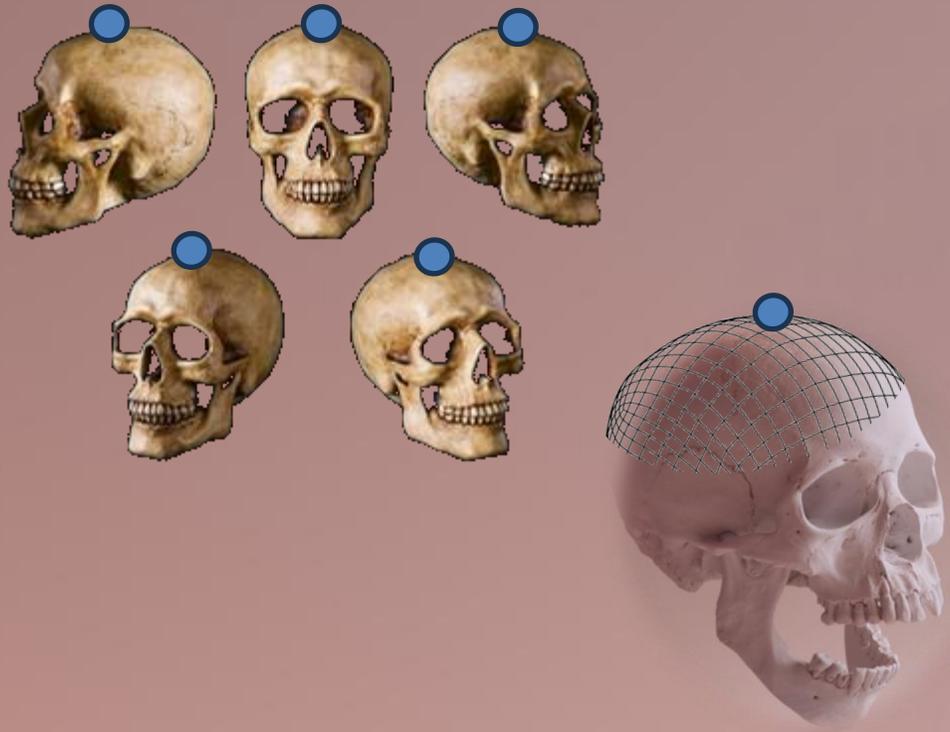


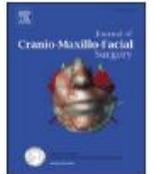
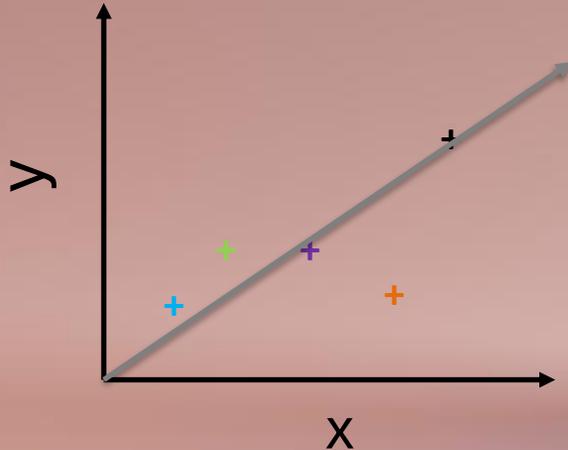
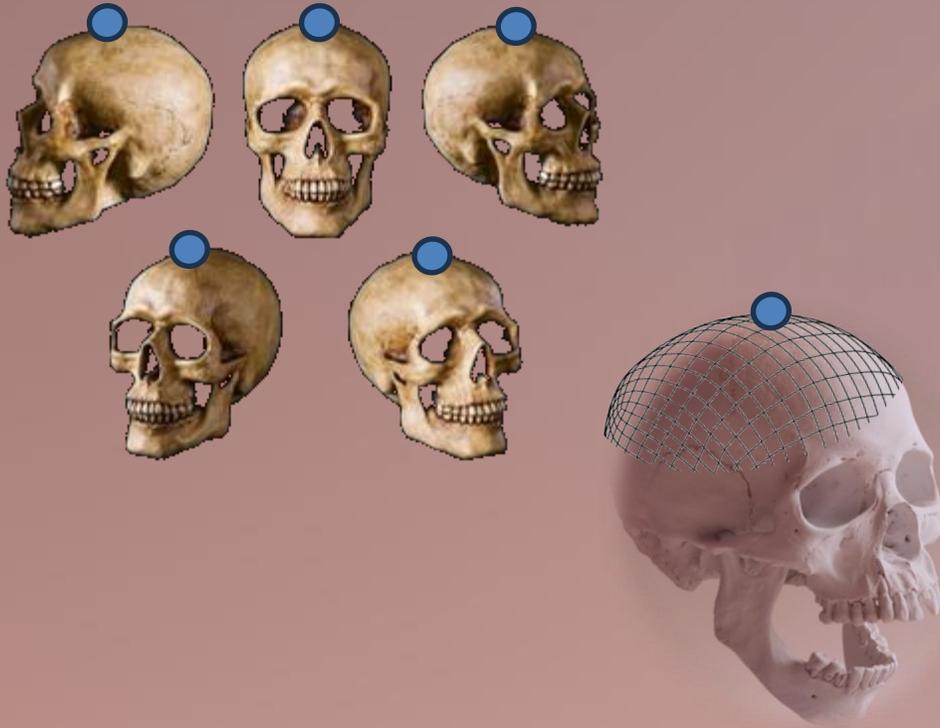












## AI-based diagnosis and phenotype – Genotype correlations in syndromic craniosynostoses

Quentin Hennocq<sup>a,b,c,\*</sup>, Giovanna Paternoster<sup>a,d</sup>, Corinne Collet<sup>e</sup>, Jeanne Amiel<sup>a,f</sup>, Thomas Bongibault<sup>a,c</sup>, Thomas Bouygues<sup>a,c</sup>, Valérie Cormier-Daire<sup>a,f</sup>, Maxime Douillet<sup>a</sup>, David J. Dunaway<sup>g</sup>, Nu Owase Jeelani<sup>g</sup>, Lara S. van de Lande<sup>g,h</sup>, Stanislas Lyonnet<sup>a,f</sup>, Juling Ong<sup>g</sup>, Arnaud Picard<sup>b</sup>, Alexander J. Rickart<sup>g</sup>, Marlène Rio<sup>a,f</sup>, Silvia Schievano<sup>g</sup>, Eric Arnaud<sup>d,i</sup>, Nicolas Garcelon<sup>a,1</sup>, Roman H. Khonsari<sup>a,b,c,d,1</sup>

<sup>a</sup> Imagine Institute, INSERM UMR1163, 75015, Paris, France

<sup>b</sup> Département de chirurgie maxillo-faciale et chirurgie plastique, Hôpital Necker – Enfants Malades, Assistance Publique – Hôpitaux de Paris, Centre de Référence des Malformations Rares de la Face et de la Cavité Buccale MAFACE, Filière Maladies Rares Tête/Cou, Faculté de Médecine, Université de Paris Cité, 75015, Paris, France

<sup>c</sup> Laboratoire 'Forme et Croissance du Crâne', Hôpital Necker-Enfants Malades, Assistance Publique-Hôpitaux de Paris, Faculté de Médecine, Université Paris Cité, Paris, France

<sup>d</sup> Département de neurochirurgie, Hôpital Necker – Enfants Malades, Assistance Publique – Hôpitaux de Paris, Centre de Référence des Malformations Rares de la Face et de la Cavité Buccale MAFACE, Filière Maladies Rares Tête/Cou, Faculté de Médecine, Université de Paris Cité, 75015, Paris, France

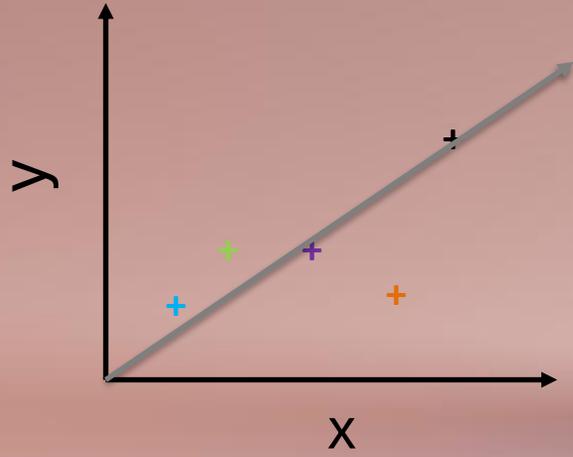
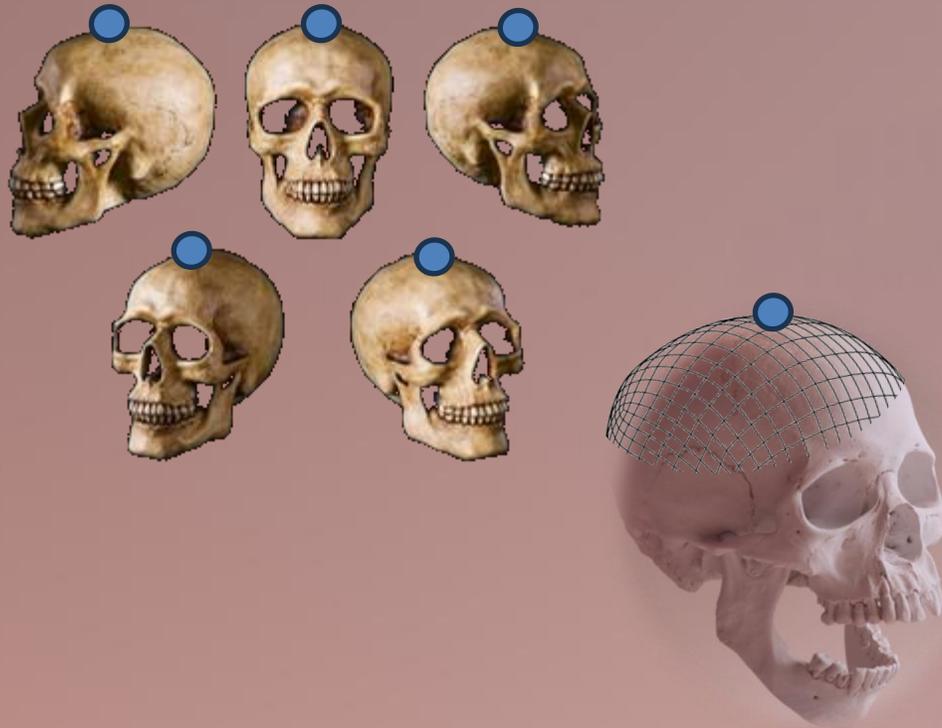
<sup>e</sup> Département de génétique moléculaire, Hôpital Robert Debré, Université de Paris Cité, Paris, France

<sup>f</sup> Service de médecine génomique des maladies rares, Hôpital Necker – Enfants Malades, Assistance Publique – Hôpitaux de Paris, Faculté de Médecine, Université de Paris Cité, 75015, Paris, France

<sup>g</sup> UCL Great Ormond Street Institute of Child Health and Craniofacial Unit, Great Ormond Street Hospital for Children, London, UK

<sup>h</sup> Department of Oral and Maxillofacial Surgery, Erasmus Medical Center, Rotterdam, the Netherlands

<sup>i</sup> Clinique Marcel Sembat (Ramsay), Boulogne, France

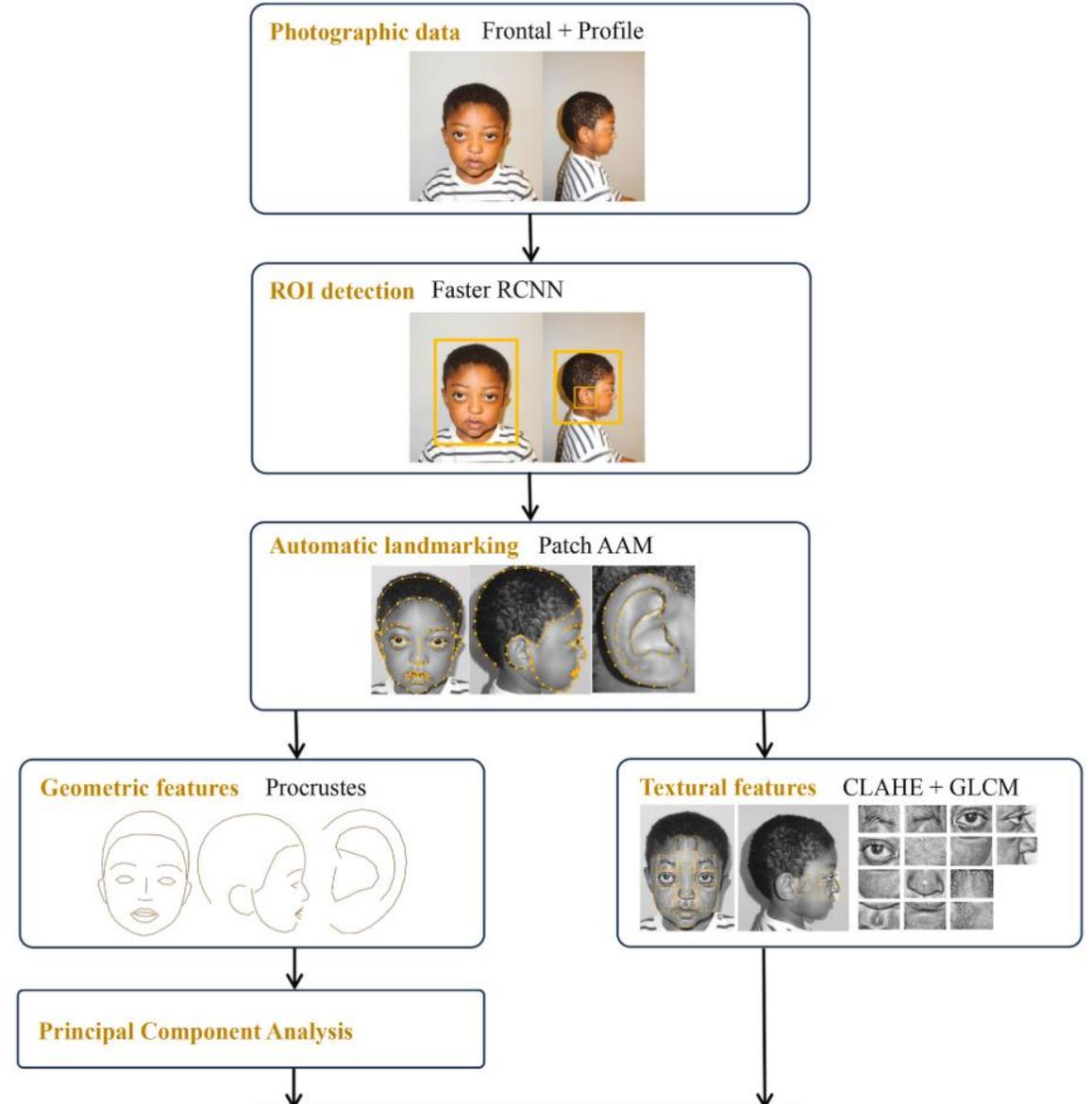


## 1. Introduction

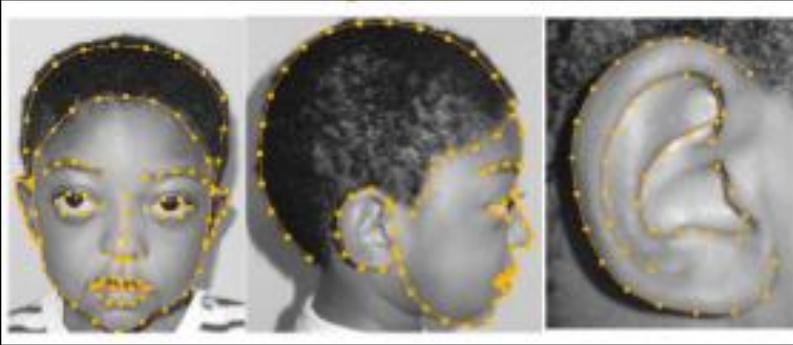
Applications of artificial intelligence (AI) are increasing in health-care (Rajkomar et al. 2019; Choy et al., 2018; Novoa et al. 2019; Loftus et al., 2020). The field of dysmorphology is currently being transformed

by these new methods (Gurovich et al., 2019). Studies comparing human performances to AI are flourishing (Zhang et al., 2022; Javitt et al., 2022; Latorre-Pellicer et al., 2020; Mishima et al., 2019), and some of them suggest that digital diagnostic tools outperform human experts (Rouxel et al., 2022).

\* Corresponding author. Laboratoire 'Forme et Croissance du Crâne', Hôpital Necker-Enfants Malades, 149 rue de Sèvres, 75015, Paris, France.

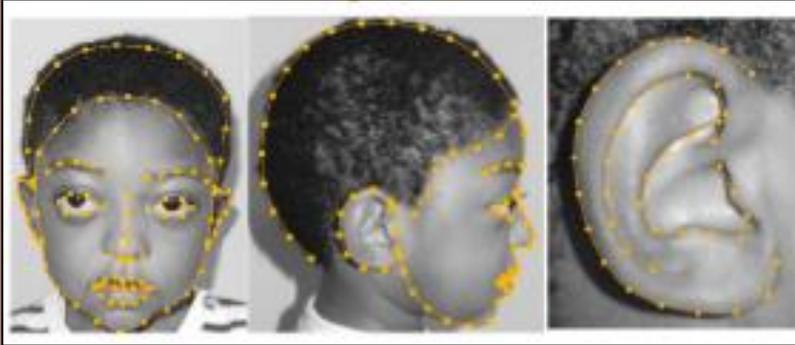


# Indications ?

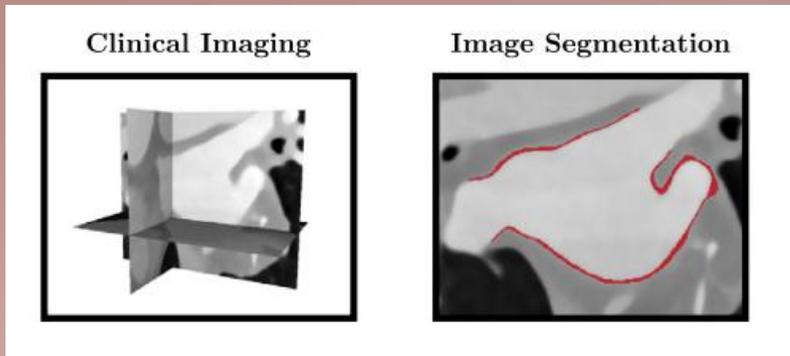


- Images 2D/3D (photographie

# Indications ?



- Images 2D/3D (photo , rx , irm)



- Fichiers 3D maillés (stl, ply...)

Clinical Imaging

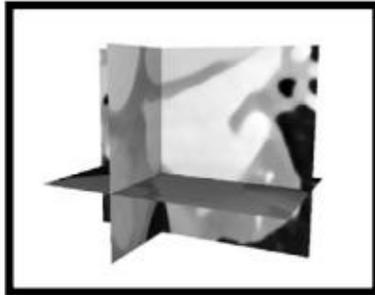
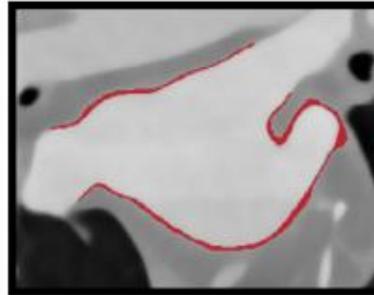


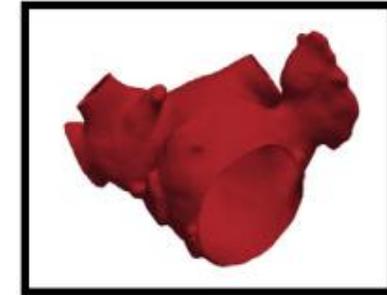
Image Segmentation



Segmentation Smoothing



Mesh Generation



## Personalized computational modeling of left atrial geometry and transmural myofiber architecture

Thomas E. Fastl<sup>a,\*</sup>, Catalina Tobon-Gomez<sup>a</sup>, Andrew Crozier<sup>b</sup>, John Whitaker<sup>a,c</sup>, Ronak Rajani<sup>a,c</sup>, Karen P. McCarthy<sup>d</sup>, Damian Sanchez-Quintana<sup>e</sup>, Siew Y. Ho<sup>d</sup>, Mark D. O'Neill<sup>a,c</sup>, Gernot Plank<sup>b</sup>, Martin J. Bishop<sup>a</sup>, Steven A. Niederer<sup>a</sup>

<sup>a</sup> Department of Biomedical Engineering, King's College London, London, United Kingdom

# Selon vous quelles sont les limites ?

Clinical Imaging

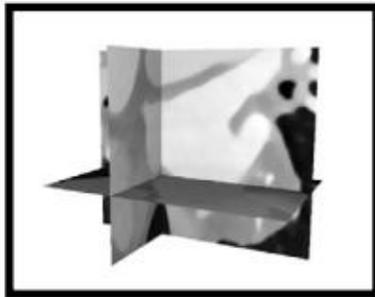
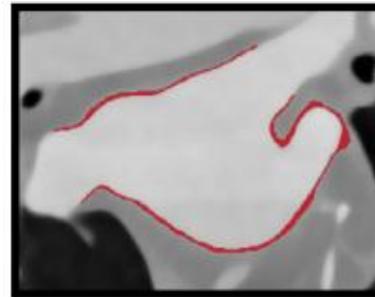
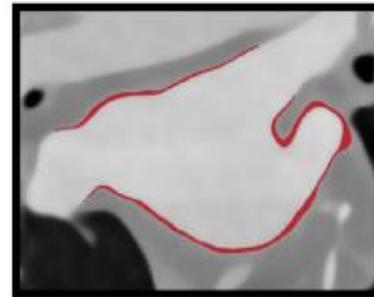


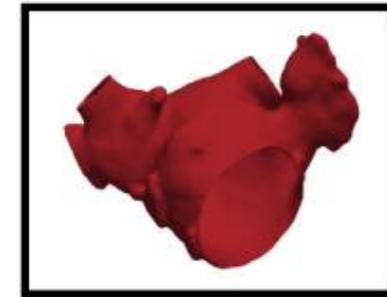
Image Segmentation



Segmentation Smoothing



Mesh Generation



Medical Image Analysis 47 (2018) 180–190



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Medical Image Analysis

journal homepage: [www.elsevier.com/locate/media](https://www.elsevier.com/locate/media)

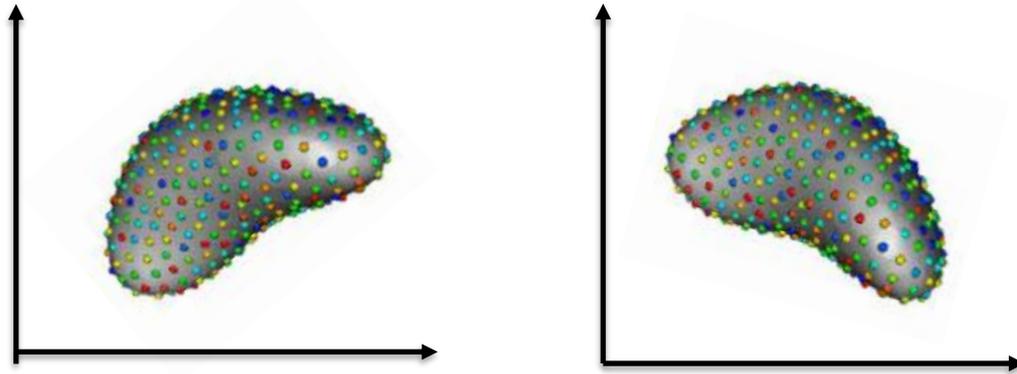
Personalized computational modeling of left atrial geometry and transmurial myofiber architecture

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# Selon vous quelles sont les limites ?

## 1) Problématique de l'alignement



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### HHS Public Access

Author manuscript

*Comput Cardiol* (2010). Author manuscript; available in PMC 2020 July 06.

Published in final edited form as:

*Comput Cardiol* (2019) ; 46: . doi:10.22489/cinc.2019.200.

### Does Alignment in Statistical Shape Modeling of Left Atrium Appendage Impact Stroke Prediction?

Riddish Bhalodia<sup>1</sup>, Archanasri Subramanian<sup>1</sup>, Alan Morris<sup>2</sup>, Joshua Cates<sup>2</sup>, Ross Whitaker<sup>1</sup>, Evgueni Kholmovski<sup>2,3</sup>, Nassir Marrouche<sup>2</sup>, Shireen Elhabian<sup>1</sup>

<sup>1</sup>Scientific Computing and Imaging Institute, University of Utah, Salt Lake City, Utah, USA

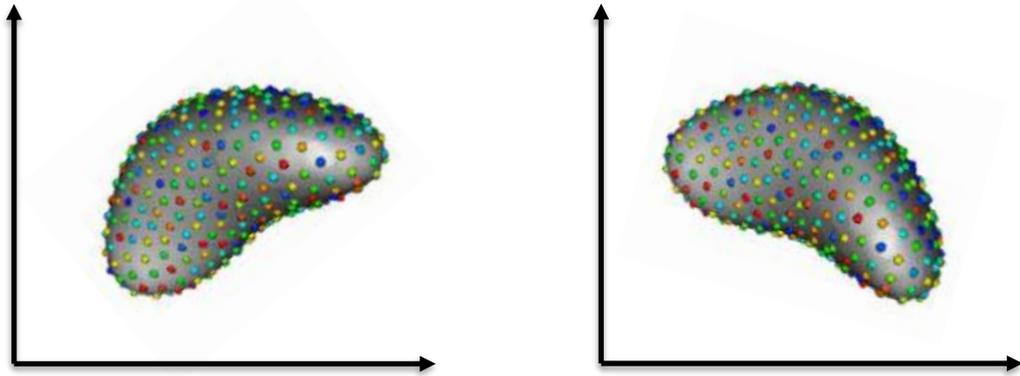
<sup>2</sup>Division of Cardiovascular Medicine, School of Medicine, University of Utah, Salt Lake City, Utah, USA

<sup>3</sup>Department of Radiology and Imaging Sciences, School of Medicine, University of Utah, Salt Lake City, Utah, USA

Abstract

# Selon vous quelles sont les limites ?

## 1) Problématique de l'alignement



Author Manuscript

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Author manuscript  
*Comput Cardiol* (2010). Author manuscript; available in PMC 2020 July 06.

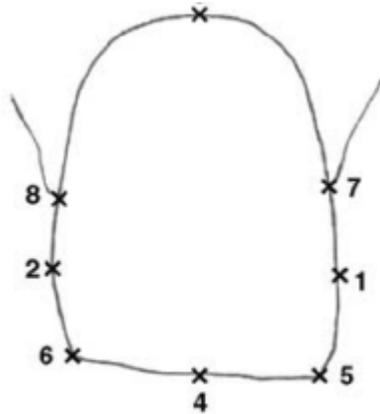
Published in final edited form as:  
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**Does Alignment in Statistical Shape Modeling of Left Atrium  
Appendage Impact Stroke Prediction?**

Même forme mais deux orientations  
⇒ le modèle apprend l'orientation mais pas la forme !!

# Selon vous quelles sont les limites ?

## 2) Positionnement du landmark



PERGAMON

Archives of Oral Biology 47 (2002) 545–554

Archives  
of  
Oral  
Biology

[www.elsevier.com/locate/archoralbio](http://www.elsevier.com/locate/archoralbio)

### Impact of landmark reliability on the planar Procrustes analysis of tooth shape

D.L. Robinson<sup>a,b,\*</sup>, P.G. Blackwell<sup>b</sup>, E.C. Stillman<sup>b</sup>, A.H. Brook<sup>a</sup>

<sup>a</sup> Department of Child Dental Health, School of Clinical Dentistry, University of Sheffield, Claremont Crescent, Sheffield S10 2TA, UK

<sup>b</sup> Department of Probability and Statistics, Hicks Building, University of Sheffield, Hounsfield Road, Sheffield S3 7RH, UK

Accepted 22 March 2002

#### Abstract

In a recent study, the ideas of Procrustes analysis were introduced to the study of tooth shape for teeth represented as configurations of 'landmarks' from digital images. This study aimed to establish how well the method could be expected to perform (in its standard form) when used on surfaces from a variety of tooth types and, in particular, how much impact inconsistencies in the positioning of landmarks would have on investigations of shape.

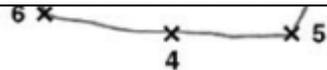
Using four different operators' images and landmarks from 10 different surfaces from each of 20 patients, the consequences of location inconsistency are evaluated by calculating its effect on the recorded variation in Procrustes fits, obtained for each set of multiple representations. The proportion of variation in shape attributable to actual differences between patients, rather than other sources of error, ranged from only 36 to 65% for the five buccal-surfaces considered and was no more than 30% for any of the five occlusal surfaces. Further examination of these results indicated that consistent orientation differences

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Methods of analysis need to accommodate these problems if landmark data are to be used to describe variations in tooth shape. Different surfaces each present their own particular difficulties and so a variety of solutions may be required.



# Selon vous quelles sont les limites ?

## 3) Sensibilité au bruit

JOURNAL OF MAGNETIC RESONANCE IMAGING 26:375-385 (2007)

Original Research

Measurement of Signal to Noise Ratios in MR Parallel

Mouchoux et al. *Head & Face Medicine* (2024) 20:10  
<https://doi.org/10.1186/s13005-024-00411-7>

Head & Face Medicine

RESEARCH Open Access

Check for updates

### Reliability of landmark identification for analysis of the temporomandibular joint in real-time MRI

Jérémy Mouchoux<sup>1\*</sup>, Philipp Meyer-Marcotty<sup>1</sup>, Florian Sojka<sup>1</sup>, Peter Dechent<sup>2</sup>, Daniela Klenke<sup>1</sup>, Bernhard Wiechens<sup>1</sup> and Anja Quast<sup>1</sup>

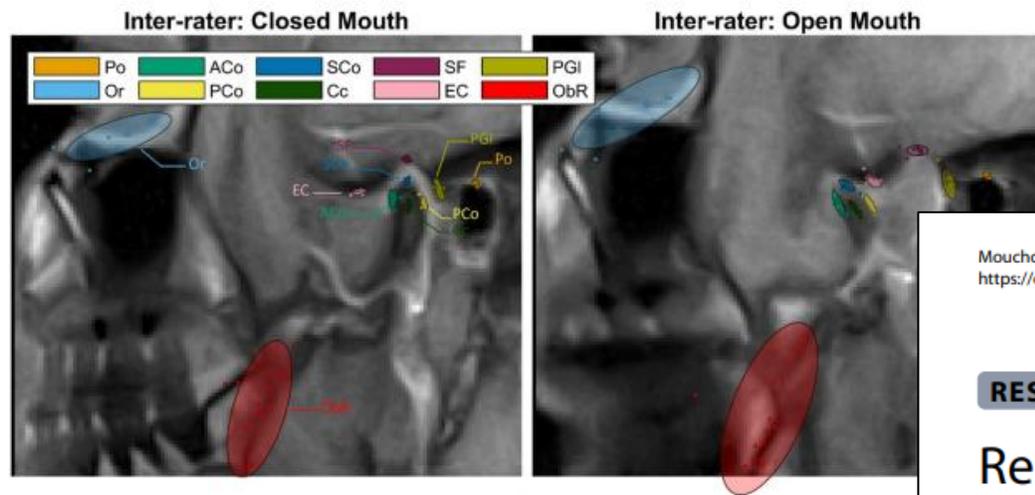
**Abstract**

**Background** Real-time magnetic resonance imaging (rtMRI) is essential for diagnosing and comprehending temporomandibular joint (TMJ) movements. Current methods for tracking and analysis require manual landmark placement

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Head & Face Medicine

RESEARCH

Open Access



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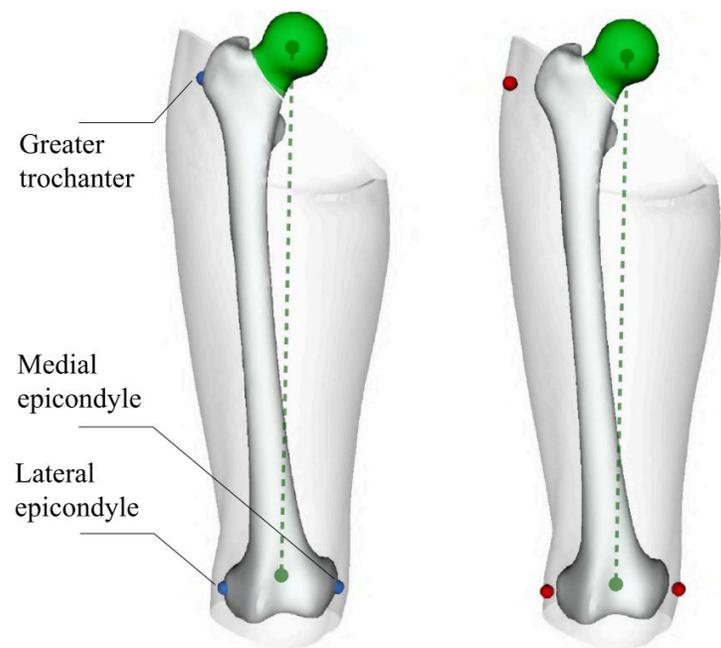
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## 4) Perte d'information



Medical Engineering and Physics 95 (2021) 30–38

Contents lists available at ScienceDirect

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Medical Engineering and Physics

journal homepage: [www.elsevier.com/locate/medengphy](http://www.elsevier.com/locate/medengphy)

Check for updates

### Bone surface reconstruction and clinical features estimation from sparse landmarks and Statistical Shape Models: a feasibility study on the femur

Alireza Asvadi<sup>a,\*</sup>, Guillaume Dardenne<sup>b,e</sup>, Jocelyne Troccaz<sup>c</sup>, Valérie Burdin<sup>d,e</sup>

<sup>a</sup> University of Western Brittany, UBO, Brest France  
<sup>b</sup> University Hospital of Brest, Brest, France  
<sup>c</sup> Univ. Grenoble Alpes, CNRS, Grenoble INP, TIMC, Grenoble F-38000, France  
<sup>d</sup> IMT Atlantique, Mines Telecom Institute, Brest, France  
<sup>e</sup> Laboratory of Medical Information Processing (LaTIM), INSERM U 1101, Brest, France

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ARTICLE INFO

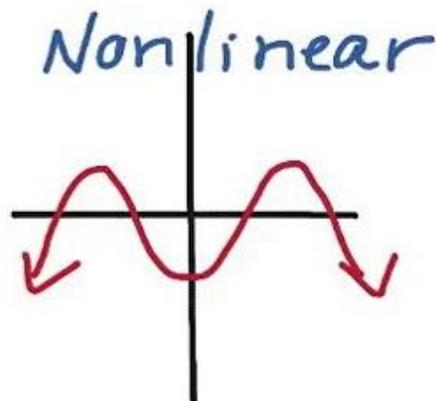
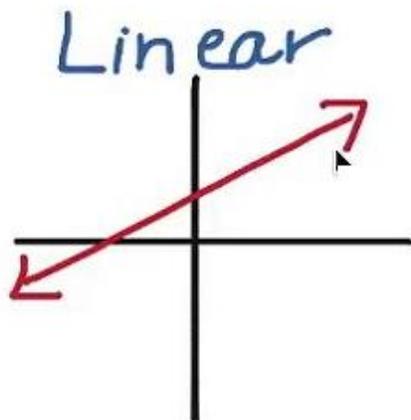
**Keywords:**  
Statistical shape models  
Shape reconstruction  
Mechanical axis estimation  
Landmark evaluation

ABSTRACT

In this study, we investigated a method allowing the determination of the femur bone surface as well as its mechanical axis from some easy-to-identify bony landmarks. The reconstruction of the whole femur is therefore performed from these landmarks using a Statistical Shape Model (SSM). The aim of this research is therefore to assess the impact of the number, the position, and the accuracy of the landmarks for the reconstruction of the femur and the determination of its related mechanical axis, an important clinical parameter to consider for the lower limb analysis. Two statistical femur models were created from our in-house dataset and a publicly available dataset. Both were evaluated in terms of average point-to-point surface distance error and through the mechanical axis of the femur. Furthermore, the clinical impact of using landmarks on the skin in replacement of bony landmarks is investigated. The predicted proximal femurs from bony landmarks were more accurate

# Selon vous quelles sont les limites ?

## 5) Non-linéarité



Computerized Medical Imaging and Graphics 77 (2019) 101638

Contents lists available at ScienceDirect

Computerized Medical Imaging and Graphics

ELSEVIER journal homepage: [www.elsevier.com/locate/compmedimag](http://www.elsevier.com/locate/compmedimag)

A novel robust kernel principal component analysis for nonlinear statistical shape modeling from erroneous data

Jingting Ma<sup>a,\*</sup>, Anqi Wang<sup>c</sup>, Feng Lin<sup>a</sup>, Stefan Wesarg<sup>c</sup>, Marius Erdt<sup>a,b</sup>

<sup>a</sup> Nanyang Technological University, Nanyang Avenue 50, Singapore 639798, Singapore  
<sup>b</sup> Fraunhofer Singapore, Nanyang Avenue 50, Singapore 639798, Singapore  
<sup>c</sup> Fraunhofer IGD, Darmstadt 64283, Germany

ARTICLE INFO

Article history:  
Received 19 December 2018  
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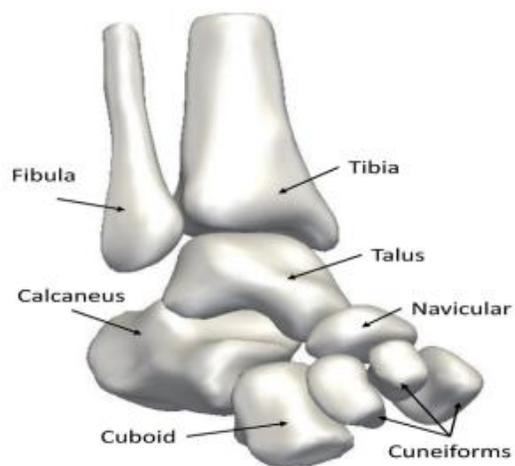
Keywords:  
Statistical shape model  
Robust Kernel principal component analysis  
Data corruption  
Segmentation

ABSTRACT

Statistical Shape Models (SSMs) have achieved considerable success in medical image segmentation. A high quality SSM is able to approximate the main plausible variances of a given anatomical structure to guide segmentation. However, it is technically challenging to derive such a quality model because: (1) the distribution of shape variance is often nonlinear or multi-modal which cannot be modeled by standard approaches assuming Gaussian distribution; (2) as the quality of annotations in training data usually varies, heavy corruption will degrade the quality of the model as a whole. In this work, these challenges are addressed by introducing a generic SSM that is able to model nonlinear distribution and is robust to outliers in training data. Without losing generality and assuming a sparsity in nonlinear distribution, a novel Robust Kernel Principal Component Analysis (RKPCA) for statistical shape modeling is proposed with the aim of constructing a low-rank nonlinear subspace where outliers are discarded. The proposed

# Selon vous quelles sont les limites ?

## 5) Non-linéarité



Computerized Medical Imaging and Graphics 77 (2019) 101638

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# Selon vous quelles sont les limites ?

## 6) Sample size

Received: 2 December 2022 | Revised: 14 January 2023 | Accepted: 26 January 2023

DOI: 10.1002/rcs.2503

REVIEW ARTICLE

The International Journal of Medical Robotics and Computer Assisted Surgery WILEY

### The accuracy of statistical shape models in predicting bone shape: A systematic review

Amogh Patil<sup>1</sup> | Krishan Kulkarni<sup>2</sup> | Shuqiao Xie<sup>3</sup> | Anthony M. J. Bull<sup>3</sup> | Gareth G. Jones<sup>1</sup>

<sup>1</sup>The MSk Lab, Imperial College London, London, UK

<sup>2</sup>Department of Trauma and Orthopaedics, East Lancashire Hospitals NHS Trust, Blackburn, UK

<sup>3</sup>Department of Bioengineering, Imperial College London, London, UK

Correspondence

Amogh Patil.  
Email: amogh.patil1@nhs.net

#### Abstract

**Background:** This systematic review aims to ascertain how accurately 3D models can be predicted from two-dimensional (2D) imaging utilising statistical shape modelling.

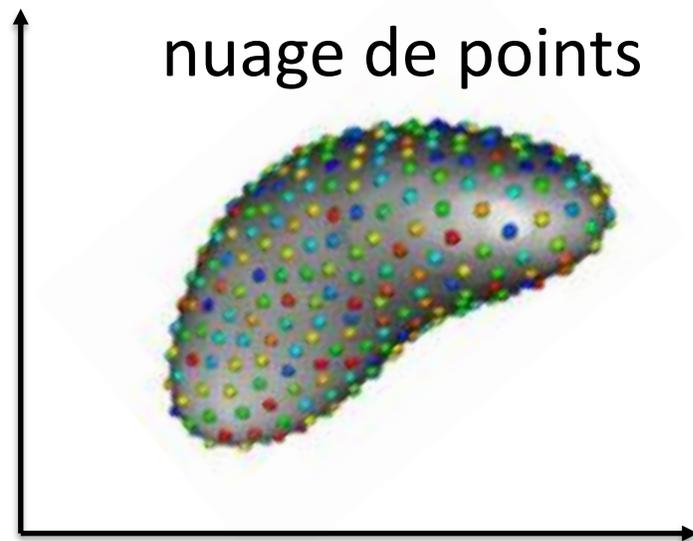
**Methods:** A systematic search of published literature was conducted in September 2022. All papers which assessed the accuracy of 3D models predicted from 2D imaging utilising statistical shape models and which validated the models against the ground truth were eligible.

**Results:** 2127 papers were screened and a total of 34 studies were included for final data extraction. The best overall achievable accuracy was 0.45 mm (root mean square error) and 0.16 mm (average error).

**Conclusion:** Statistical shape modelling can predict detailed 3D anatomical models

# *L'analyse statistique de formes*

## *En résumé*



Réduire la  
dimensionnalité

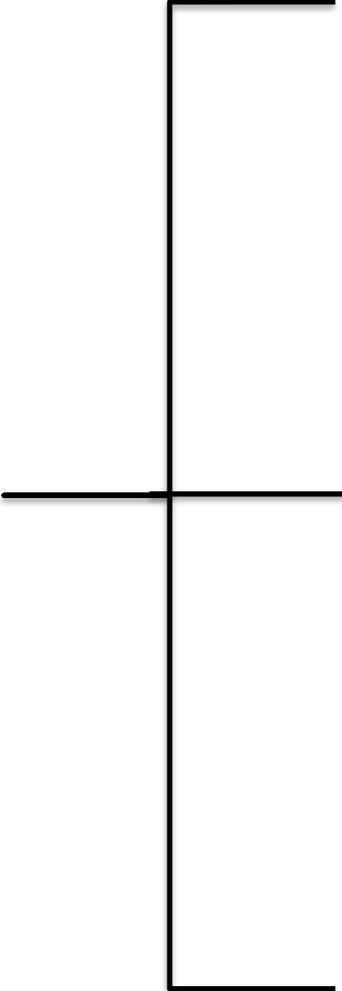
# *L'analyse statistique de formes*

## *En résumé*



**Réduire la  
dimensionnalité**

Erreur



Données (bruit à l'acquisition,  
diversité/représentativité)

Annotation et pré-traitement  
(précision, robustesse, alignement)

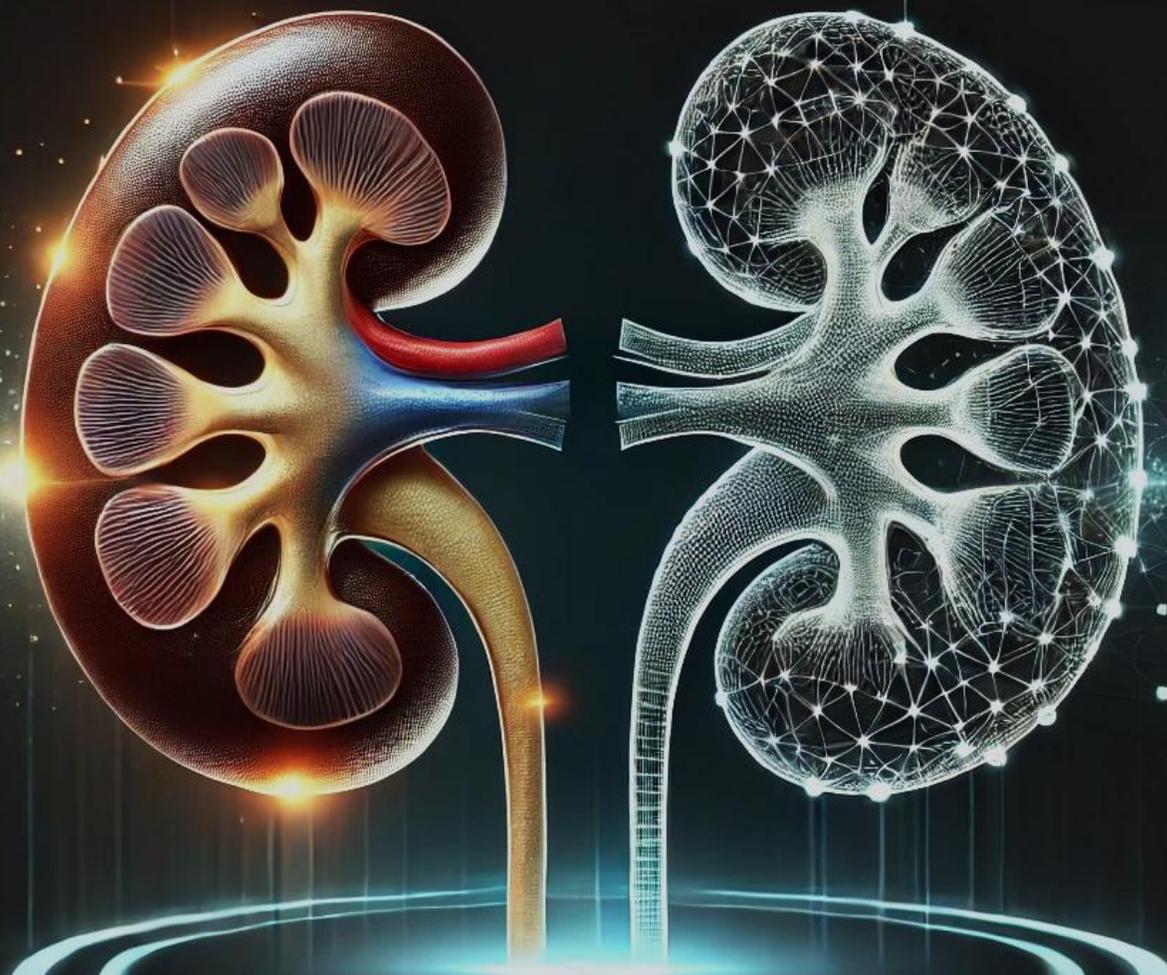
Apprentissage (surapprentissage,  
non-linéarité)

Erreur

Données (bruit à l'acquisition,  
diversité/représentativité)

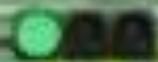
Annotation et pré-traitement  
(précision, robustesse, alignement)

Apprentissage (surapprentissage,  
non-linéarité)



# **Chapitre 2** Réseaux de neurone

green 0.81



green 0.81





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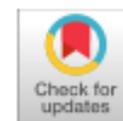
Contents lists available at ScienceDirect

## Healthcare Analytics

journal homepage: [www.elsevier.com/locate/health](http://www.elsevier.com/locate/health)



# A comprehensive review of deep neural networks for medical image processing: Recent developments and future opportunities



Pawan Kumar Mall <sup>a,\*</sup>, Pradeep Kumar Singh <sup>b</sup>, Swapnita Srivastav <sup>c</sup>, Vipul Narayan <sup>c</sup>,  
Marcin Paprzycki <sup>d</sup>, Tatiana Jaworska <sup>d</sup>, Maria Ganzha <sup>d</sup>

<sup>a</sup> *Lovely Professional University, Jalandhar - Delhi G.T. Road, Phagwara, Punjab 144411, India*

<sup>b</sup> *Department of Computer Science and Engineering, Madan Mohan Malaviya University of Technology, Gorakhpur, U.P, 273008, India*

<sup>c</sup> *Galgotias University, Greater Noida, India*

<sup>d</sup> *Systems Research Institute, Polish Academy of Sciences, Poland*

### ARTICLE INFO

#### Keywords:

Artificial intelligence  
Deep neural networks  
Predictive analytics  
Machine learning

### ABSTRACT

Artificial Intelligence (AI) solutions have been widely used in healthcare, and recent developments in deep neural networks have contributed to significant advances in medical image processing. Much ongoing research is aimed at helping medical practitioners by providing automated systems to analyze images and diagnose acute diseases, such as brain tumors, bone cancer, breast cancer, bone fracture, and many others. This comprehensive review delivers an overview of recent advances in medical imaging using deep neural networks. In addition to

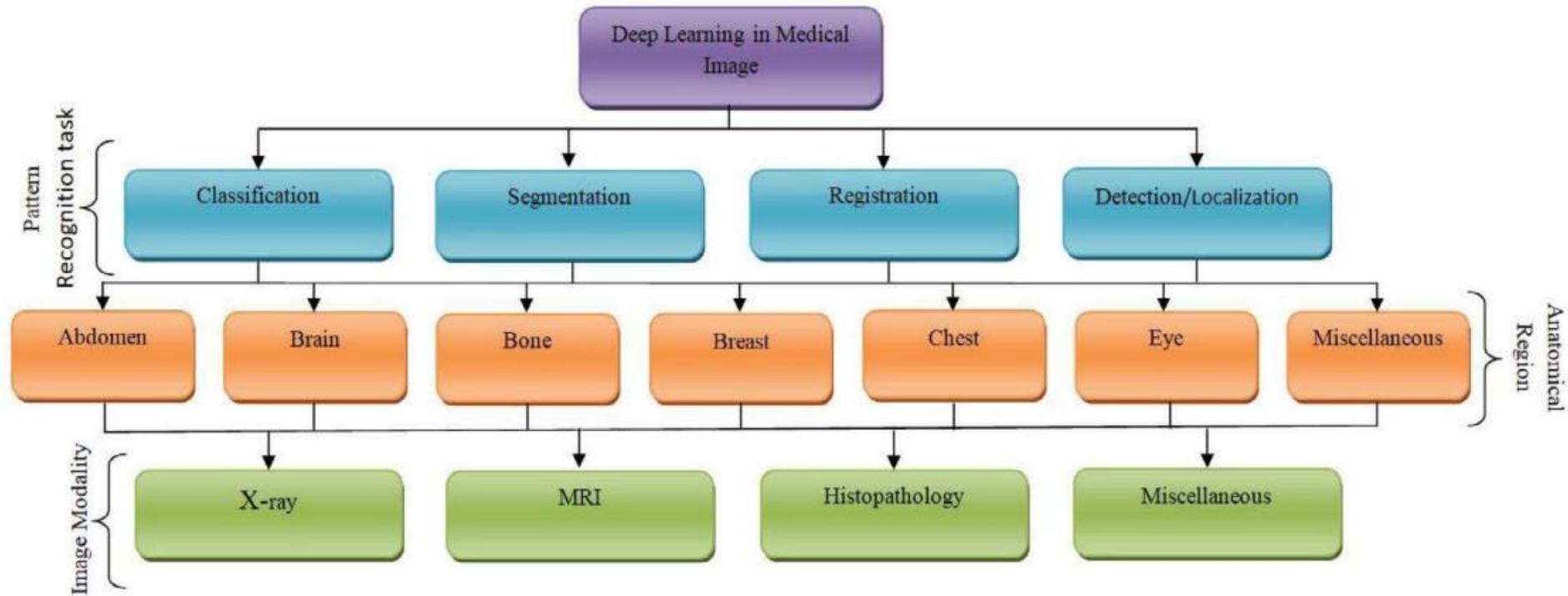


Fig. 1. Hierarchical representation of medical image analysis, in which neural networks have been applied.

set of features based on which classification is conducted. The ConvNet consists of three elementary types of layers: convolution, max-pooling, fully connected (FC), and softmax for classification.

Several essential processes are employed in convolutional neural networks (CNNs) for image classification, including convolution, max-pooling, fully connected (FC) layers, and softmax activation. Here

The significance of CNNs in disease detection lies in their ability to leverage the power of deep learning, extracting meaningful and discriminative features from medical images. By improving detection accuracy, reducing interpretation time, and providing consistent results, CNNs contribute to more effective and efficient disease diagnosis, enabling early intervention, better patient outcomes, and enhanced

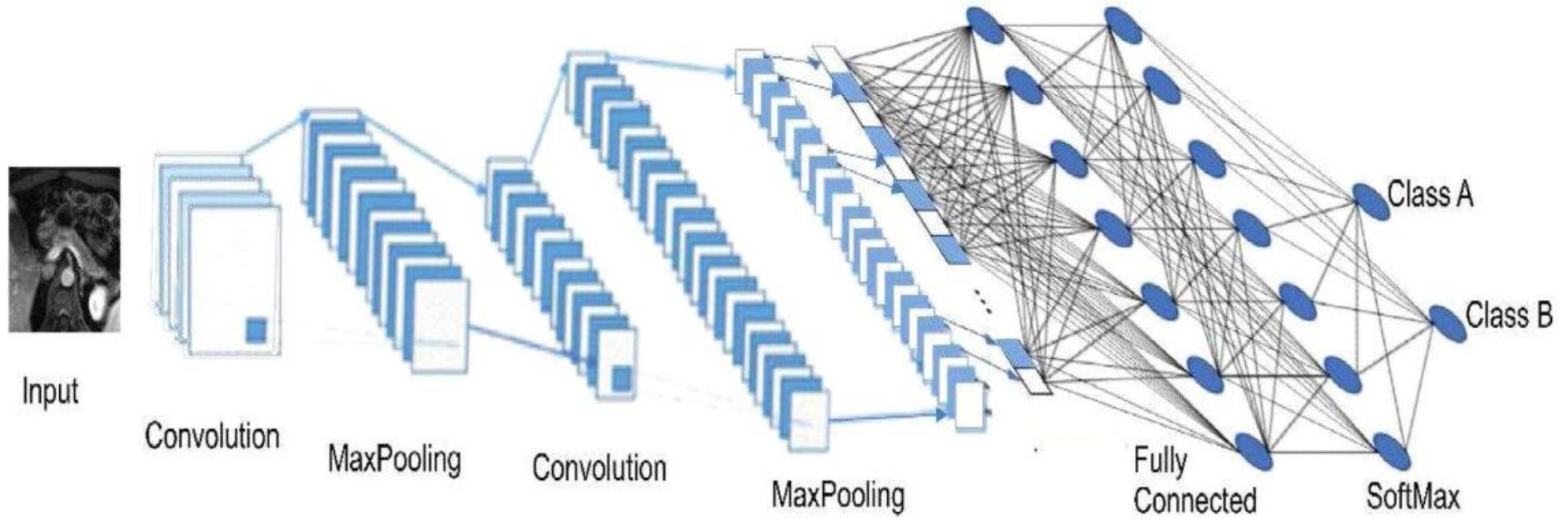
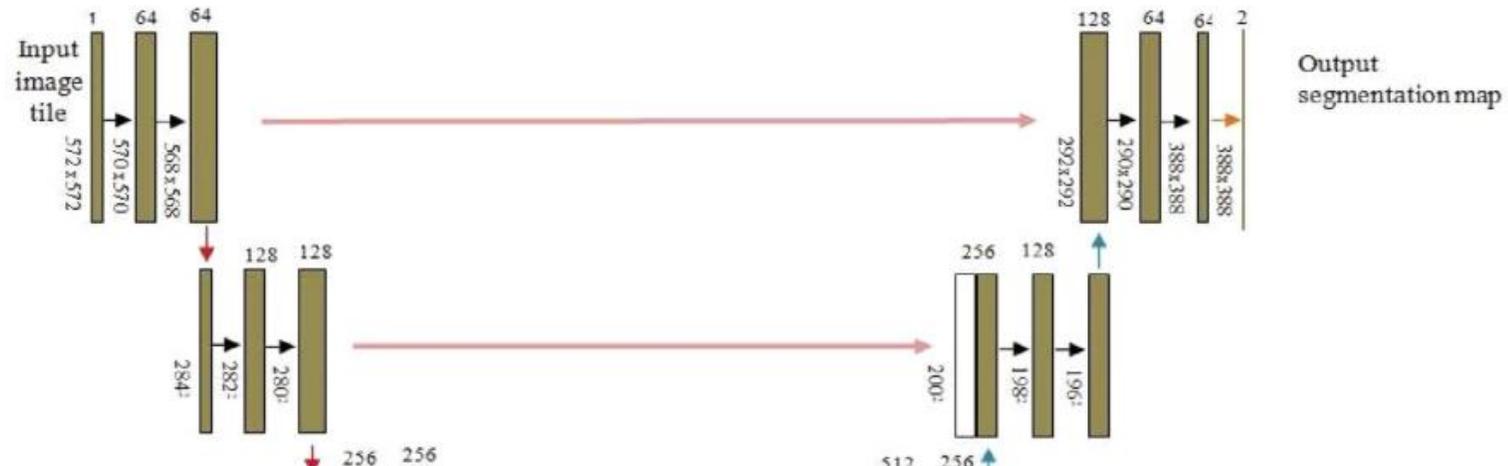
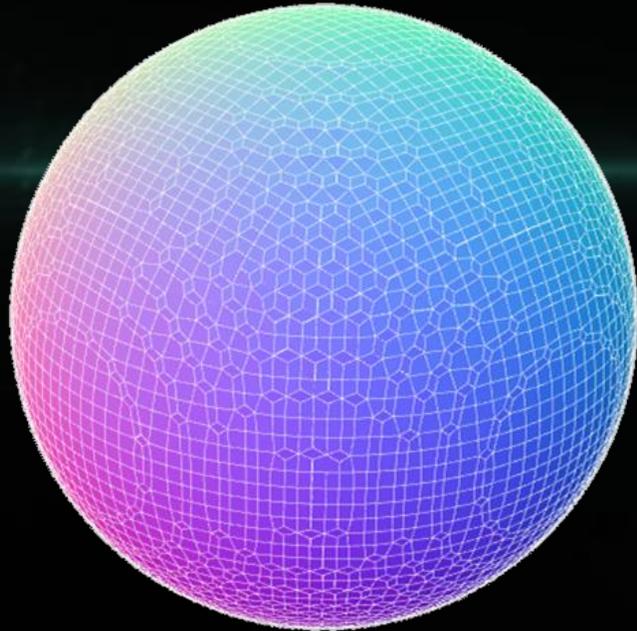


Fig. 2. CNN architecture for classification.

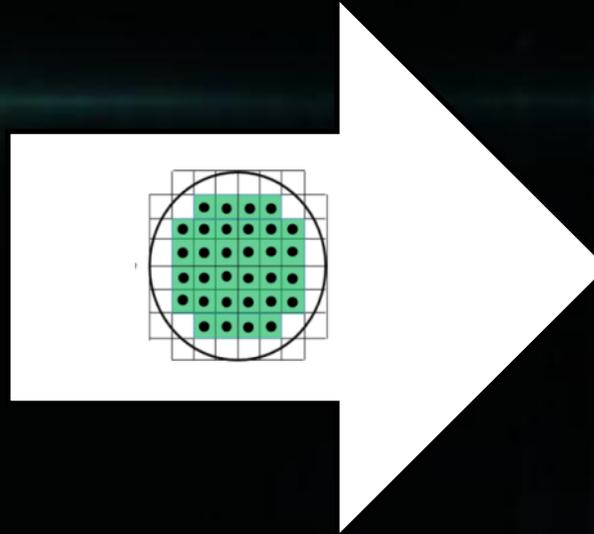
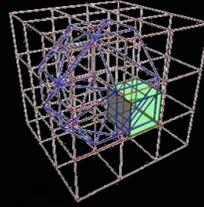
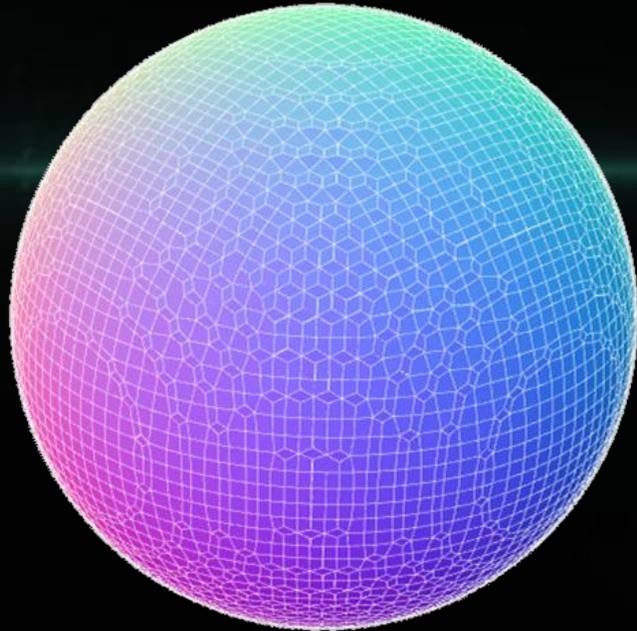


<b>Méthode</b>	<b>Avantages</b>	<b>Inconvénients</b>
<b>CNN</b>	<ul style="list-style-type: none"><li>- Capacité à gérer des données hétérogènes (IRM, CT).</li><li>- Reconst rapide avec données structurées</li></ul>	<ul style="list-style-type: none"><li>- Nécessité de grilles régulières : peu adapté maillages / nuages de pts.</li><li>- Difficultés pour surfaces complexes ou des détails fins</li></ul>

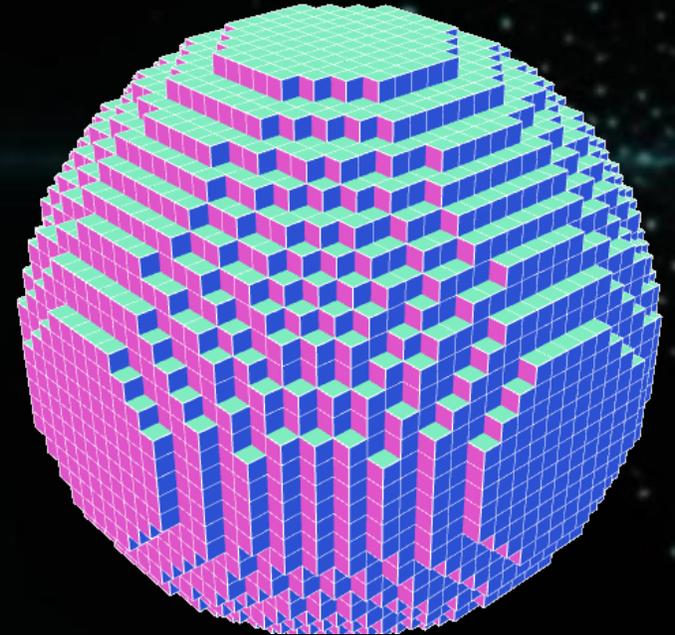
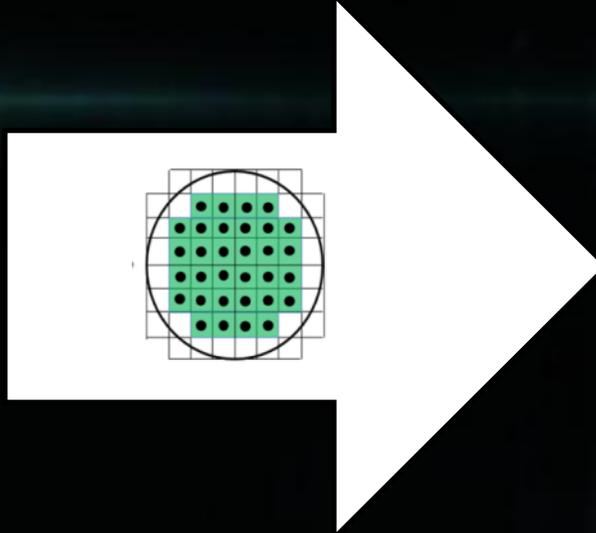
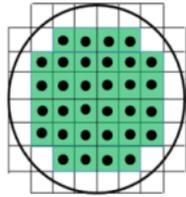
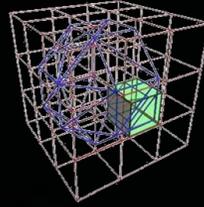
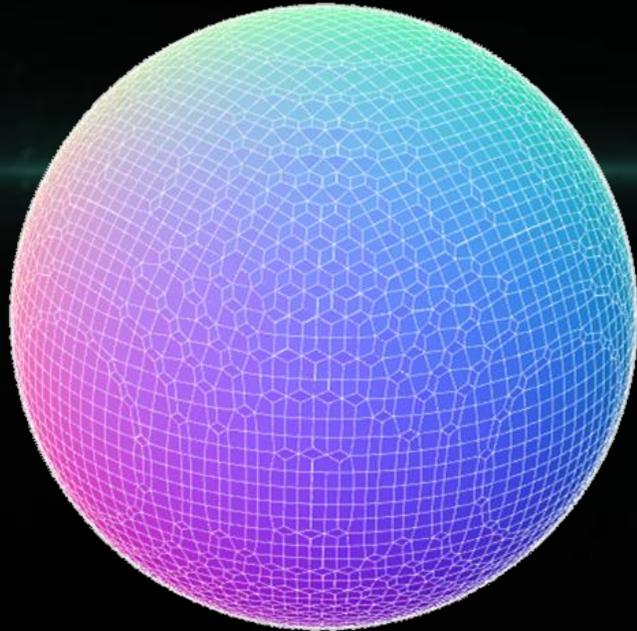
**Représenter une sphère avec des voxels ?**



# Représenter une sphère avec des voxels ?



# Représenter une sphère avec des voxels ?





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## Computers in Biology and Medicine

journal homepage: [www.elsevier.com/locate/combiomed](http://www.elsevier.com/locate/combiomed)



### Generative adversarial networks in medical image segmentation: A review

Siyi Xun<sup>a</sup>, Dengwang Li<sup>a,\*</sup>, Hui Zhu<sup>b</sup>, Min Chen<sup>c</sup>, Jianbo Wang<sup>d</sup>, Jie Li<sup>e</sup>, Meirong Chen<sup>f</sup>,  
Bing Wu<sup>g</sup>, Hua Zhang<sup>h</sup>, Xiangfei Chai<sup>i</sup>, Zekun Jiang<sup>a</sup>, Yan Zhang<sup>a</sup>, Pu Huang<sup>a,\*\*</sup>

<sup>a</sup> Shandong Key Laboratory of Medical Physics and Image Processing, Shandong Institute of Industrial Technology for Health Sciences and Precision Medicine, School of Physics and Electronics, Shandong Normal University, Jinan, Shandong, 250358, China

<sup>b</sup> Department of Radiation Oncology, Shandong Cancer Hospital and Institute, Shandong First Medical University and Shandong Academy of Medical Sciences, Jinan, Shandong, China

<sup>c</sup> The Second Hospital of Shandong University, Shandong University, The Department of Medicine, The Second Hospital of Shandong University, Jinan, China

<sup>d</sup> Department of Radiation Oncology, Qilu Hospital, Cheeloo College of Medicine, Shandong University, Jinan, Shandong, 250012, China

<sup>e</sup> Department of Infectious Disease, Shandong Provincial Hospital Affiliated to Shandong University, Cheeloo College of Medicine, Shandong University, Jinan, Shandong, China

<sup>f</sup> Affiliated Hospital of Shandong University of Traditional Chinese Medicine, Jinan, Shandong, China

<sup>g</sup> Laibo Biotechnology Co., Ltd., Jinan, Shandong, China

<sup>h</sup> LinkingMed Technology Co., Ltd., Beijing, China

<sup>i</sup> Shandong Key Laboratory of Medical Physics and Image Processing, Shandong Institute of Industrial Technology for Health Sciences and Precision Medicine, School of Physics and Electronics, Shandong Normal University, Jinan, Shandong, 250358, China

## GAN

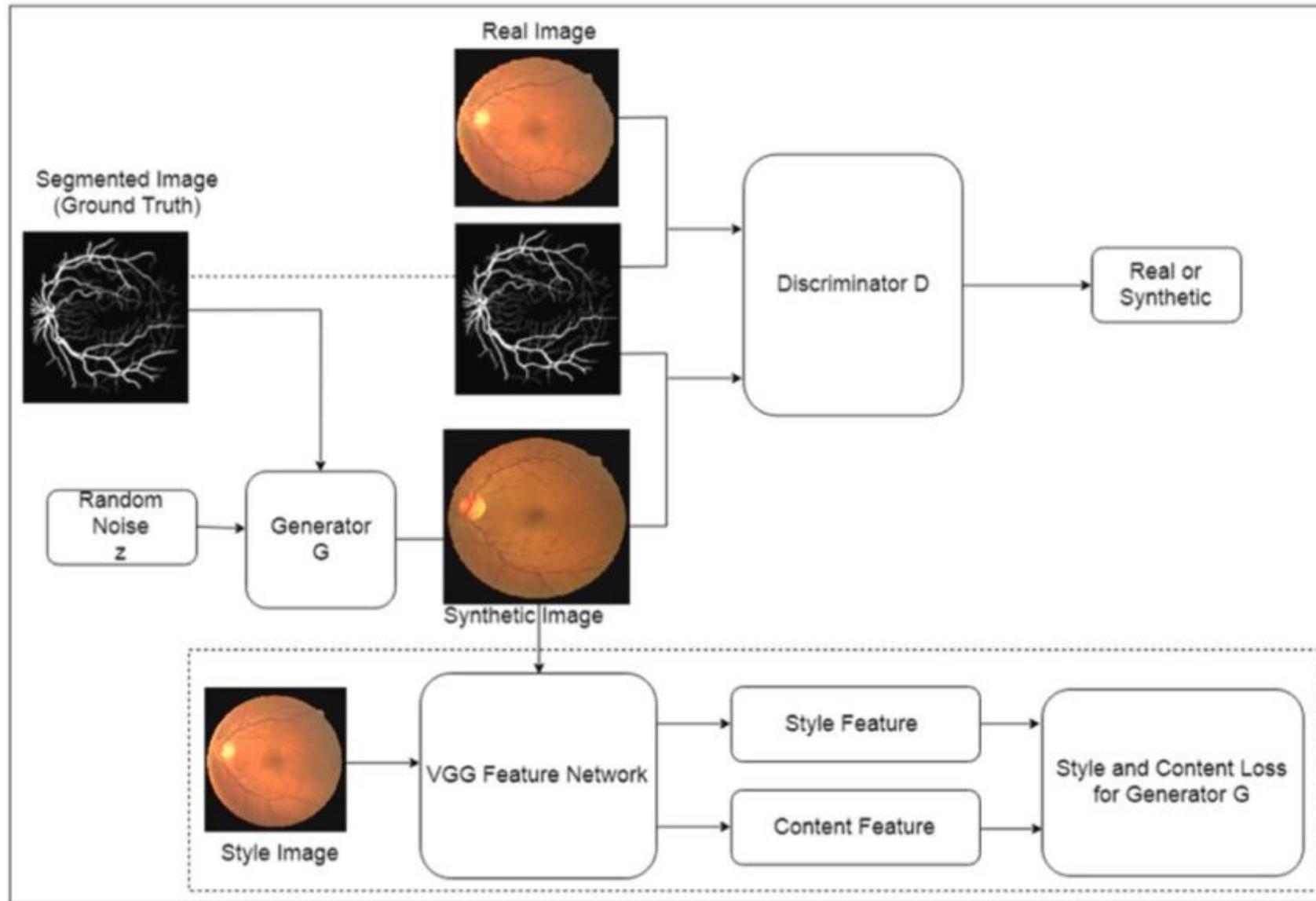
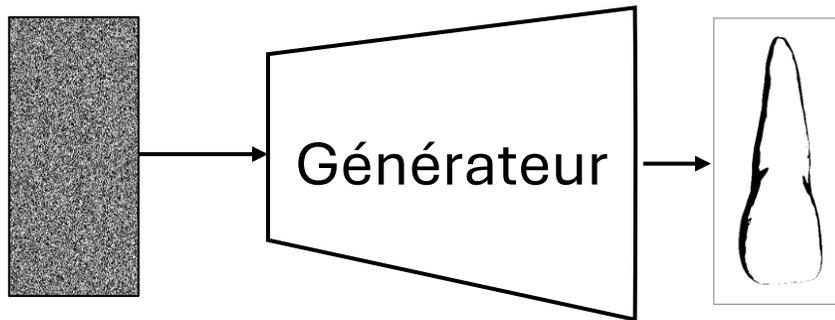


Fig. 5. The schematic diagram of retinal vascular segmentation process proposed in Iqbal and Ali (2018) [42].

of  $x$  and it outputs a probability. The model loss includes  $L_1$  loss and found that applying orthogonal regularization to the generator is

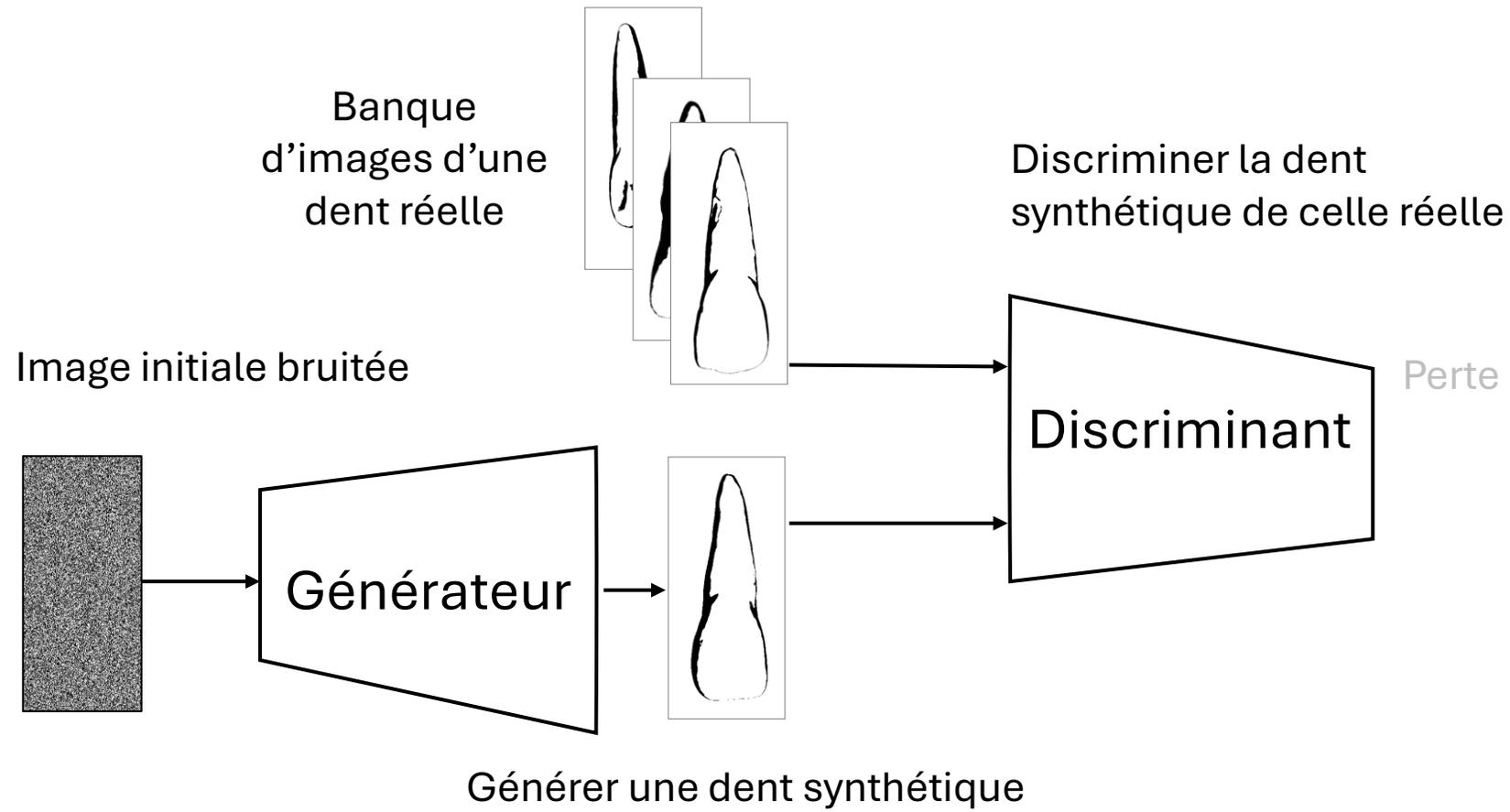
# GAN

Image initiale bruitée

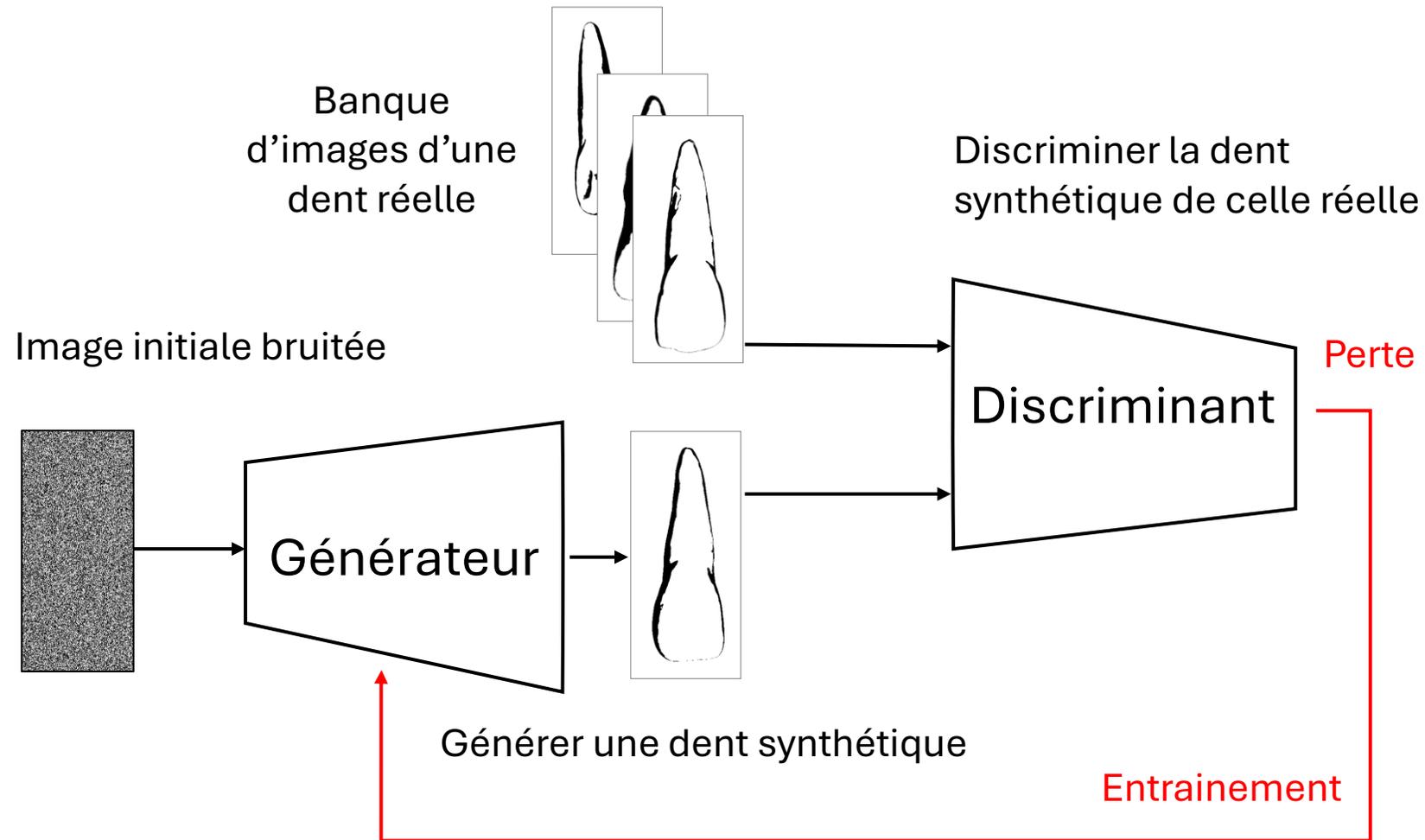


Générer une dent synthétique

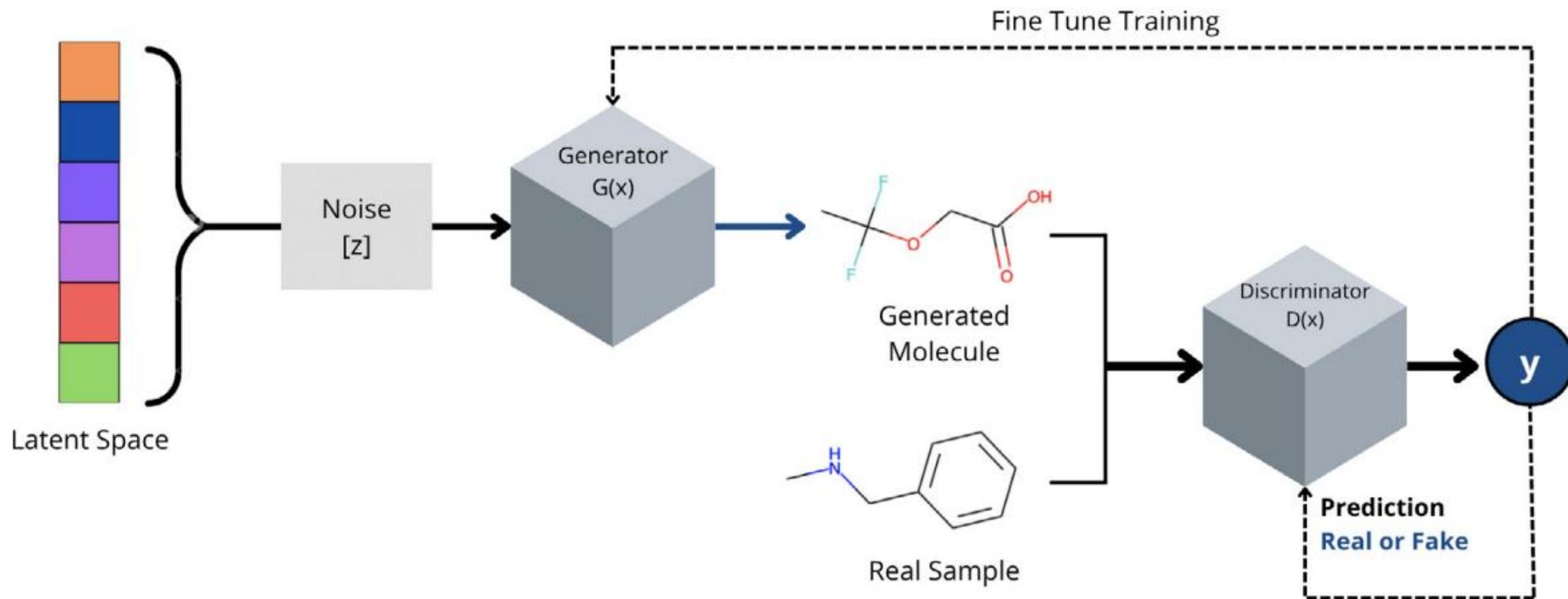
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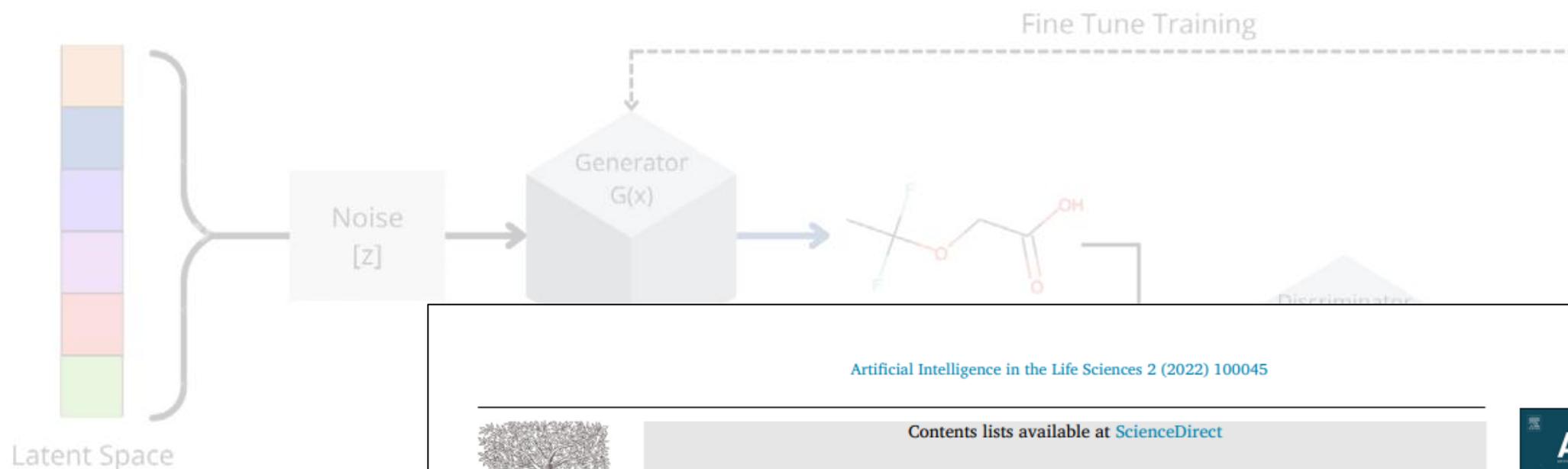
# GAN



# GAN



# GAN



Artificial Intelligence in the Life Sciences 2 (2022) 100045



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## Artificial Intelligence in the Life Sciences

journal homepage: [www.elsevier.com/locate/ailsci](http://www.elsevier.com/locate/ailsci)



Review

### Recent advances and application of generative adversarial networks in drug discovery, development, and targeting



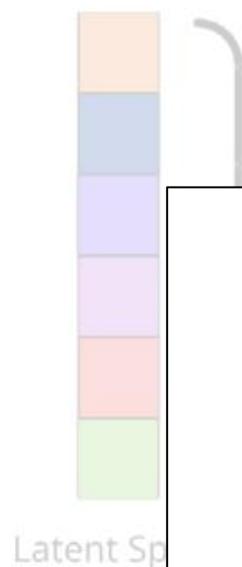
Satvik Tripathi<sup>a,\*</sup>, Alisha Isabelle Augustin<sup>b</sup>, Adam Dunlop<sup>c</sup>, Rithvik Sukumaran<sup>a</sup>,  
Suhani Dheer<sup>c</sup>, Alex Zavalny<sup>a</sup>, Owen Haslam<sup>c</sup>, Thomas Austin<sup>d</sup>, Jacob Donchez<sup>e</sup>,  
Pushpendra Kumar Tripathi<sup>f</sup>, Edward Kim<sup>a</sup>

<sup>a</sup> College of Computing and Informatics Drexel University Philadelphia, PA 19104 USA

<sup>b</sup> College of Engineering Drexel University Philadelphia, USA

<sup>c</sup> College of Arts and Sciences Drexel University Philadelphia, PA 19104 USA

# GAN



## Trends in Pharmacological Sciences

CellPress  
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### Review

# Advancing non-destructive analysis of 3D printed medicines

Anna Kirstine Jørgensen,<sup>1</sup> Jun Jie Ong,<sup>1</sup> Maryam Parhizkar,<sup>1</sup> Alvaro Goyanes,<sup>1,2,3,4,\*</sup> and Abdul W. Basit <sup>1,3,4,\*</sup>

Pharmaceutical 3D printing (3DP) has attracted significant interest over the past decade for its ability to produce personalised medicines on demand. However, current quality control (QC) requirements for traditional large-scale pharmaceutical manufacturing are irreconcilable with the production offered by 3DP. The US Food and Drug Administration (FDA) and the UK Medicines and Healthcare Products Regulatory Agency (MHRA) have recently published documents supporting the implementation of 3DP for point-of-care (PoC) manufacturing along with regulatory hurdles. The importance of process analytical technology (PAT) and non-

### Highlights

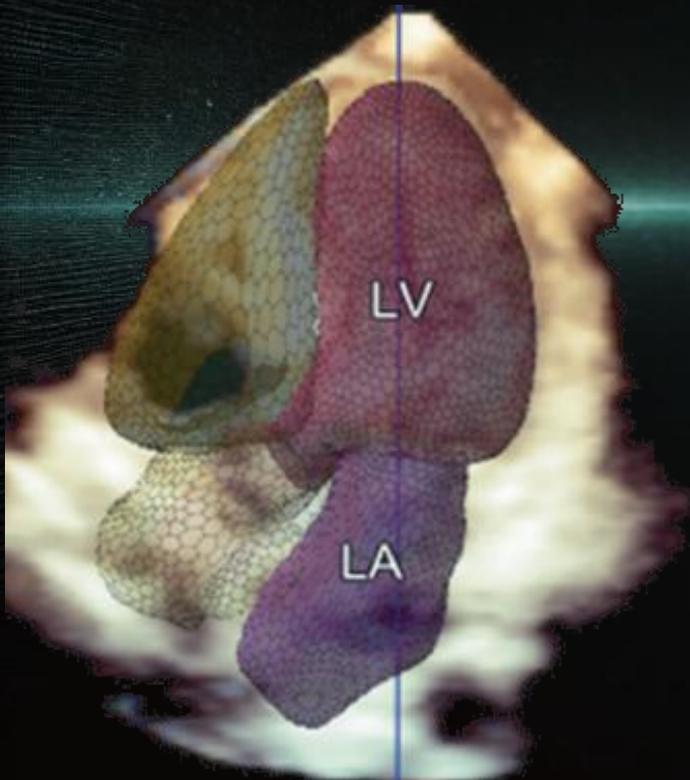
3D printing of medicines holds the potential to revolutionise therapeutic regimens and manufacture by offering tuneable, personalised, and on-demand manufacture at a small scale and at the PoC.

Regulatory authorities have established expert working groups and have called



Méthode	Avantages	Inconvénients
<b>CNN</b>	<ul style="list-style-type: none"> <li>- Capacité à gérer des données hétérogènes (IRM, CT).</li> <li>- Reconst rapide avec données structurées</li> </ul>	<ul style="list-style-type: none"> <li>- Nécessité de grilles régulières : peu adapté maillages / nuages de pts.</li> <li>- Difficultés pour surfaces complexes ou des détails fins</li> </ul>
<b>GAN</b>	<ul style="list-style-type: none"> <li>- Capacité à gérer des données hétérogènes (IRM, CT).</li> <li>- Capacité générer rapidement des données synthétiques.</li> </ul>	<ul style="list-style-type: none"> <li>- Nécessité de grilles régulières : peu adapté maillages / nuages de pts.</li> <li>- Diff de stabilité d'entraînement (générateur/discriminateur) &amp; risque d'artefacts (surtt si détails fins à apprendre)</li> </ul>

# DeepSDF



Computers in Biology and Medicine 164 (2023) 107266



Contents lists available at ScienceDirect

Computers in Biology and Medicine

journal homepage: [www.elsevier.com/locate/compbio](http://www.elsevier.com/locate/compbio)

## Reconstruction and completion of high-resolution 3D cardiac shapes using anisotropic CMRI segmentations and continuous implicit neural representations

Jörg Sander<sup>a,b,d,\*</sup>, Bob D. de Vos<sup>a</sup>, Steffen Bruns<sup>a</sup>, Nils Planken<sup>c</sup>, Max A. Viergever<sup>e</sup>, Tim Leiner<sup>f</sup>, Ivana Išgum<sup>a,b,c,d</sup>

<sup>a</sup> Department of Biomedical Engineering and Physics, Amsterdam University Medical Center location University of Amsterdam, The Netherlands

<sup>b</sup> Amsterdam Cardiovascular Sciences, Amsterdam, The Netherlands

<sup>c</sup> Department of Radiology and Nuclear Medicine, Amsterdam University Medical Center location University of Amsterdam, Amsterdam, The Netherlands

<sup>d</sup> Informatics Institute, University of Amsterdam, Amsterdam, The Netherlands

<sup>e</sup> Image Sciences Institute, University Medical Center Utrecht, Utrecht, The Netherlands

<sup>f</sup> Department of Radiology, Mayo Clinic, Rochester, MN, USA

### ARTICLE INFO

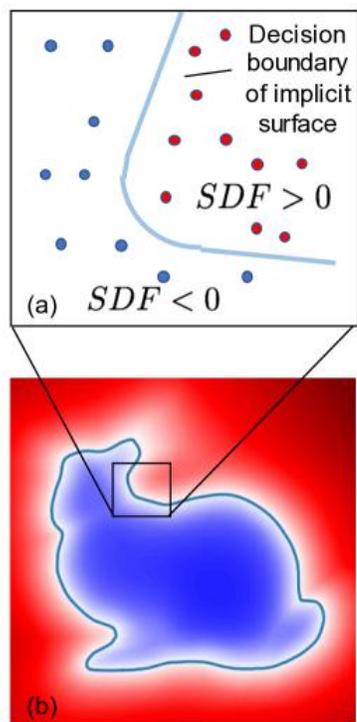
#### Keywords:

Cardiac MRI  
Neural implicit function  
Super-resolution  
Shape completion  
Shape reconstruction

### ABSTRACT

Since the onset of computer-aided diagnosis in medical imaging, voxel-based segmentation has been the primary methodology for automatic analysis of left ventricle (LV) function and morphology from cardiac magnetic resonance images (CMRI). In standard clinical practice, simultaneous multi-slice 2D cardiac MR imaging is performed under multiple breath-holds resulting in highly anisotropic 3D images. Sparse-view CMRI often lacks whole heart coverage caused by large slice thickness and often suffers from slice misalignment induced by respiratory motion. Therefore, these volumes only provide limited information about the true 3D cardiac anatomy which may hamper highly accurate assessment of functional and anatomical abnormalities. To address this, we propose a method that learns a continuous implicit neural representation of 3D LV shapes by training an auto-decoder. For training, high-resolution segmentations are used to supervise the reconstruction of the LV shapes. For inference, the learned implicit neural representation is used to reconstruct and complete the LV shapes from sparse-view CMRI. The proposed method achieves high-resolution reconstruction and completion of the LV shapes from sparse-view CMRI. The proposed method achieves high-resolution reconstruction and completion of the LV shapes from sparse-view CMRI.

# DeepSDF



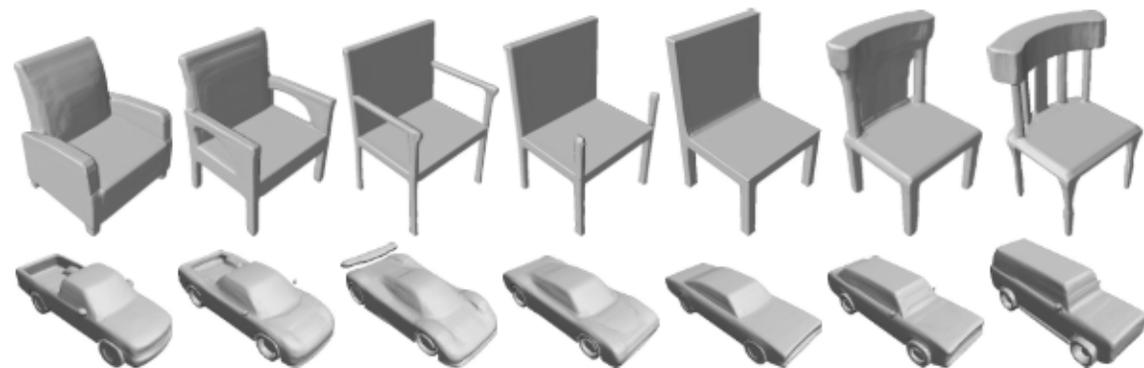
(c)



## DeepSDF: Learning Continuous Signed Distance Functions for Shape Representation

Jeong Joon Park<sup>1,3†</sup> Peter Florence<sup>2,3†</sup> Julian Straub<sup>3</sup> Richard Newcombe<sup>3</sup> Steven Lovegrove<sup>3</sup>

<sup>1</sup>University of Washington <sup>2</sup>Massachusetts Institute of Technology <sup>3</sup>Facebook Reality Labs



**Figure 1:** DeepSDF represents signed distance functions (SDFs) of shapes via latent code-conditioned feed-forward decoder networks. Above images are raycast renderings of DeepSDF interpolating between two shapes in the learned shape latent space. Best viewed digitally.

### Abstract

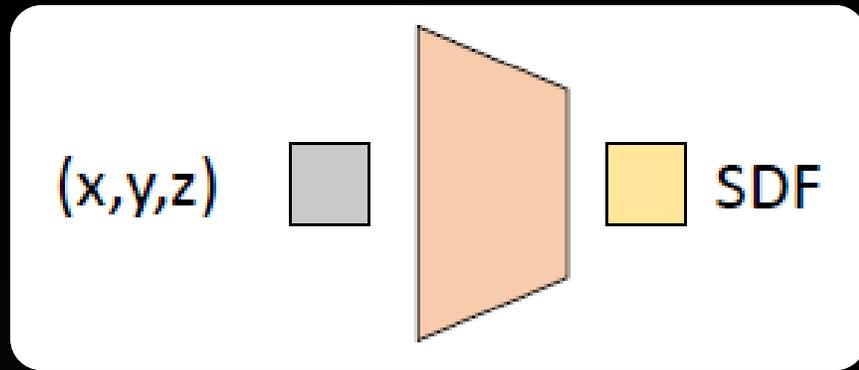
Computer graphics, 3D computer vision and robotics communities have produced multiple approaches to representing 3D geometry for rendering and reconstruction. These provide trade-offs across fidelity, efficiency and compression capabilities. In this work, we introduce DeepSDF, a learned continuous Signed Distance Function (SDF) representation of a class of shapes that enables high quality shape representation, interpolation and completion from partial and noisy 3D input data. DeepSDF, like its clas-

### 1. Introduction

Deep convolutional networks which are a mainstay of image-based approaches grow quickly in space and time complexity when directly generalized to the 3rd spatial dimension, and more classical and compact surface representations such as triangle or quad meshes pose problems in training since we may need to deal with an unknown number of vertices and arbitrary topology. These challenges have limited the quality, flexibility and fidelity of

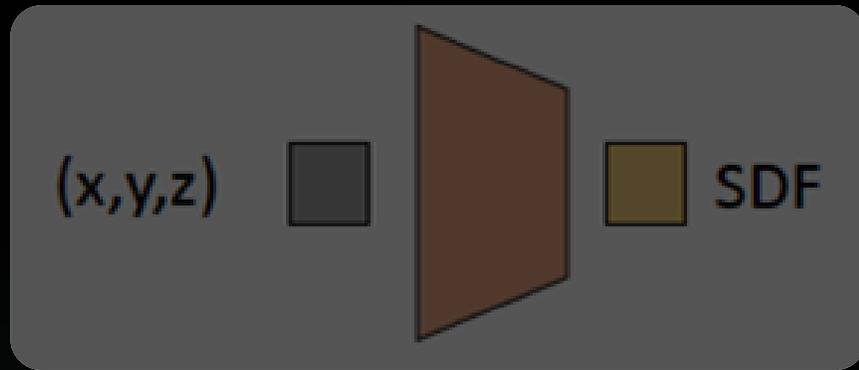
1901.05103v1 [cs.CV] 16 Jan 2019

# Représenter une forme avec une fonction de distance

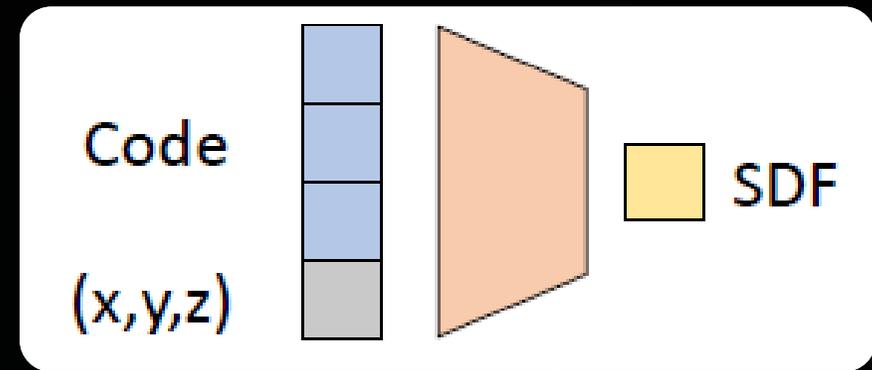


Apprendre une forme

# Représenter des formes avec une fonction de distance

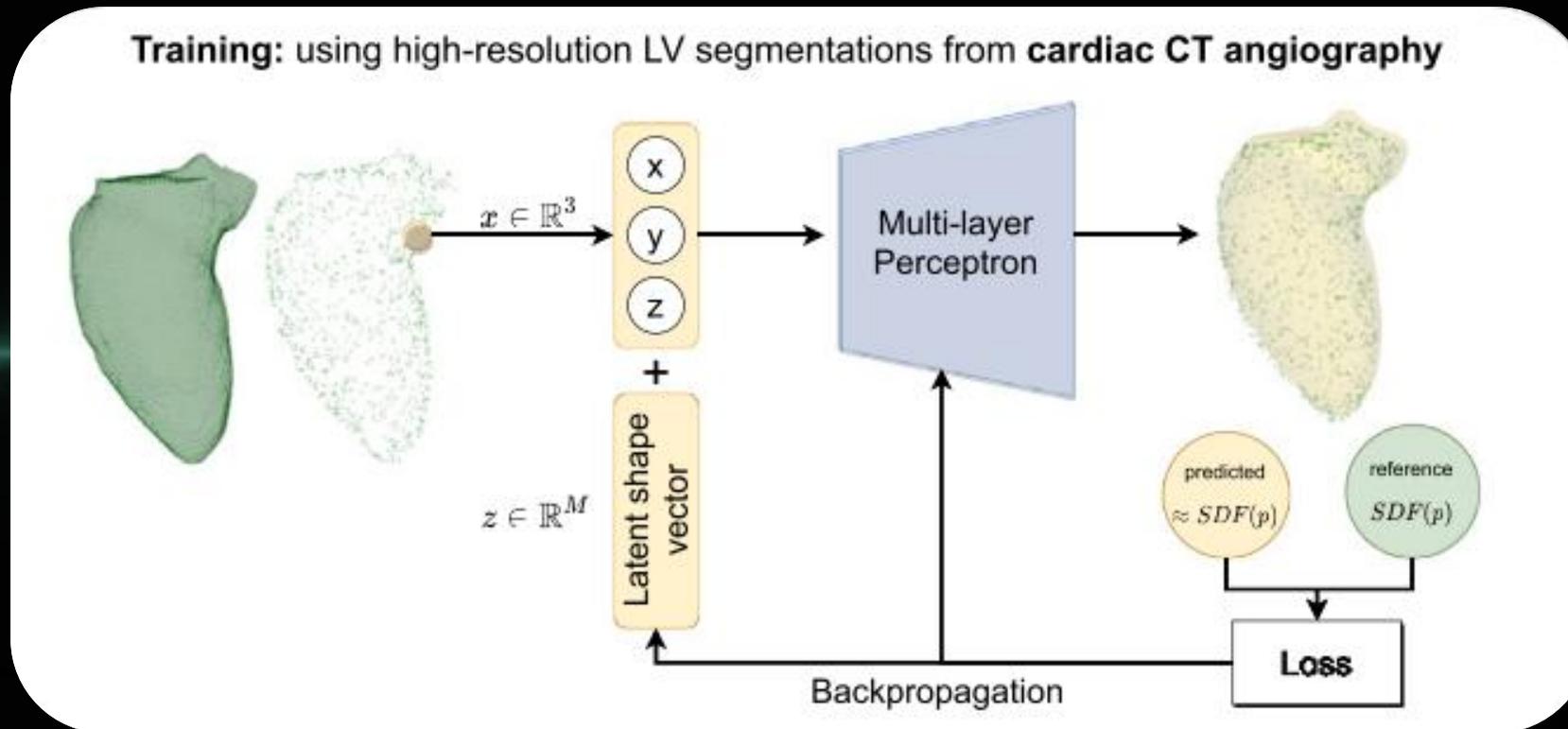


Apprendre une forme



Apprendre des formes

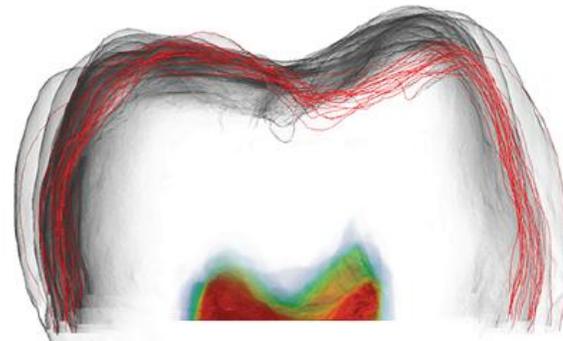
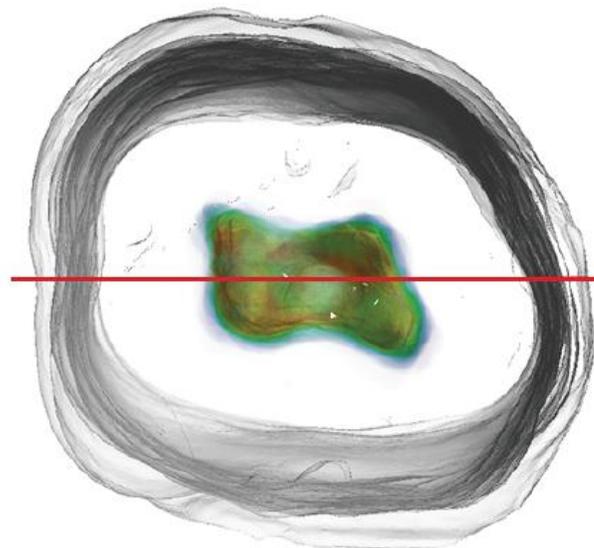
# Représenter des formes avec une fonction de distance



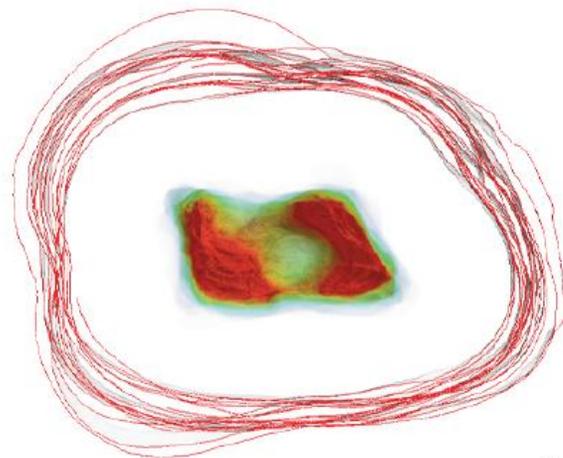
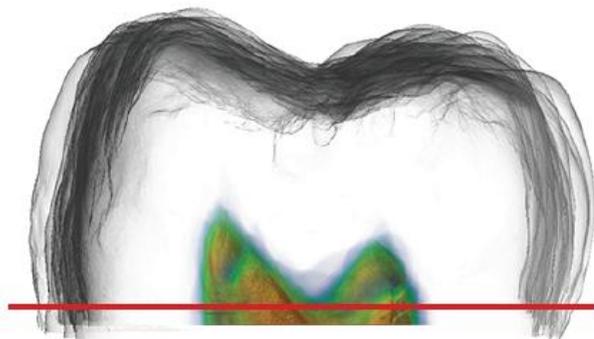
Overview

Slice View

Sagittal Slice



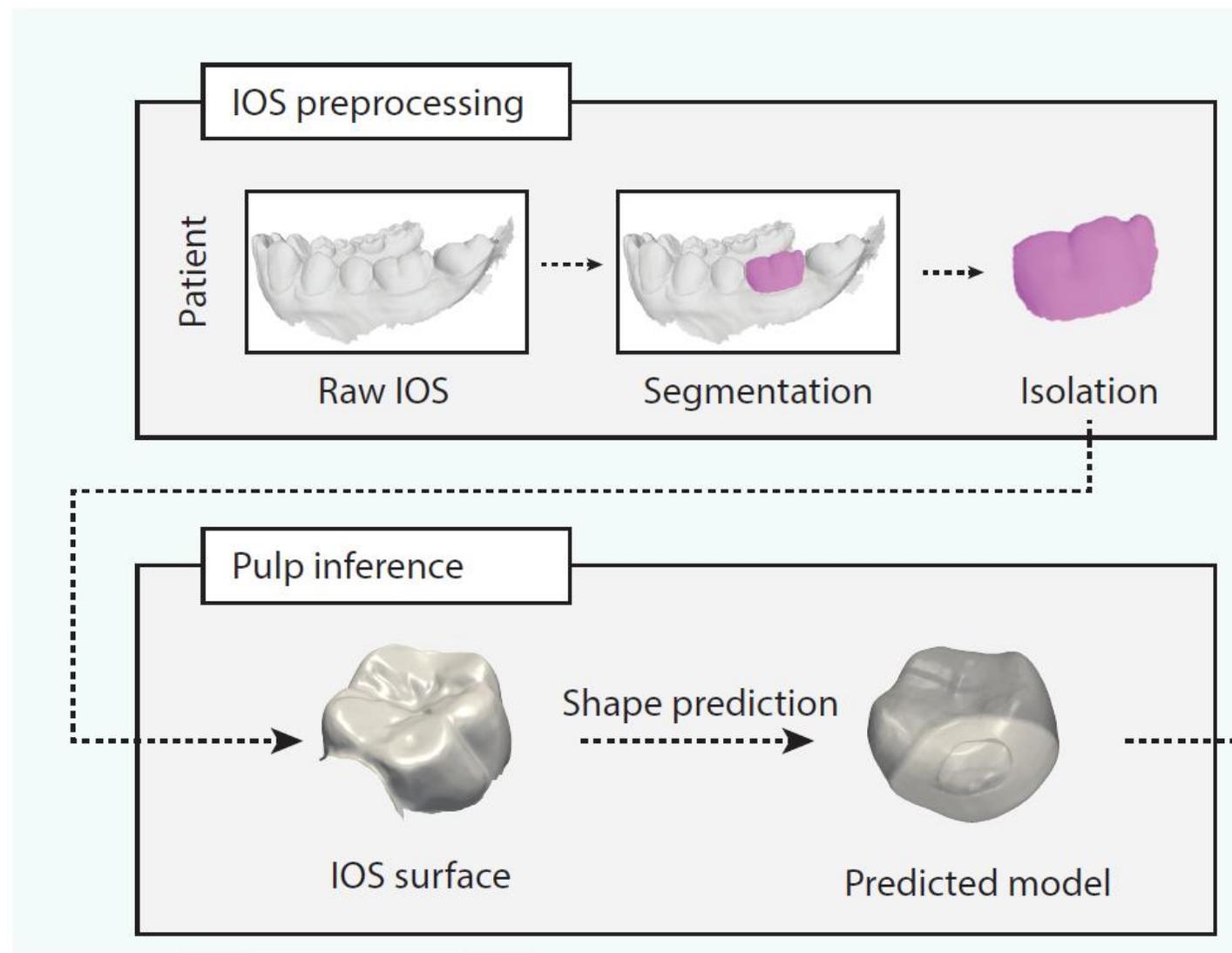
Horizontal Slice



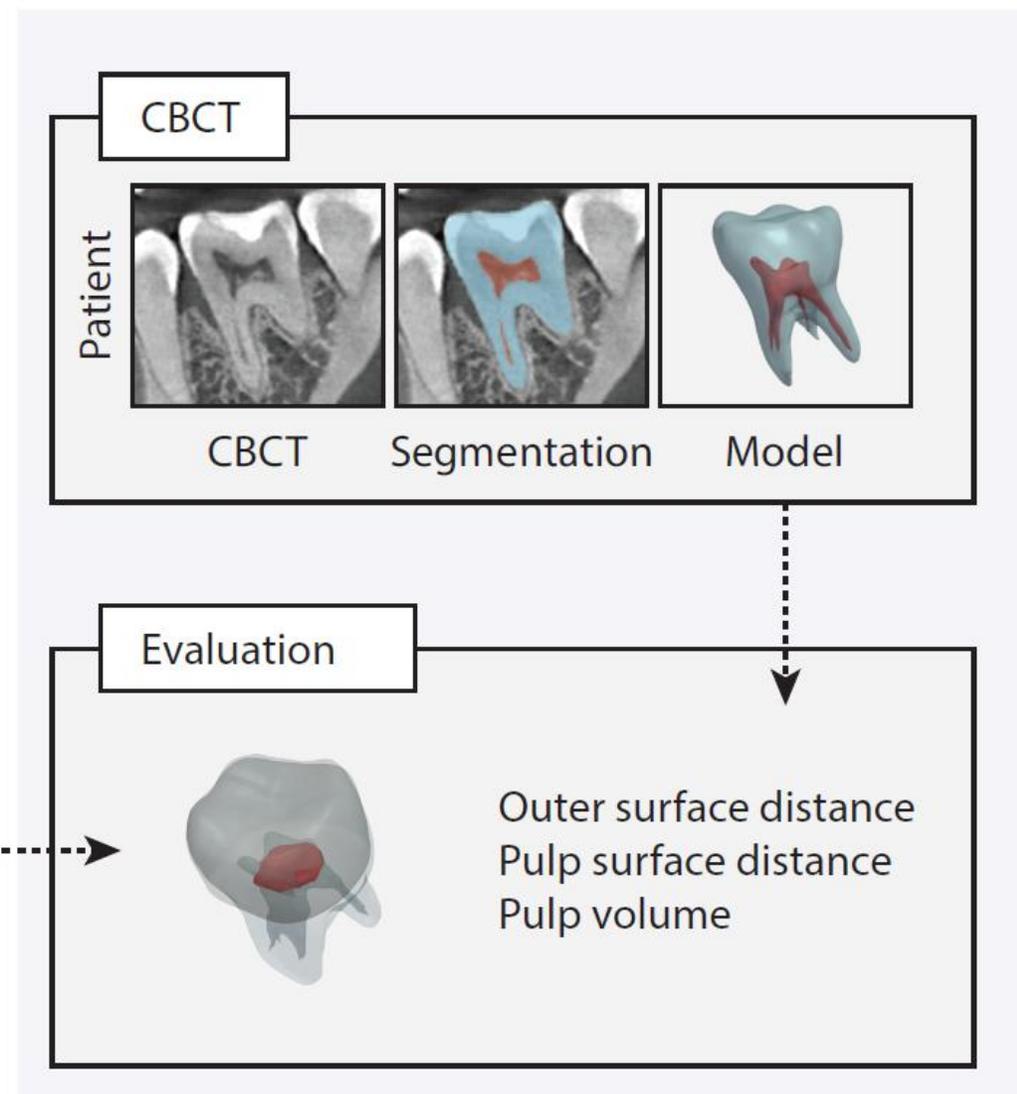
2 AU



## A Clinical Workflow



## B Validation



Méthode	Avantages	Inconvénients
<b>CNN</b>	<ul style="list-style-type: none"> <li>- Capacité à gérer des données hétérogènes (IRM, CT).</li> <li>- Reconst rapide avec données structurées</li> </ul>	<ul style="list-style-type: none"> <li>- Nécessité de grilles régulières : peu adapté maillages / nuages de pts.</li> <li>- Difficultés pour surfaces complexes ou des détails fins</li> </ul>
<b>GAN</b>	<ul style="list-style-type: none"> <li>- Capacité à gérer des données hétérogènes (IRM, CT).</li> <li>- Capacité générer rapidement des données synthétiques.</li> </ul>	<ul style="list-style-type: none"> <li>- Nécessité de grilles régulières : peu adapté maillages / nuages de pts.</li> <li>- Diff de stabilité d'entraînement (générateur/discriminateur) &amp; risque d'artefacts (surtt si détails fins à apprendre)</li> </ul>
<b>DeepSDF</b>	<ul style="list-style-type: none"> <li>- Représent continue et compacte via fonctions de distance signée.</li> <li>- Précis pour les surfaces complexes</li> <li>- Adapté données non structurées maillages /nuages de pts.</li> </ul>	<ul style="list-style-type: none"> <li>- Plus lent pour les reconstructions volumineuses ou de grandes structures (calcul point-par-point).</li> </ul>

Méthode	Avantages	Inconvénients
CNN	<ul style="list-style-type: none"><li>- Capacité à gérer des données hétérogènes (IRM, CT).</li><li>- Reconst rapide avec données structurées</li></ul>	<b>Pas explicable</b>
GAN	<ul style="list-style-type: none"><li>- Capacité à gérer des données hétérogènes (IRM, CT).</li><li>- Capacité générer rapidement des données synthétiques.</li></ul>	<b>Pas explicable</b>
DeepSDF	<ul style="list-style-type: none"><li>- Représent continue et compacte via fonctions de distance signée.</li><li>- Précis pour les surfaces complexes</li><li>- Adapté données non structurées maillages /nuages de pts.</li></ul>	<b>Peu explicable</b>





# Chapitre 3 : Les métriques

Comment  
évaluer ces  
approches?



Chapitre 3 : Les métriques

<b>Catégorie</b>	<b>Critères d'évaluation</b>
<b>Objectifs et bénéfices attendus</b>	Quel problème clinique l'IA vise-t-elle à résoudre ? Quels avantages pour les praticiens et patients ?
<b>Données et qualité</b>	Les données 3D sont-elles représentatives ? Les annotations sont-elles fiables ?
<b>Modèle d'IA et méthodologie</b>	Type de modèle utilisé (CNN, GAN, DeepSDF...) ? Le modèle a-t-il été validé sur des bases externes ?
<b>Performance et précision</b>	Quels indicateurs de performance sont utilisés ? Le modèle est-il robuste face aux variations ?

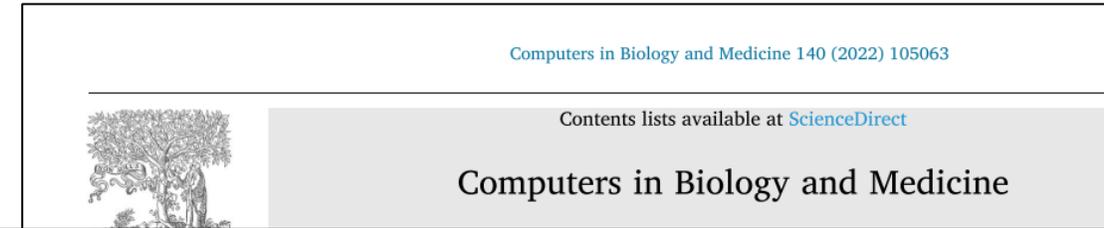
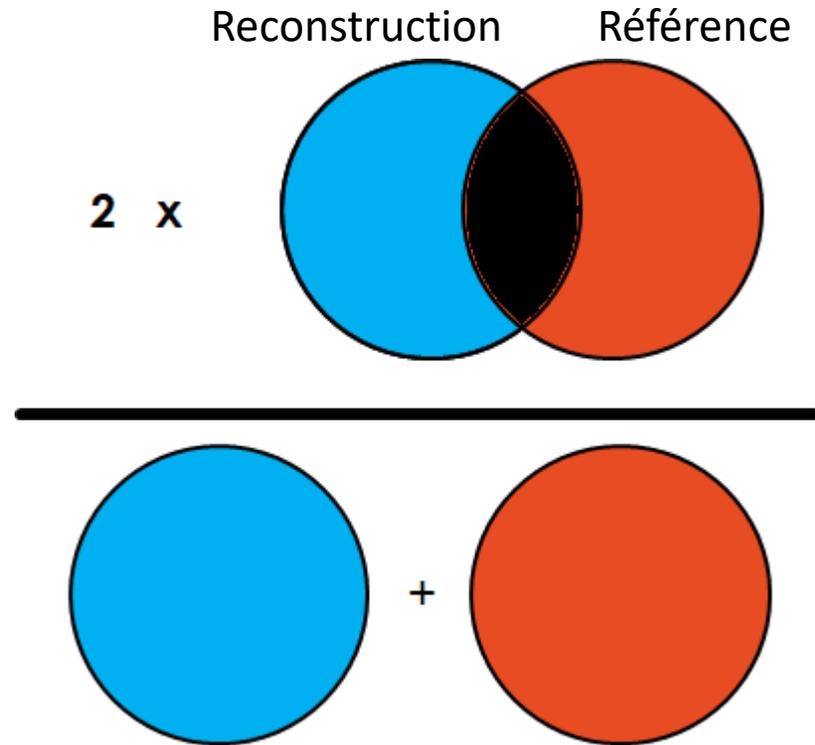
<b>Performance et précision</b>	Quels indicateurs de performance sont utilisés ? Le modèle est-il robuste face aux variations ?
<b>Biais et équité</b>	Présence de biais affectant certains groupes ? Quelles mesures ont-elles été mises en place pour les atténuer ?
<b>Risques et sécurité</b>	Quels sont les risques cliniques en cas d'erreur de l'IA ? Quelles conséquences pour le patient ?
<b>Validation clinique et réglementation</b>	Le modèle a-t-il été testé en conditions réelles ? Respecte-t-il les réglementations médicales ?
<b>Intégration et formation</b>	Comment la solution IA est-elle intégrée dans le workflow clinique ?

<b>formation</b>	workflow clinique ?
<b>Surveillance et maintenance</b>	Suivi des performances post-mise en œuvre ? Comment les mises à jour sont-elles gérées ?
<b>Considérations éthiques et légales</b>	Les patients sont-ils informés de l'utilisation de l'IA ? Comment la confidentialité des données est-elle assurée ?

*A vous de jouer*

# Les métriques

## Dice Similarity Coefficient (DSC)



Sarmah et al.  
*Visual Computing for Industry, Biomedicine, and Art* (2023) 6:15  
<https://doi.org/10.1186/s42492-023-00142-7>

Visual Computing for Industry,  
Biomedicine, and Art

REVIEW

Open Access

### Survey of methods and principles in three-dimensional reconstruction from two-dimensional medical images

Mriganka Sarmah<sup>1\*</sup>, Arambam Neelima<sup>1</sup> and Heisnam Rohen Singh<sup>2</sup>

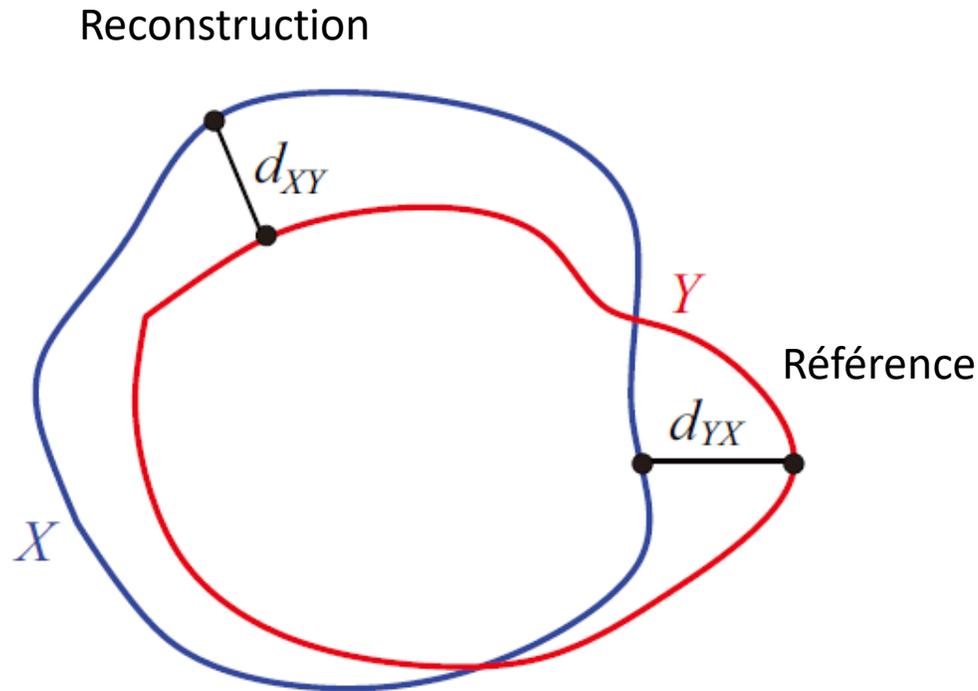
#### Abstract

Three-dimensional (3D) reconstruction of human organs has gained attention in recent years due to advances in the Internet and graphics processing units. In the coming years, most patient care will shift toward this new paradigm. However, development of fast and accurate 3D models from medical images or a set of medical scans remains

# Les métriques

## Hausdorff Distance

$$D_h(P_a, P_b) = \max(\max_{p_n \in P_b} \min_{p_m \in P_a} \|p_m - p_n\|_2), \max_{p_m \in P_a} \min_{p_n \in P_b} \|p_n - p_m\|_2)$$



Computers in Biology and Medicine 140 (2022) 105063

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Computers in Biology and Medicine

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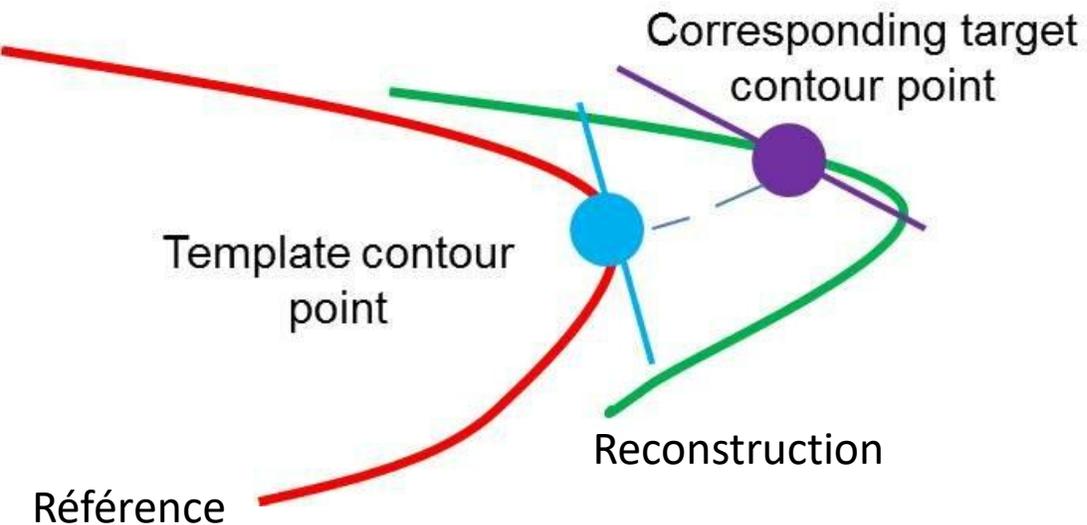
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# Les métriques

## Chamfer Distance

$$D_c(P_a, P_b) = \frac{1}{|P_a|} \sum_{p_m \in P_a} \min_{p_n \in P_b} \|p_m - p_n\|_2 + \frac{1}{|P_b|} \sum_{p_n \in P_b} \min_{p_m \in P_a} \|p_n - p_m\|_2$$



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Visual Computing for Industry,  
Biomedicine, and Art

REVIEW

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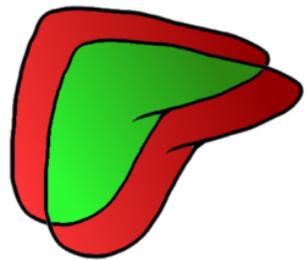
Mriganka Sarmah<sup>1\*</sup>, Arambam Neelima<sup>1</sup> and Heisnam Rohen Singh<sup>2</sup>

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# Les métriques

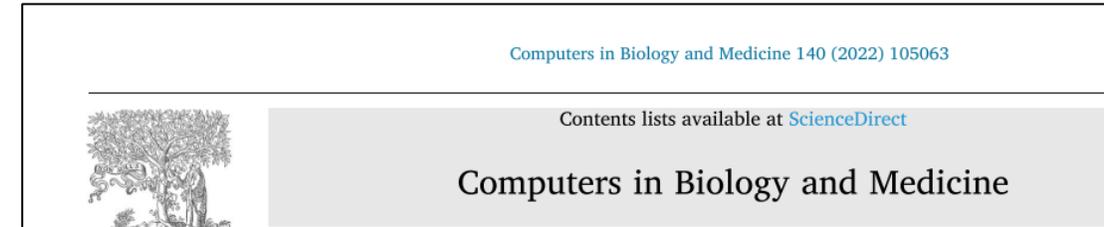
- Average Symmetric Surface Distance (ASSD)
- Surface Dice
- Volume Overlap Error (VOE)



$$|A \cap B| = \text{● (Intersection)}$$

$$|A \cup B| = \text{●} + \text{● (Union)}$$

$$VOE(A, B) = \left(1 - \frac{|A \cap B|}{|A \cup B|}\right) \times 100\%$$



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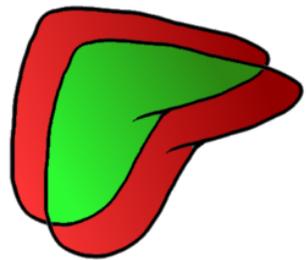
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# Les métriques

- Average Symmetric Surface Distance (ASSD)
- Surface Dice
- Volume Overlap Error (VOE)

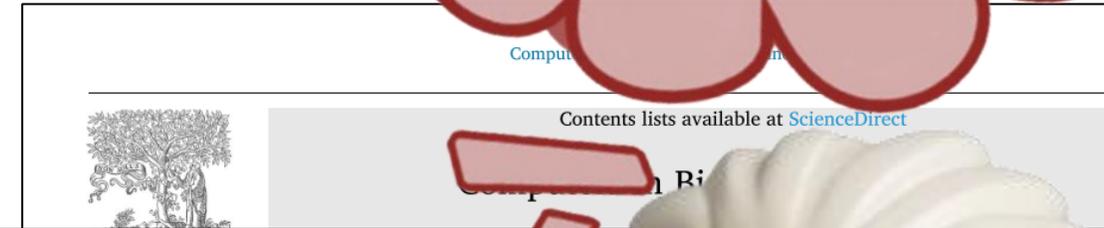
Quel sens clinique?



$$|A \cap B| = \text{● (Intersection)}$$

$$|A \cup B| = \text{●} + \text{● (Union)}$$

$$VOE(A, B) = \left(1 - \frac{|A \cap B|}{|A \cup B|}\right) \times 100\%$$



Sarmah et al.  
*Visual Computing for Industry, Biomedicine, and Art* (2023) 6:15  
<https://doi.org/10.1186/s42492-023-00142-7>

## REVIEW

### Survey of methods and applications in three-dimensional reconstruction from two-dimensional medical images

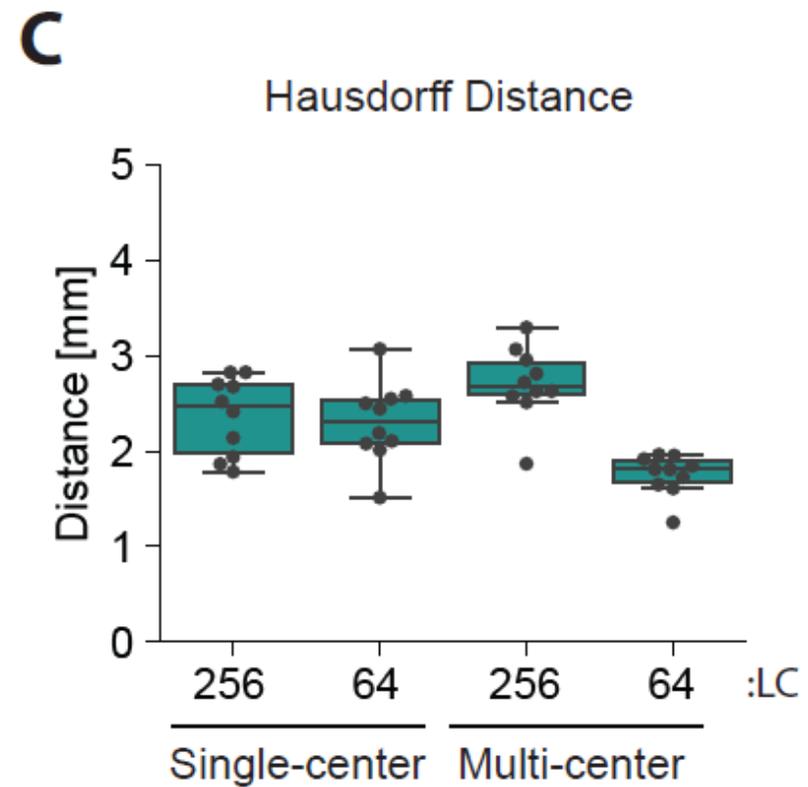
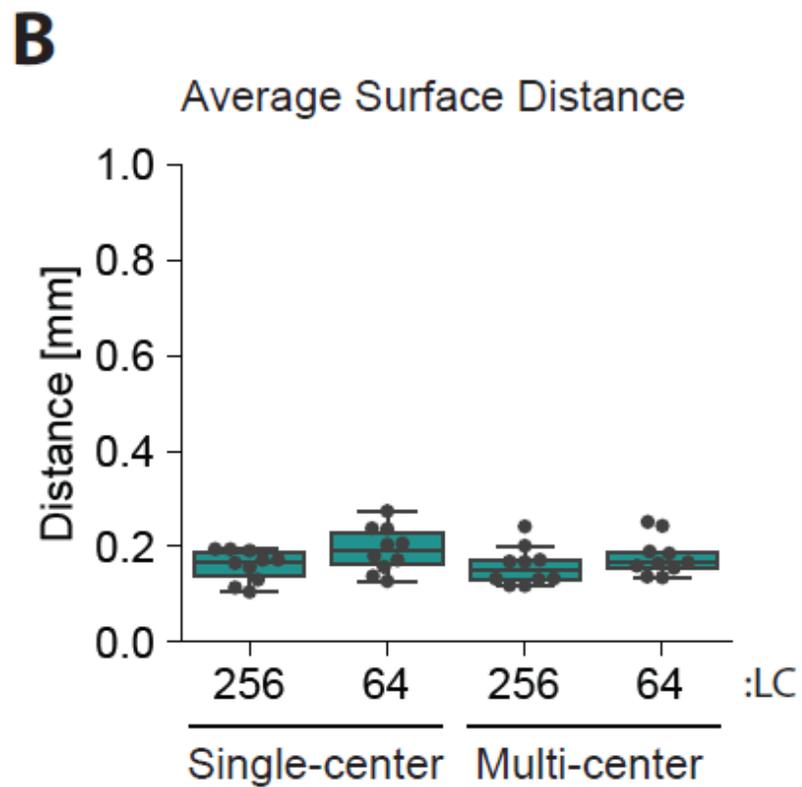
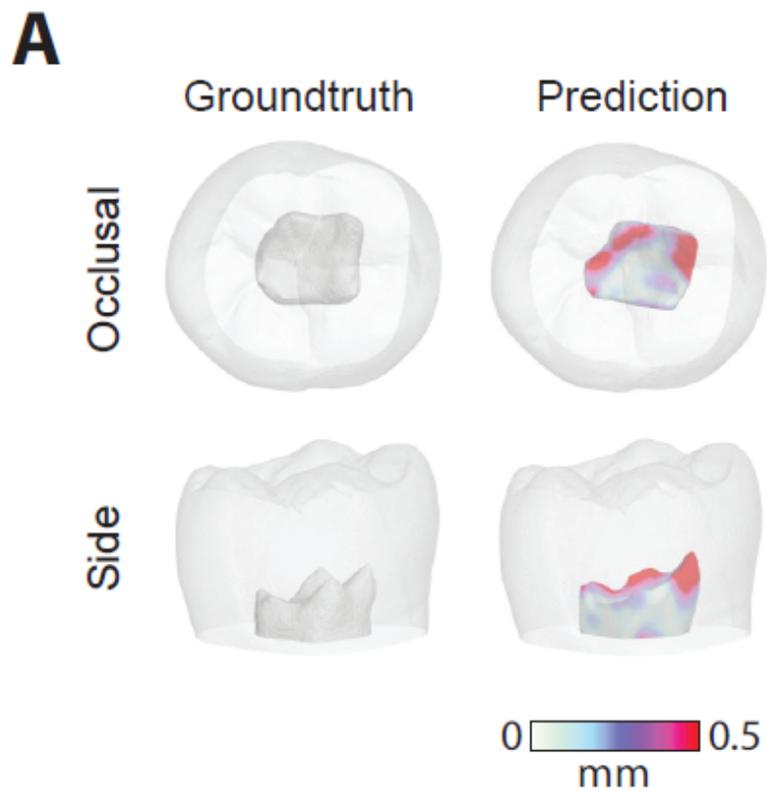
Mriganka Sarmah<sup>1\*</sup>, Arambam Neelima

#### Abstract

Three-dimensional (3D) reconstruction is a challenging task in the Internet and graphics processing industries. In the digital age, however, development of fast and accurate methods is required.

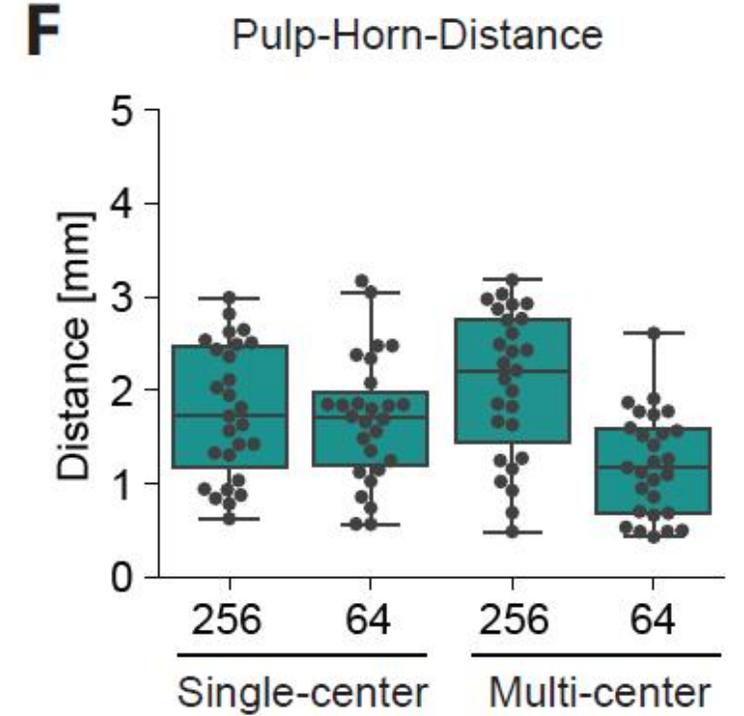
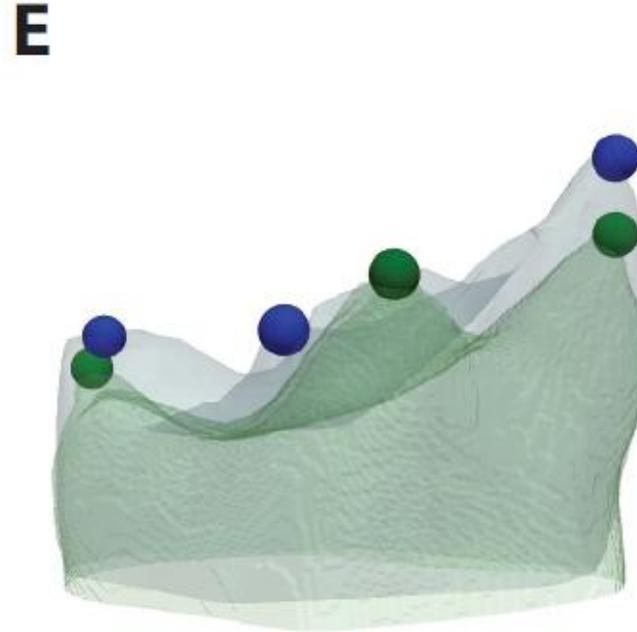
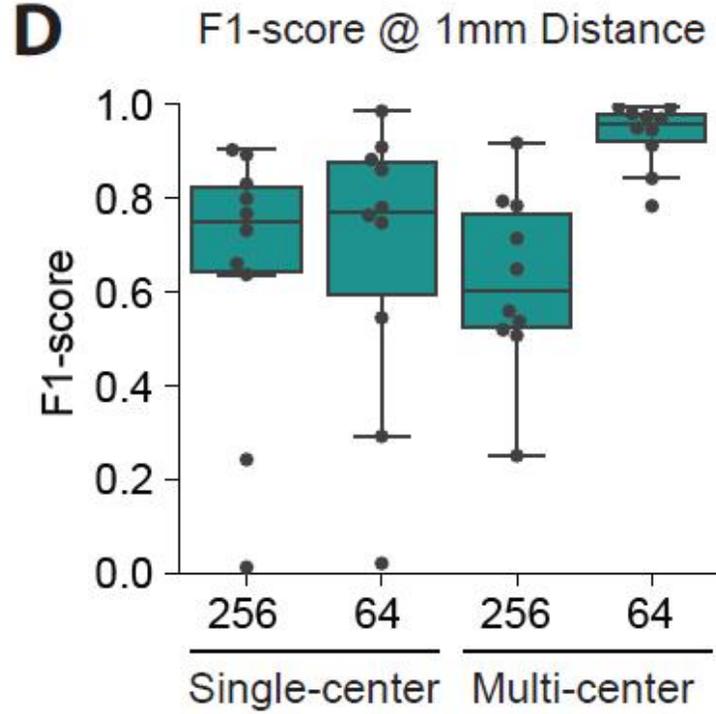


# In vitro



# ~~In vitro~~

# Clinique



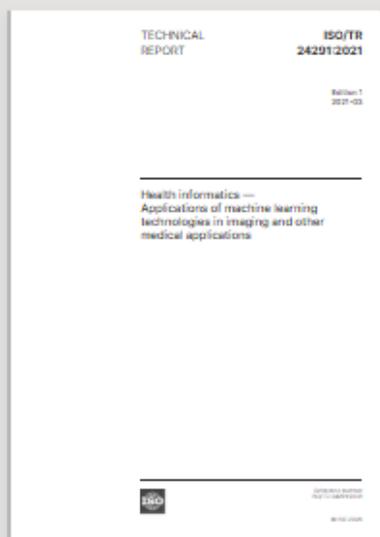


# ISO/IEC 3532-1:2023

Information technology — Medical image-based modelling for 3D printing

**Part 1: General requirements**

---



# ISO/TR 24291:2021

Health informatics — Applications of machine learning technologies in imaging and other medical applications

---



# ISO/IEC 3532-1:2020

Information technology — Medical  
based modelling for 3D printing  
Part 1: General requirements

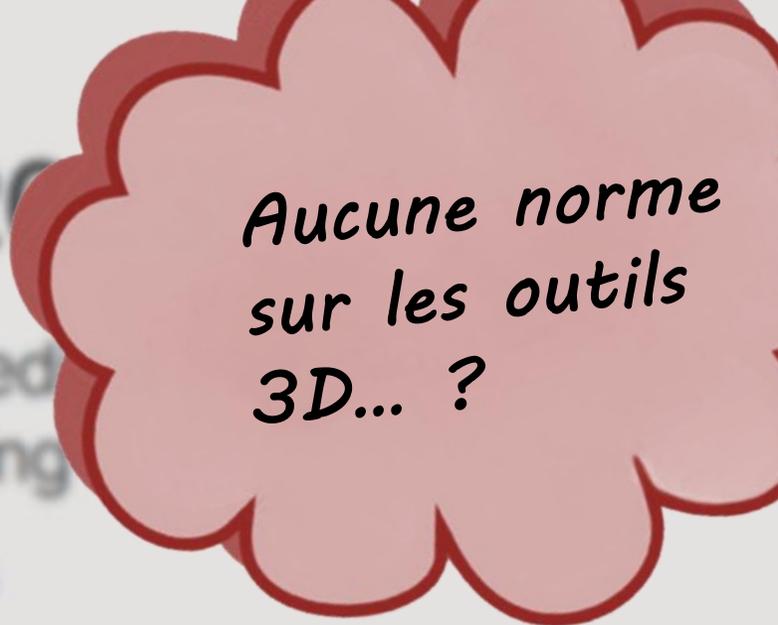
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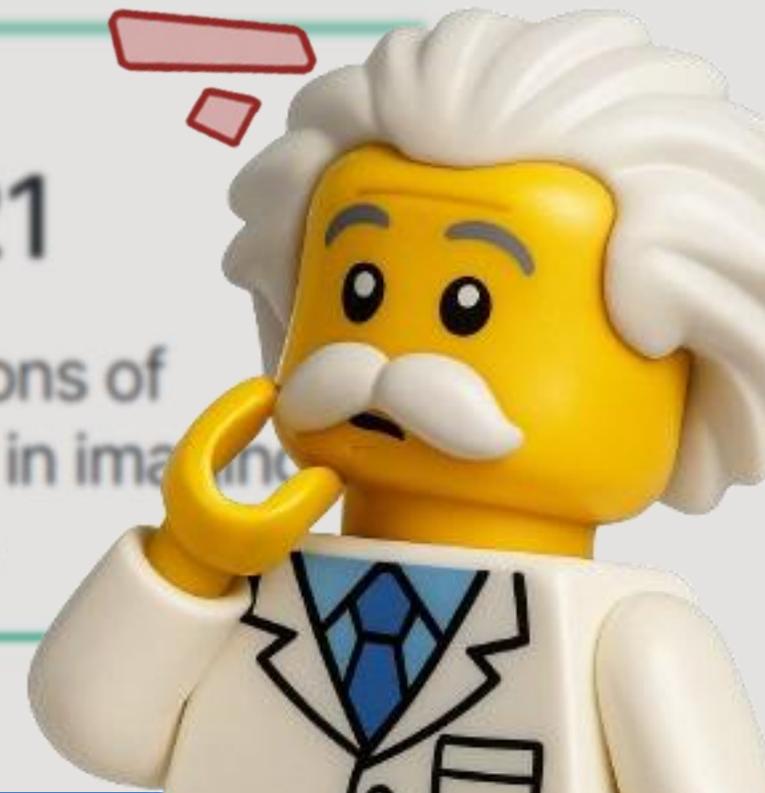
# ISO/TR 24291:2021

Health informatics — Applications of  
machine learning technologies in imaging  
and other medical applications

---



*Aucune norme  
sur les outils  
3D... ?*



Discovery!

## Trustworthy Artificial Intelligence in Dentistry: Learnings from the EU AI Act

M. Ducret<sup>1,2,3</sup> , E. Wahal<sup>4</sup>, D. Gruson<sup>5,6,7</sup>, S. Amrani<sup>6,7</sup>, R. Richert<sup>1,2,8</sup>, M. Mouncif-Mougache<sup>9</sup>, and F. Schwendicke<sup>10</sup> 

Journal of Dental Research  
1–6  
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### Abstract

Artificial intelligence systems (AIs) gain relevance in dentistry, encompassing diagnostics, treatment planning, patient management, and therapy. However, questions about the generalizability, fairness, and transparency of these systems remain. Regulatory and governance bodies worldwide are aiming to address these questions using various frameworks. On March 13, 2024, members of the European Parliament approved the Artificial Intelligence Act (AIA), which emphasizes trustworthiness and human-centeredness as relevant aspects to regulate AIs beyond safety and efficacy. This review presents the AIA and similar regulatory and governance efforts in other jurisdictions and lays out that regulations such as the AIA are part of a complex ecosystem of interdependent and interwoven legal requirements and standards. Current efforts to regulate dental AIs require active input from the dental community, with participation of dental research, education, providers, and patients being relevant to shape the future of dental AIs.

**Keywords:** algorithms, biomedical ethics, Europe, machine learning, regulation, deep learning

### Introduction

An artificial intelligence system (AIS) is “a machine-based system that can, for a given set of human-defined objectives, make predictions, recommendations, or decisions influencing real or virtual environments” (OECD 2023). The interest in AIs in dentistry has been growing exponentially over the past years (Mörch et al. 2021; Mohammad-Rahimi et al. 2023). Dental AIs were proposed for tasks ranging from diagnostics to treatment planning, therapy support, practice and patient management, and dental research (e.g., for support materials

protection of health, safety, fundamental rights” (European Commission 2024).

Regulatory frameworks are often neglected within the dental community, while they have broad relevance for manufacturers, researchers, educators, and clinicians alike. For researchers and manufacturers, regulation shapes the landscape into which any research or developed product shall be implemented; early consideration of regulatory aspects will help implementation and reduce the widely known implementation gap. Educators will need to consider regulatory frameworks both during the execution of clinical education and



A risk-based approach

Unacceptable risk

High risk

AI with specific transparency obligations

Minimal or no risk

Discovery!

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# A risk-based approach

**Unacceptable risk**  
e.g. social scoring  
Prohibited

**High risk**  
e.g. recruitment, medical devices

Permitted subject to compliance with AI requirements and ex-ante conformity assessment

**AI with specific transparency obligations**  
(e.g. bots)

Permitted but subject to information/transparency obligations

**Minimal or no risk**

Permitted with no restrictions

Discovery!

## Trustworthy Artificial Intelligence in Dentistry: Learnings from the EU AI Act

M. Ducret<sup>1,2,3</sup>, E. Wahal<sup>4</sup>, D. Gruson<sup>5,6,7</sup>, S. Amrani<sup>6,7</sup>, R. Richert<sup>1,2,8</sup>, M. Mouncif-Mougache<sup>9</sup>, and F. Schwendicke<sup>10</sup>

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# EU AI Regulatory Landscape

**Medical Device Regulation** is a set of rules and standards that govern the manufacturing and marketing of medical devices to ensure their safety, quality, and effectiveness.

**AI Act Regulation** is a framework to govern the development and deployment of AIS within the EU, including ethical and responsible AI practices.



**General Data Protection Regulation** governs collection, processing, and storage of personal data, with the aim to safeguard individuals' privacy.

**AI Liability Directive** is a proposal designed to establish a framework for determining liability and compensation in cases where AIS cause harm or damage.

shen ai

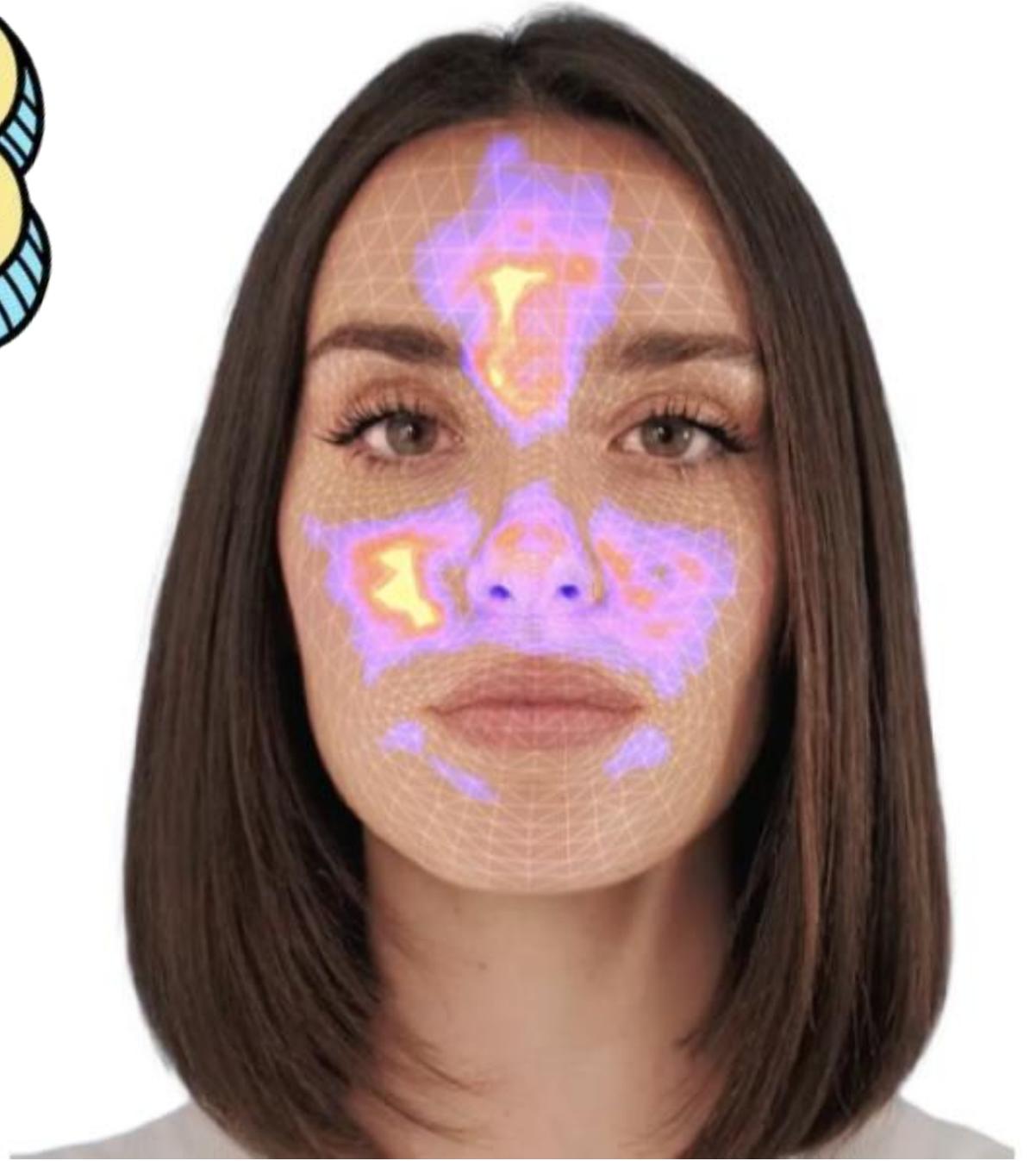
**Monitor 30+  
health markers**  
through a face scan  
using any camera



shen ai

*Ou intervient  
l'IA?*

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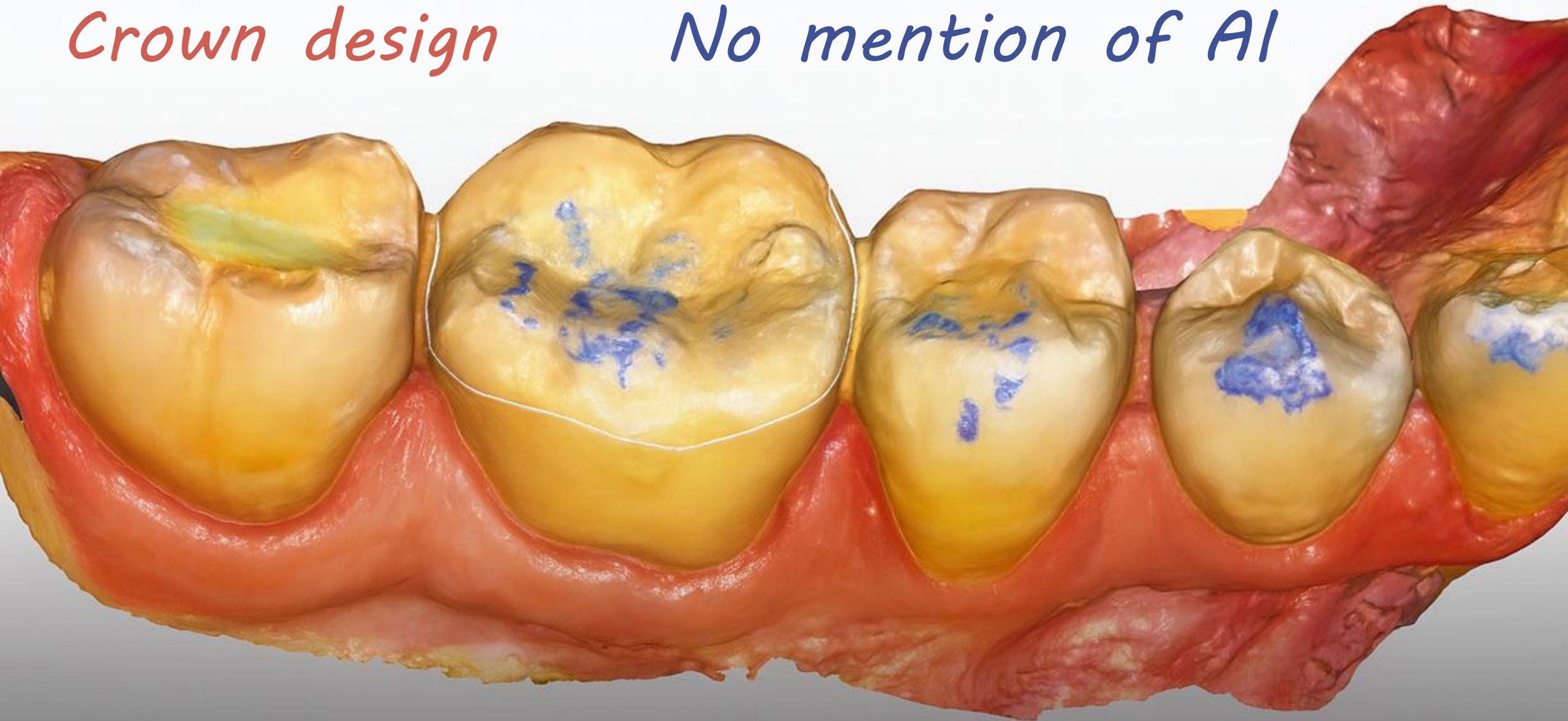


# *Crown design*



*Crown design*

*No mention of AI*





Est-ce  
l'IA?

*Eur J Oral Sci* 2005; 113: 333–340  
Printed in Singapore. All rights reserved

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*European Journal of  
Oral Sciences*

## Biogeneric tooth: a new mathematical representation for tooth morphology in lower first molars

*Mehl A, Blanz V, Hickel R. Biogeneric tooth: a new mathematical representation for tooth morphology in lower first molars. Eur J Oral Sci* 2005; 113: 333–340. © *Eur J Oral Sci*, 2005

A mathematical representation of tooth morphology may help to improve and automate restorative computer-aided design processes, virtual dental education, and parametric morphology. However, to date, no quantitative formulation has been identified for the description of dental features. The aim of this study was to establish and to validate a mathematical process for describing the morphology of first lower molars. Stone replicas of 170 caries-free first lower molars from young patients were measured three-dimensionally with a resolution of about 100,000 points. First, the average tooth was computed, which captures the common features of the molar's surface quantitatively. For this, the crucial step was to establish a dense point-to-point correspondence between all teeth. The algorithm did not involve any prior knowledge about teeth. In a second step, principal component analysis was carried out. Repeated for 3 different reference teeth, the procedure yielded average teeth that were nearly independent of the reference (less than  $\pm 40 \mu\text{m}$ ). Additionally, the results indicate that only a few principal components determine a high percentage of the three-dimensional shape variability of first lower molars (e.g. the first five principal com-

**Albert Mehl<sup>1</sup>, Volker Blanz<sup>2</sup>,  
Reinhard Hickel<sup>1</sup>**

<sup>1</sup>Department of Restorative Dentistry, Ludwig Maximilians University, Munich; <sup>2</sup>Max-Planck-Institute for Computer Science, Saarbruecken, Germany

Prof. Dr Albert Mehl, Department of Restorative Dentistry, Ludwig Maximilians University, Goethestr. 70, 80336 Munich, Germany

Telefax: +49–89–51605344  
E-mail: amehl@dent.med.uni-muenchen.de



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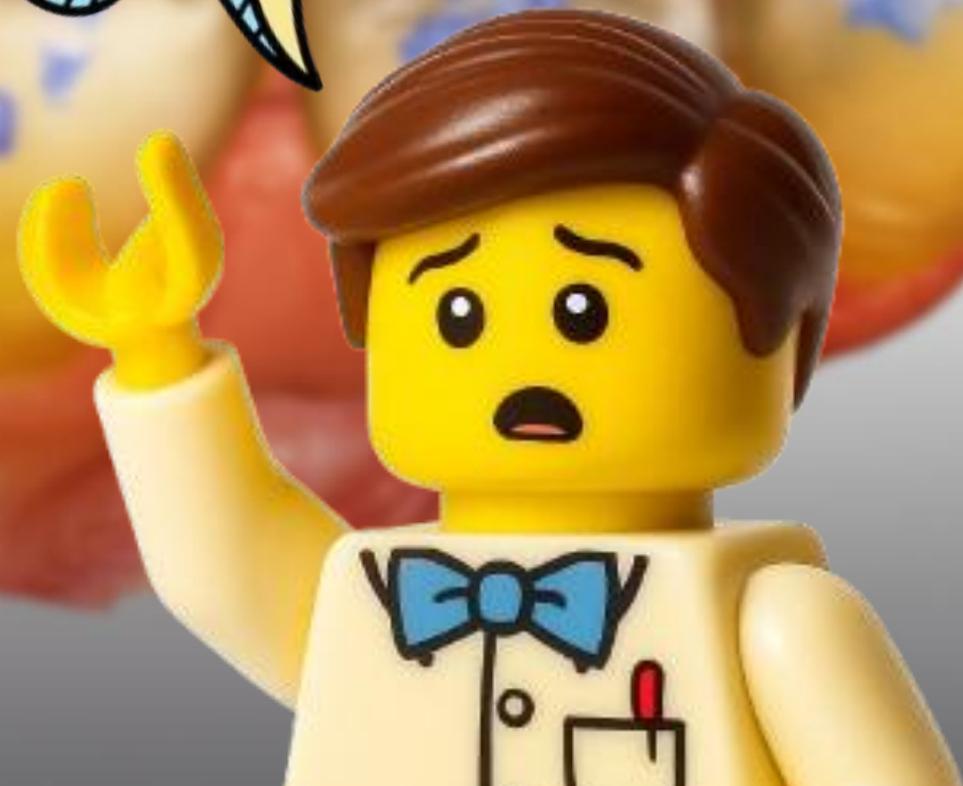
**Albert Mehl<sup>1</sup>, Volker Blanz<sup>2</sup>,  
Reinhard Hickel<sup>1</sup>**

<sup>1</sup>Department of Restorative Dentistry, Ludwig Maximilians University, Munich; <sup>2</sup>Max-Planck-Institute for Computer Science, Saarbruecken, Germany

Prof. Dr Albert Mehl, Department of Restorative Dentistry, Ludwig Maximilians University, Goethestr. 70, 80336 Munich, Germany

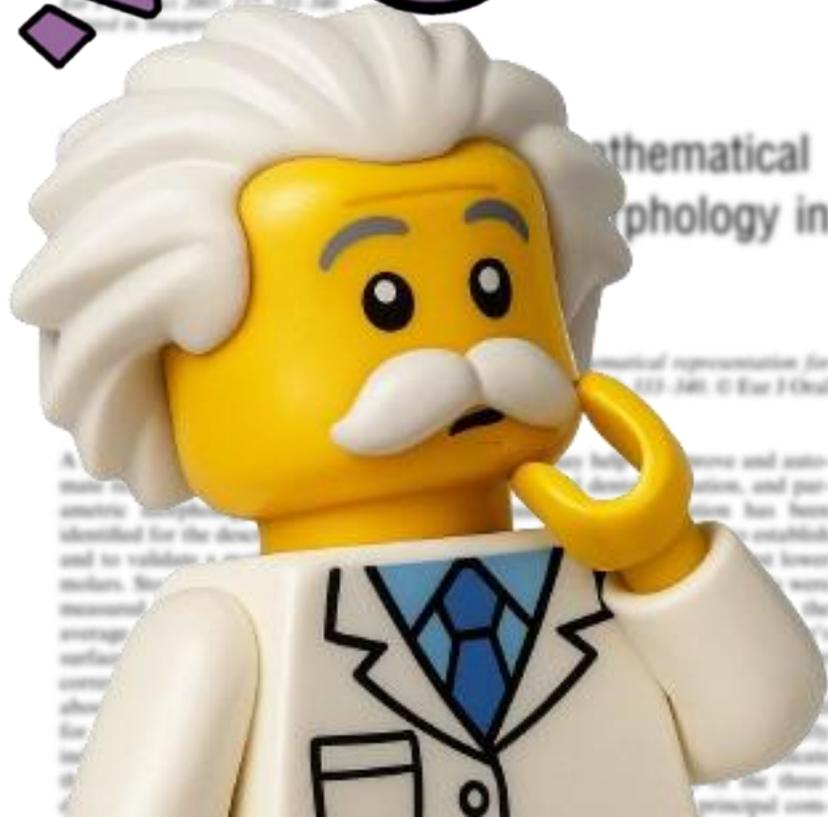
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E-mail: amehl@dent.med.uni-muenchen.de

Comment  
sont collectées  
les données?



Aucun  
comité  
éthique?

Comment  
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Oral Science*

Mathematical  
morphology in

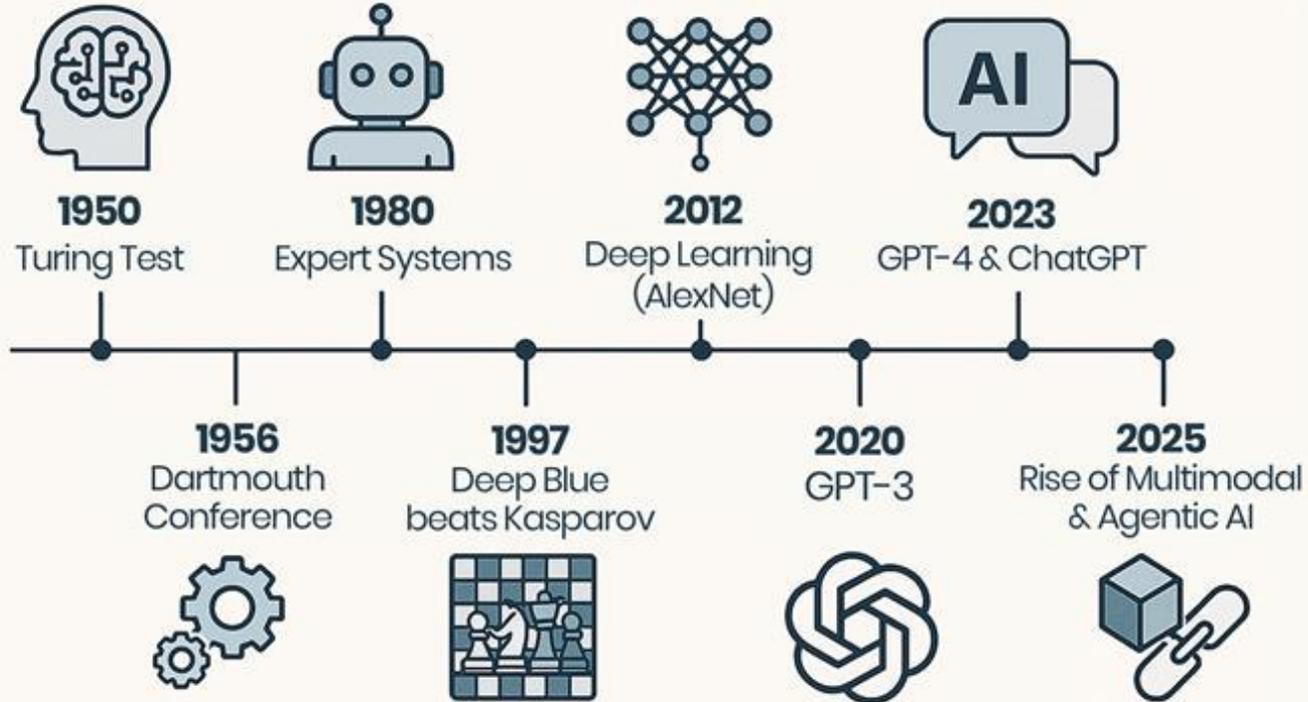
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Germany

Prof. Dr. Albert Mehl, Department of Restorative  
Dentistry, Ludwig Maximilians University,  
Goschwinckelstr. 70, 80336 Munich, Germany  
Tel: +49-89-21803244  
E-mail: mehl@dent.klinik.uni-muenchen.de



# HISTORY OF ARTIFICIAL INTELLIGENCE

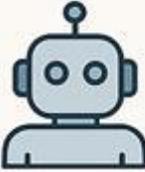


# HISTORY OF ARTIFICIAL INTELLIGENCE



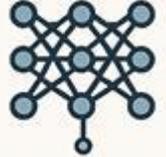
**1950**

Turing Test



**1980**

Expert Systems



**2012**

Deep Learning  
(AlexNet)



**2023**

GPT-4 & ChatGPT



**1956**

Dartmouth  
Conference



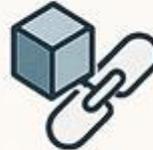
**1997**

Deep Blue  
beats Kasparov



**2020**

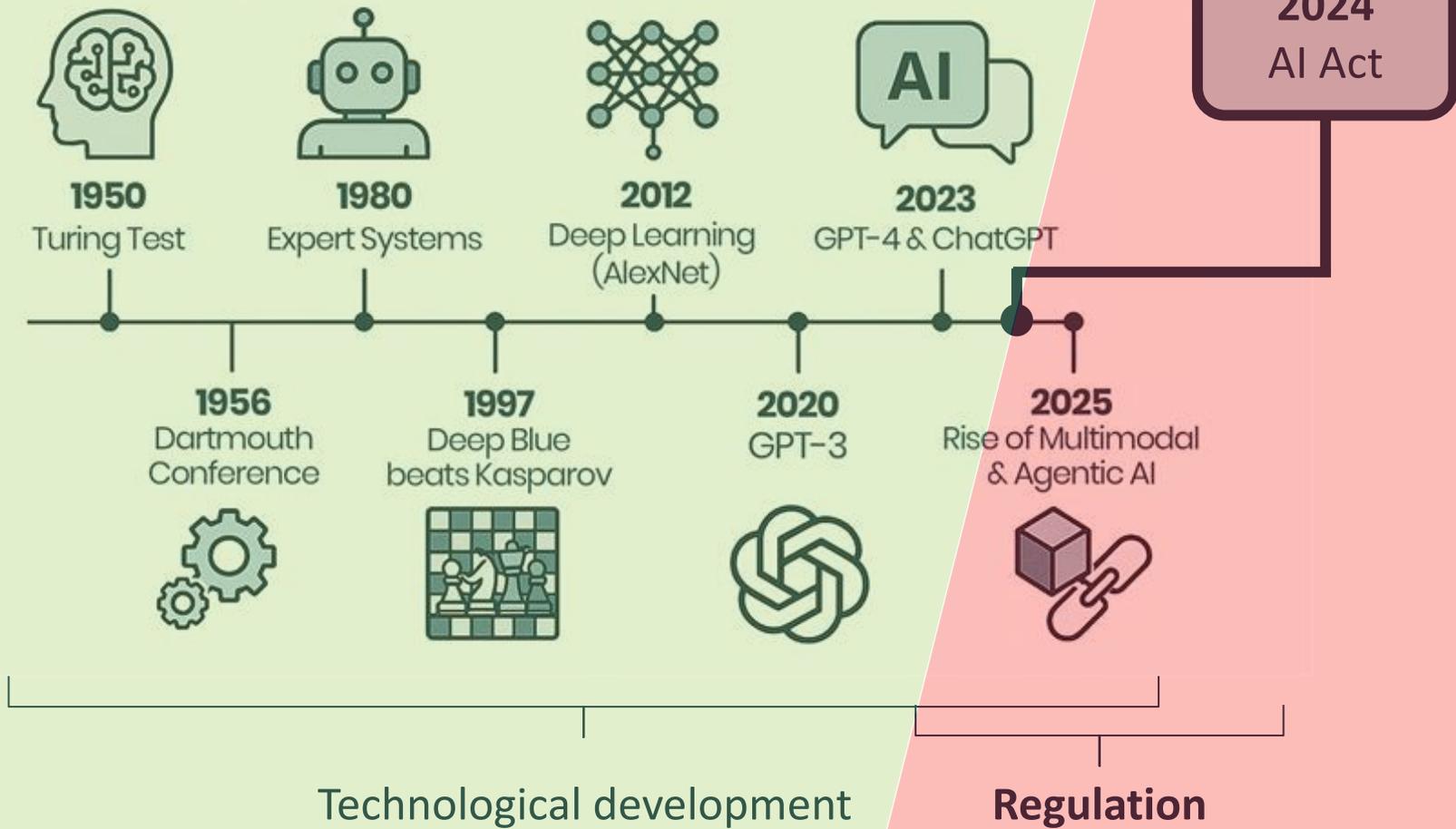
GPT-3



**2025**

Rise of Multimodal  
& Agentic AI

# HISTORY OF ARTIFICIAL INTELLIGENCE



[Role] Tu es un ingénieur biomédical spécialisé en modélisation anatomique osseuse.

[Context] Usage pédagogique enseignement.

[Task] Partager code python pour générer un fémur 3D synthétique paramétrique .

[Process] Assembler des primitives (cylindre, cône, sphère) de manière anatomiquement cohérente et exporter le modèle en STL.

[Characteristics] Code clair et commenté avec paramètres ajustables et dépendances légères.

Parametric Synthetic Femur Generator (python) · python

Copier Modifier Télécharger

Exécuter le code

```
"""
Parametric synthetic femur generator
Author: ChatGPT
Context: Pedagogical use (biomedical engineering / anatomical modelling)
```

Principle:

- Assemble simple geometric primitives (cylinders, cones, spheres)
- Ensure anatomically coherent proportions (simplified femur)
- Export as STL for visualization / teaching / FEM pre-processing

Dependencies (lightweight):

- numpy
- trimesh

Install:

```
pip install numpy trimesh
```

```
"""
```

```
import numpy as np
```

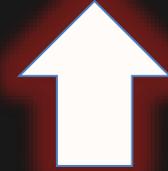


table across trimesh versions.

ests (important for teaching & debugging)

were no tests, I added minimal sanity checks:

idity

Copier le code

```
instance(femur, trimesh.Trimesh)
```

```
ur.vertices.shape[0] > 0
```

```
ur.faces.shape[0] > 0
```

cal plausibility

Copier le code

```
c = femur.bounds[1, 2] - femur.bounds[0, 2]
```

```
ct_height > 0.8 * expected_height
```

ht

dependent

ul in a pedagogical setting

l behavior (please confirm)

further, I want to confirm one point:

outcome:

t should always export a valid STL, even if

rs are modified (within reasonable ranges),

arly with clear assertions if geometry becomes

ent.

avior you want f

ia

could be:

une question

```
Parametric Synthetic Femur Gen...  
107     subdivisions=3  
108 )  
109 condyle_lateral.apply_translation([CONDYLE_OFFSET, 0, 0])  
110  
111 # =====  
112 # Assembly  
113 # =====  
114  
115 femur = trimesh.util.concatenate(  
116     shaft,  
117     neck,  
118     head,  
119     condyle_medial,  
120     condyle_lateral  
121 ])  
122  
123 # Mesh cleanup (API-safe)  
124 femur = femur.clean()  
125  
126 # =====  
127 # Basic sanity tests (pedagogical)  
128 # =====  
129  
130 # Test 1: mesh validity  
131 assert isinstance(femur, trimesh.Trimesh), "Femur is not a Trimesh object"  
132 assert femur.vertices.shape[0] > 0, "Femur mesh has no vertices"  
133 assert femur.faces.shape[0] > 0, "Femur mesh has no faces"  
134  
135 # Test 2: mesh plausibility  
136 # Roughly matches anatomy  
137 c = femur.bounds[1, 2] - femur.bounds[0, 2]  
138 ct_height = c + HEAD_RADIUS  
139 assert ct_height > 0.8 * expected_height, "Femur height seems inconsistent"  
140  
141 # =====  
142 # Export to STL  
143 # =====  
144 femur.export("femur.stl")
```

ChatGPT

The error occurs because the `Trimesh` object does not have a method called `clean()`. The correct method to clean a mesh in `trimesh` is `repair`, not `clean`. You should replace `femur = femur.clean()` with `femur = femur.repair()` to fix the error.

Corriger le bug

```
AttributeError: 'Trimesh' object has no attribute 'clean'
```



Explorer des idées

Mes créations

# Copilot 3D LABORATOIRES

La 3D pour tous, de l'imagination à la création



+ Charger une image

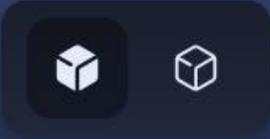
Fonctionne de manière optimale avec un seul sujet, un éclairage uniforme et un arrière-plan simple.

Créer

Recommandé

Véhicules

Afficher le Bureau



REQUÊTE



Standard

↻ Recréer

↓ Télécharger

🔗 Partager





Ton odontoblaste en 3D est prêt maintenant.



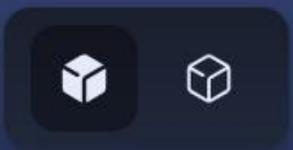
Si tu veux une autre version — plus réaliste, plus stylisée, plus colorée, ou même intégrée dans un

Écrire un message à Copilot



Smart ▼





REQUÊTE



Standard

🔄 Recréer

↓ Télécharger

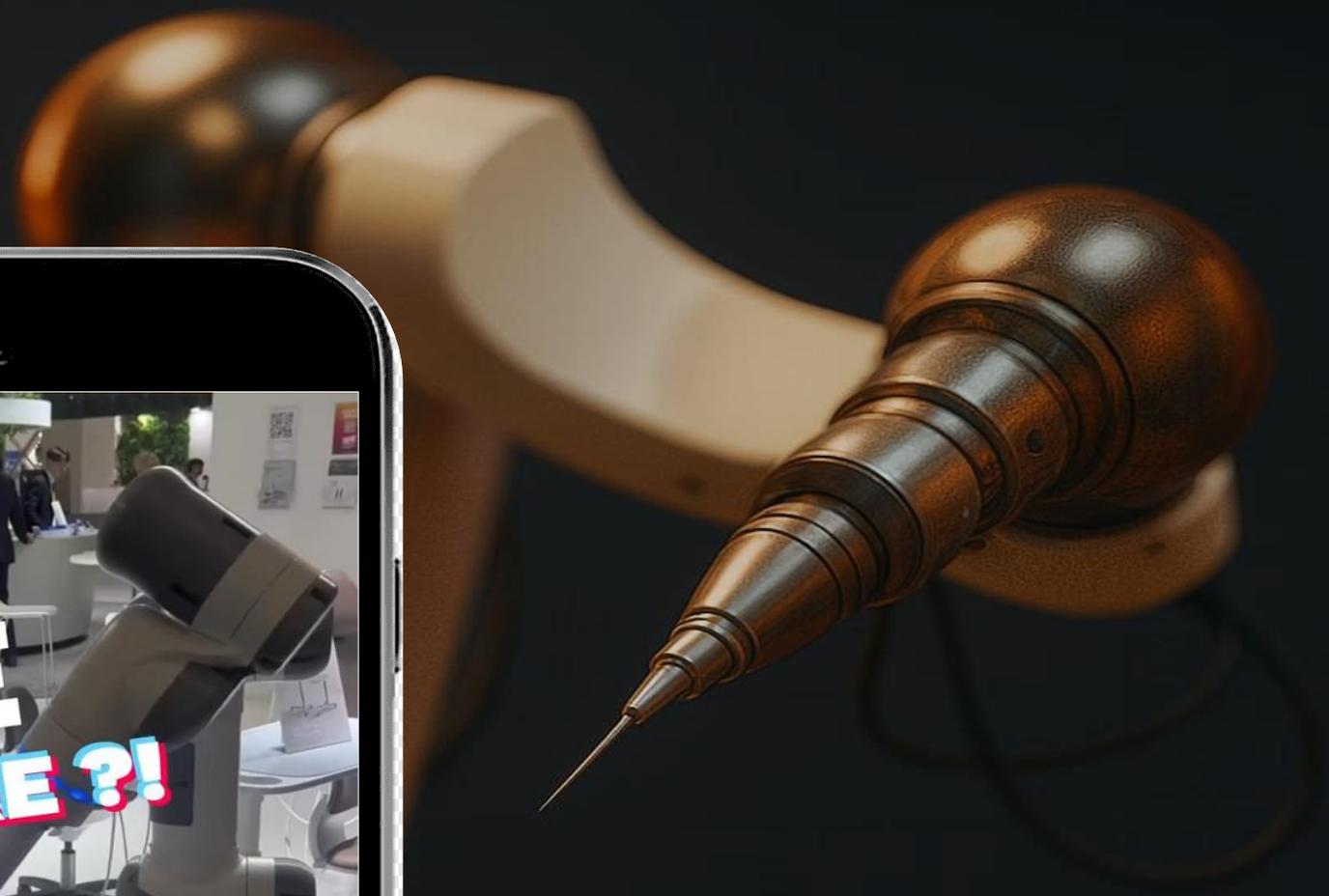
🔗 Partager



*Performances*



**I AM  
THE BEST**



*Robot-assisted  
interventions*



## ORIGINAL ARTICLE

# Accuracy, Safety, and Efficiency in Robotic-Assisted vs. Freehand Dental Implant Surgery: A 6-Month Follow-Up Randomized Controlled Trial

Jiaxian Chen<sup>1,2</sup> | Yulan Wang<sup>1,2</sup> | Yi Bai<sup>1,2</sup> | Yan Chen<sup>1,2</sup> | Zhenqi Chen<sup>1,2</sup> | Qi Yan<sup>1,2</sup> | Yufeng Zhang<sup>1,2,3</sup> 

<sup>1</sup>State Key Laboratory of Oral & Maxillofacial Reconstruction and Regeneration, Key Laboratory of Oral Biomedicine Ministry of Education, Hubei Key Laboratory of Stomatology, School & Hospital of Stomatology, Wuhan University, Wuhan, China | <sup>2</sup>Department of Oral Implantology, School & Hospital of Stomatology, Wuhan University, Wuhan, China | <sup>3</sup>Oral Biomaterials and Application Technology Engineering Research Center of Hubei Province, Wuhan, China

**Correspondence:** Qi Yan ([yanqi@whu.edu.cn](mailto:yanqi@whu.edu.cn)) | Yufeng Zhang ([zyf@whu.edu.cn](mailto:zyf@whu.edu.cn))

**Received:** 3 October 2024 | **Revised:** 20 January 2025 | **Accepted:** 21 January 2025

**Funding:** This work was supported by THETA, Jianjia, Hangzhou, China.

**Keywords:** dental implant | digital dentistry | positional accuracy | robot assisted surgery | survival rate

## ABSTRACT

**Objectives:** To assess the implant accuracy, safety, and efficiency between robotic-assisted and freehand dental implant placement with a half-year follow-up.

**Methods:** Patients requiring single-tooth implant restorations were recruited and randomized into two groups: robotic-assisted surgery and freehand implant surgery. The accuracy of implant positioning was compared by assessing immediate postoperative CBCT scans against preoperative planning software. Intraoperative and postoperative complications were recorded, and data were analyzed using an intention-to-treat approach. The time required for implant placement in each group was documented. A



### 5 | Conclusion

Within the constraints of this study, this randomized clinical trial provided preliminary evidence of the ability of robot-assisted surgery to improve the accuracy of implant placement, without identifying any significant harms. Importantly, this trial offers valuable insights for the design of future studies using surgical robots for dental implant placement. Further clinical trials are needed to validate the efficacy and safety of the THETA Surgical Implant Robot for broader clinical application in dental implant surgery.

#### Author Contributions

**Jiaxian Chen:** writing – original draft, investigation, methodology, formal analysis. **Yulan Wang:** writing – original draft, investigation, methodology, formal analysis. **Yi Bai:** investigation, methodology. **Yan Chen:** investigation, data curation, resources. **Zhenqi Chen:** methodology, formal analysis, software. **Qi Yan:** conceptualization, project administration, writing – review and editing, methodology. **Yufeng Zhang:** conceptualization, funding acquisition, writing – review and editing, methodology.

#### Acknowledgments

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#### Conflicts of Interest

The authors declare no conflicts of interest.

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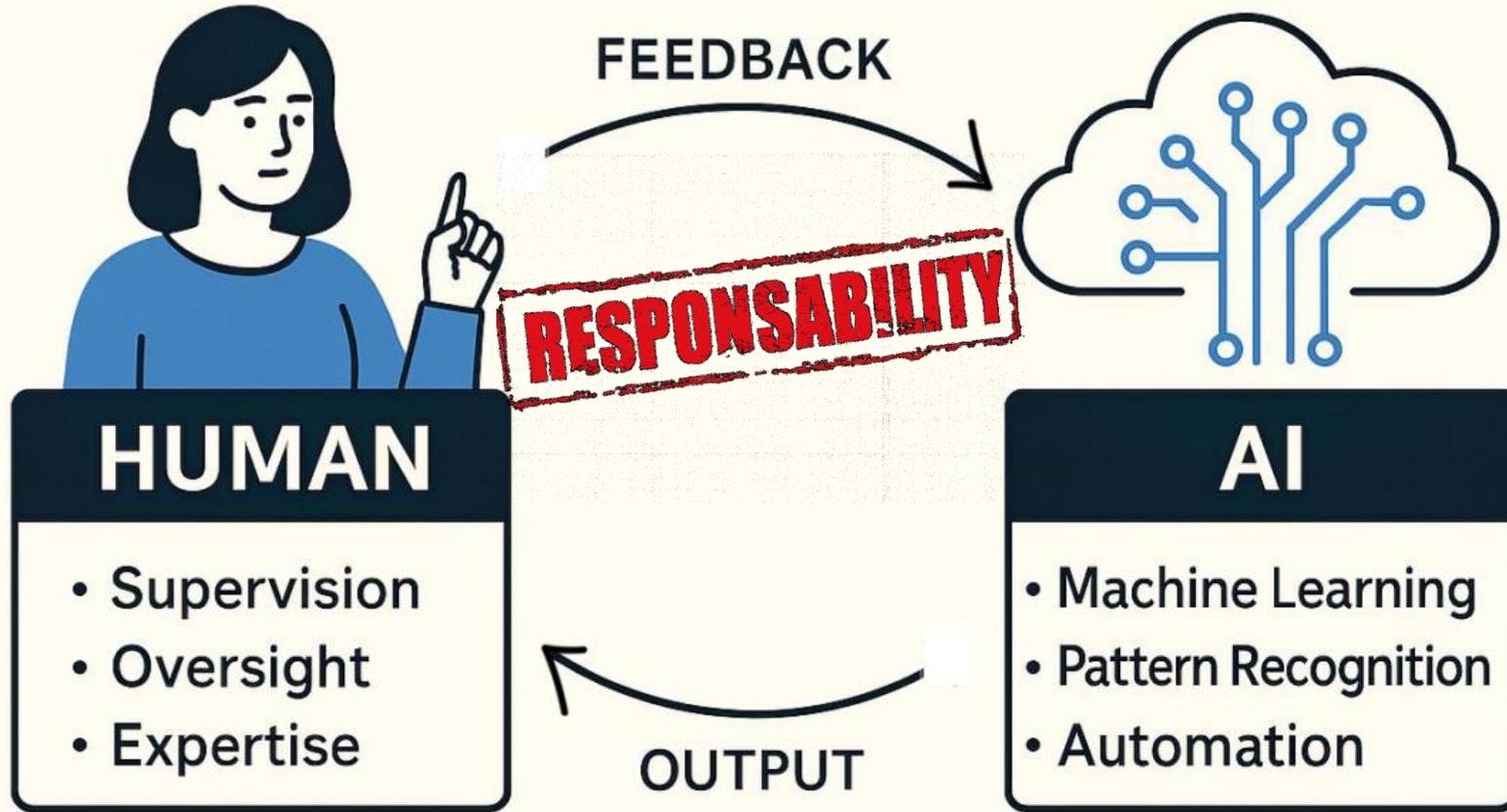
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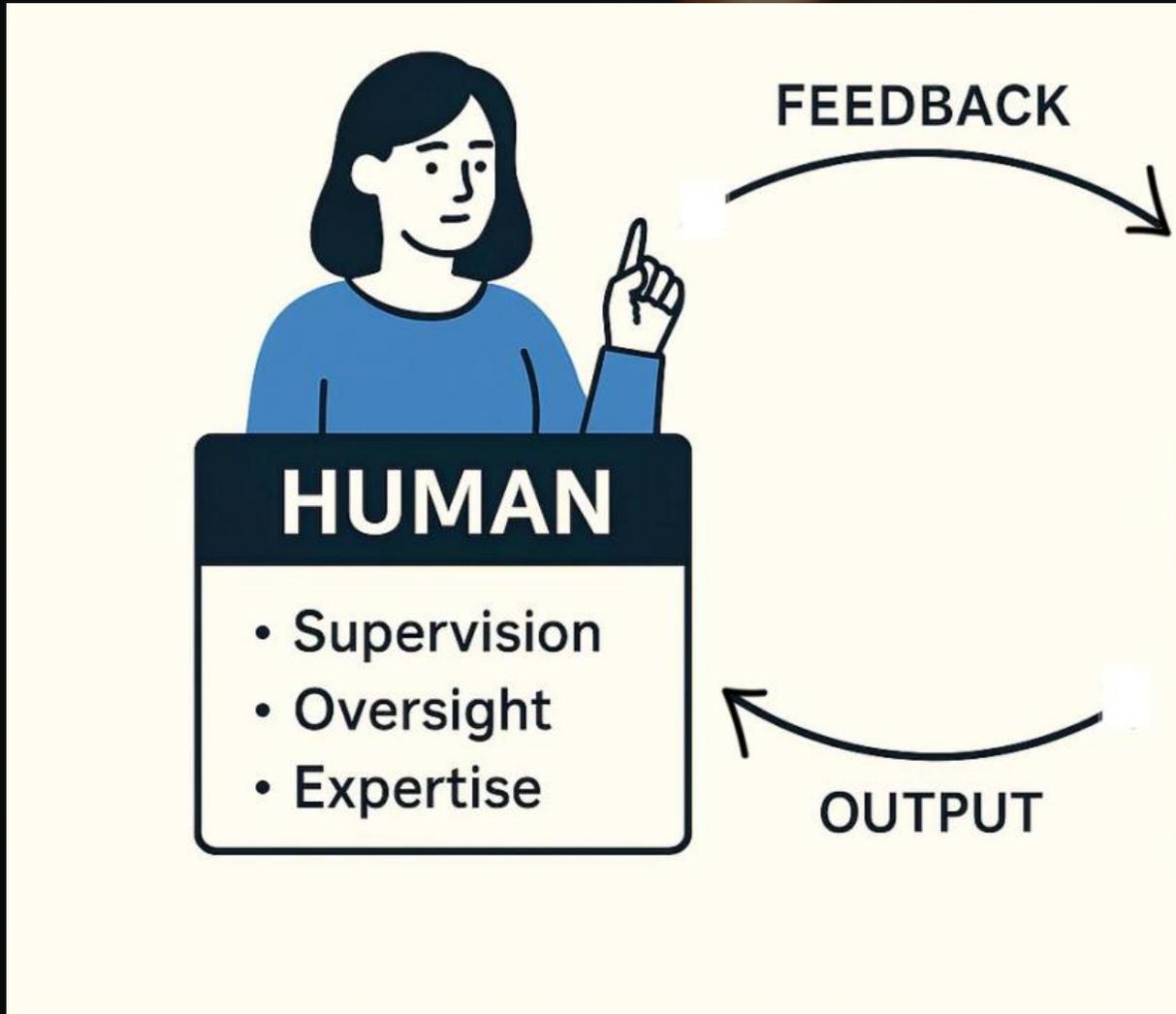
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*Robot-assisted interventions*



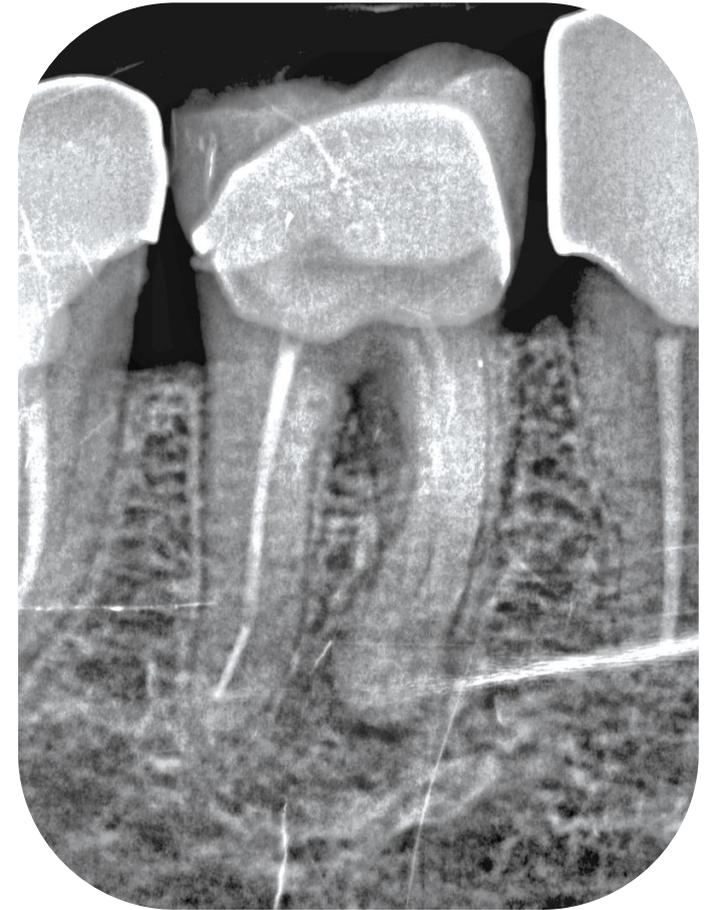
## Medical Device Regulation



## AI Act Regulation

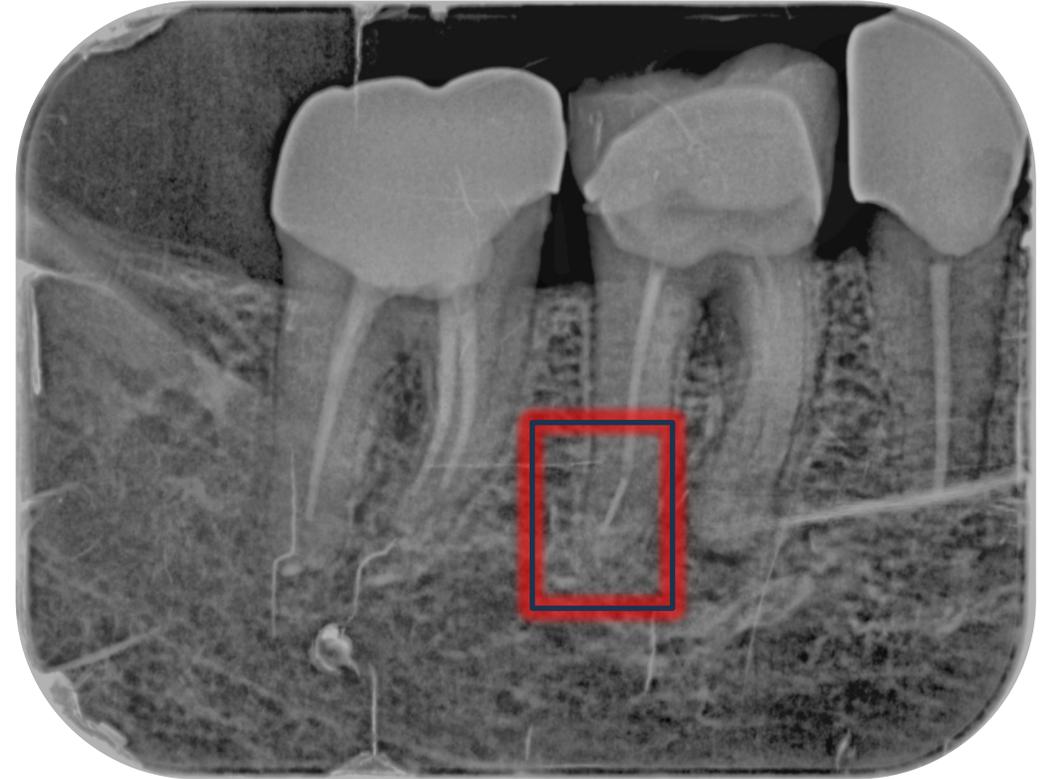
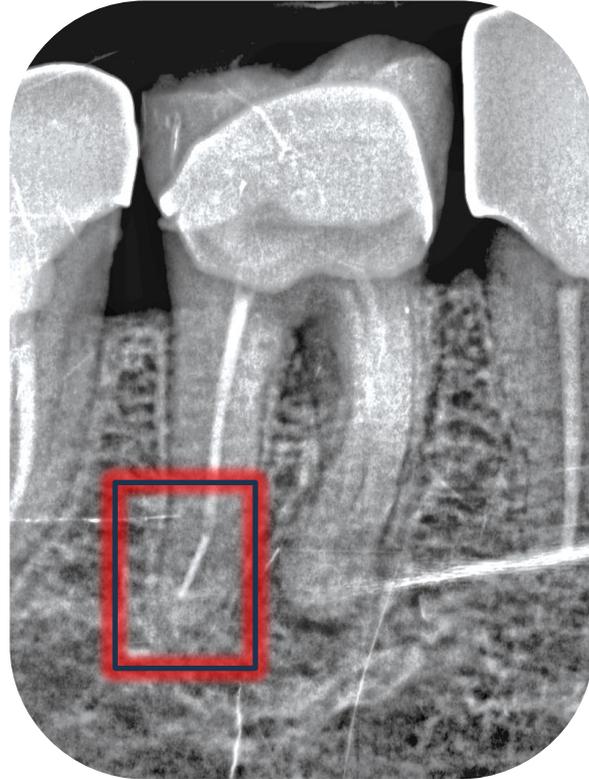
*Robot-assisted interventions*







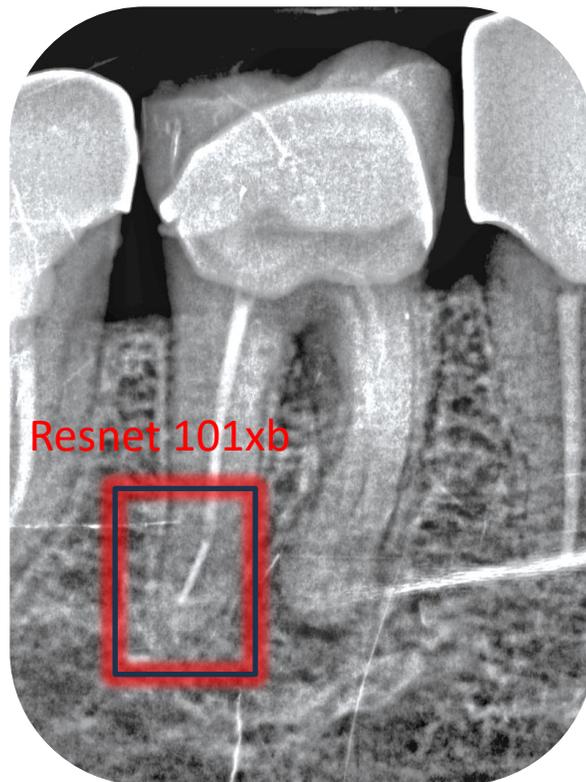
*A fractured instrument in a crowned first molar*



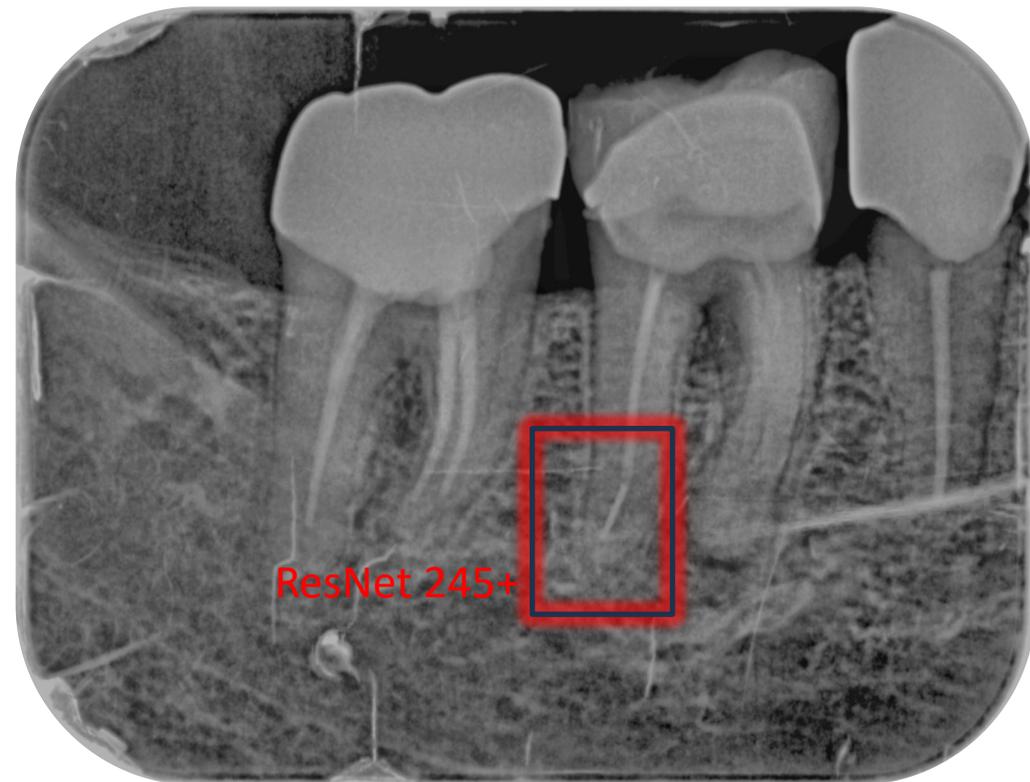
# *A fractured instrument in a crowned first molar*



**Accuracy 85%**



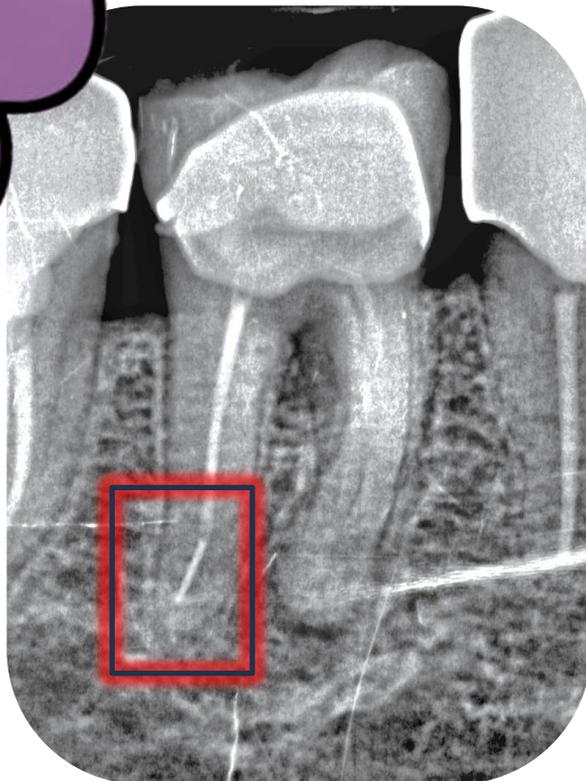
**Accuracy 91%**



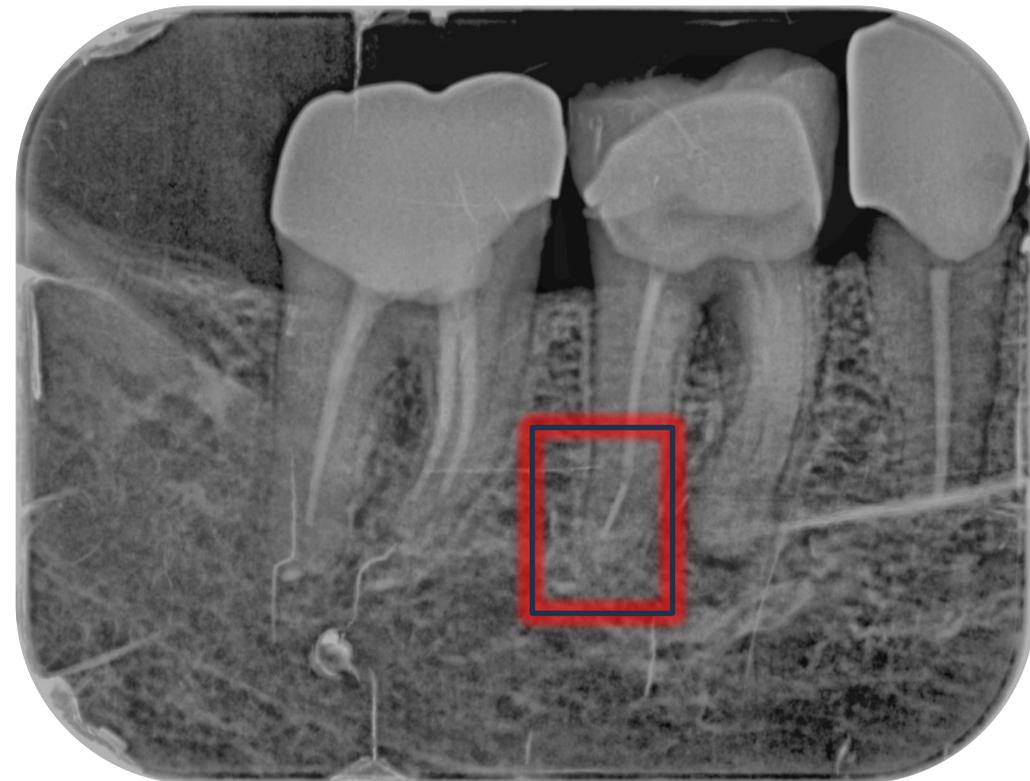
**Accuracy 99,99999%**

Is it really  
the right  
question?

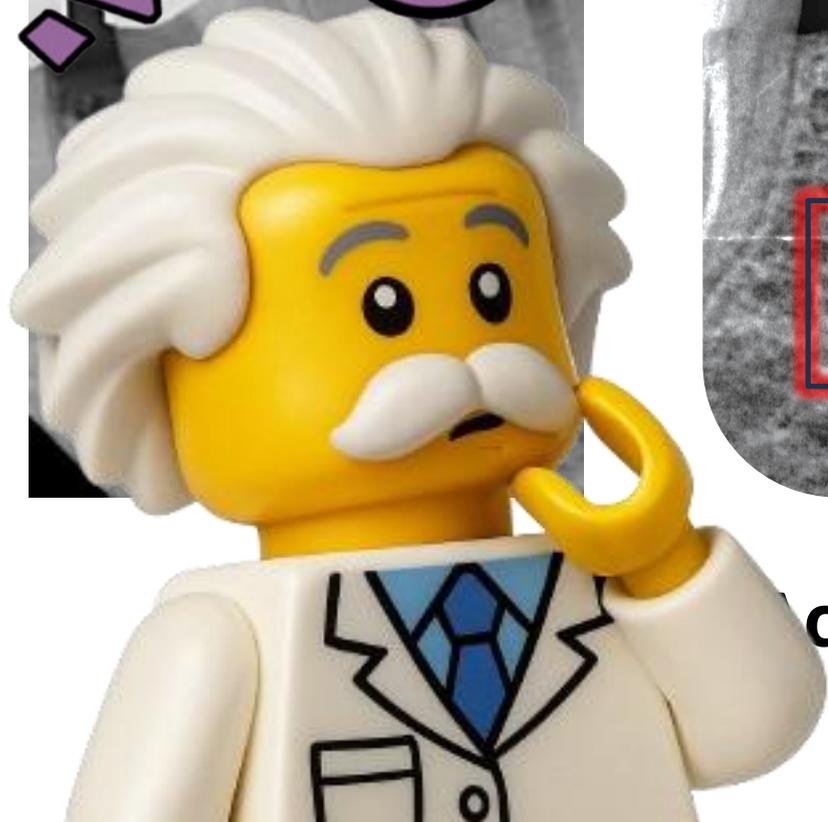
*Instrument in a crowned first molar*



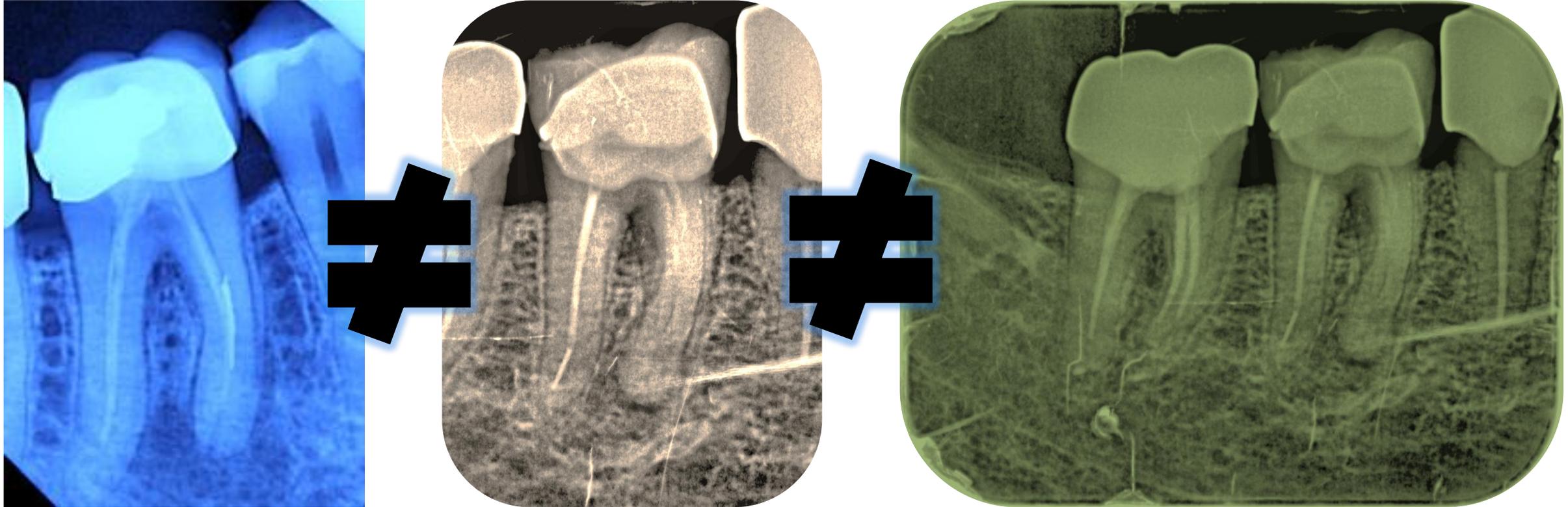
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Accuracy 99,99999%

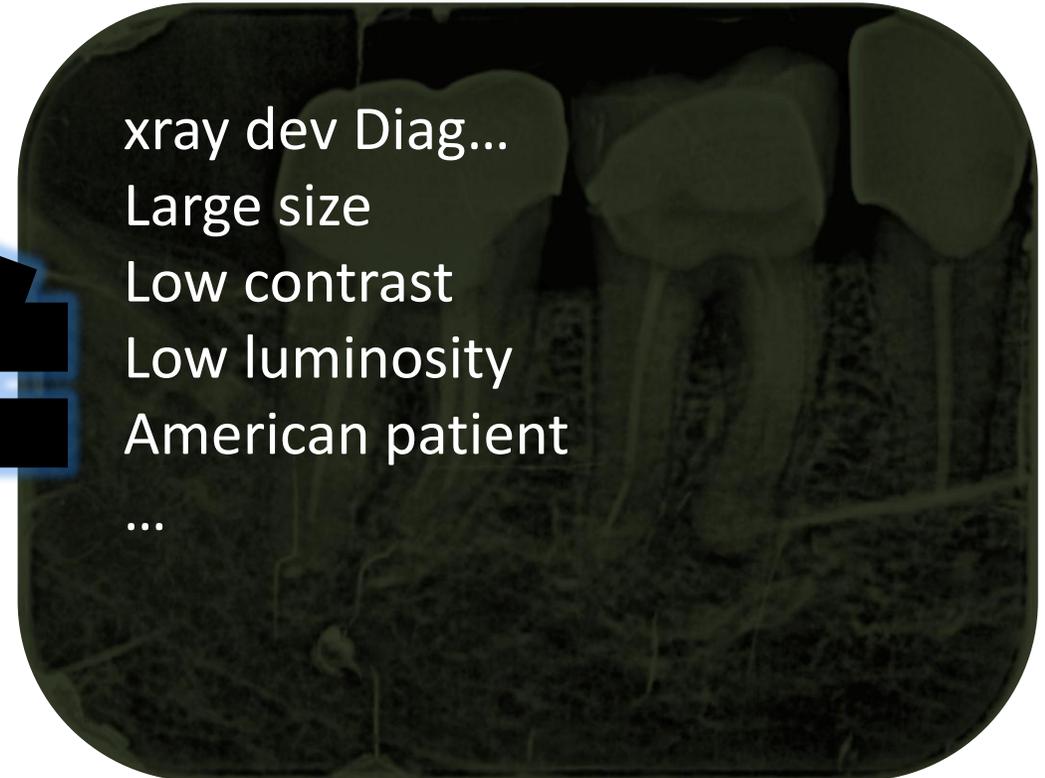
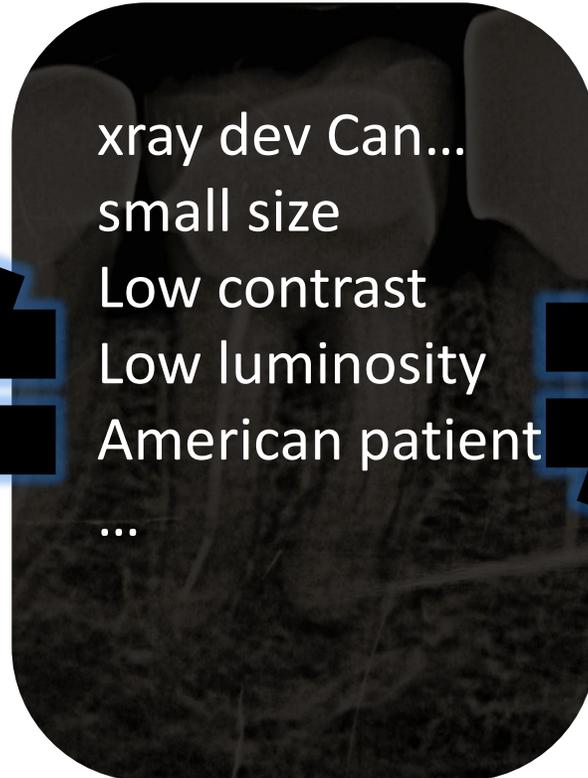
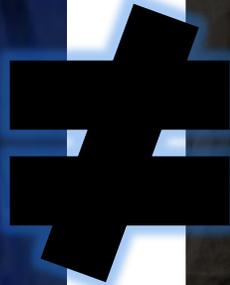


*A fractured instrument in a crowned first molar*

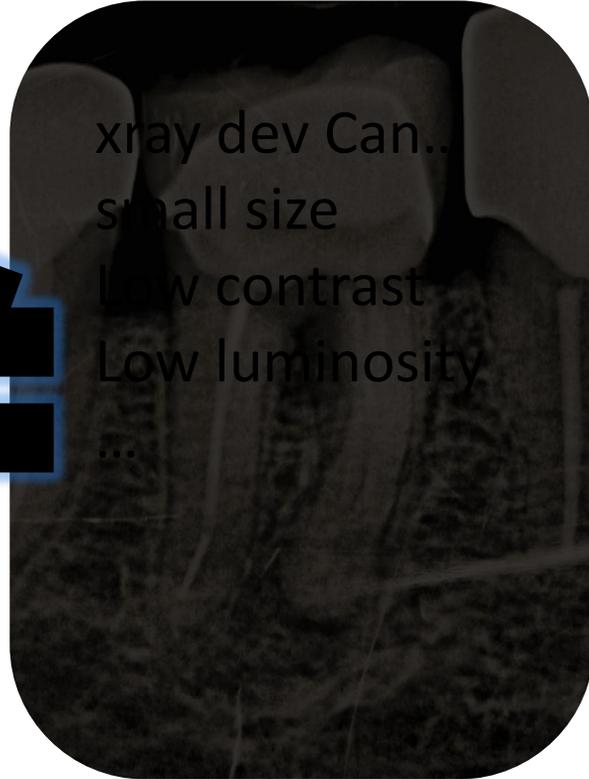
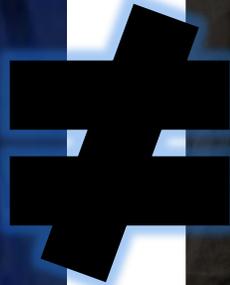


*...but 3 three different stories for the computer*

# *A fractured instrument in a crowned first molar*

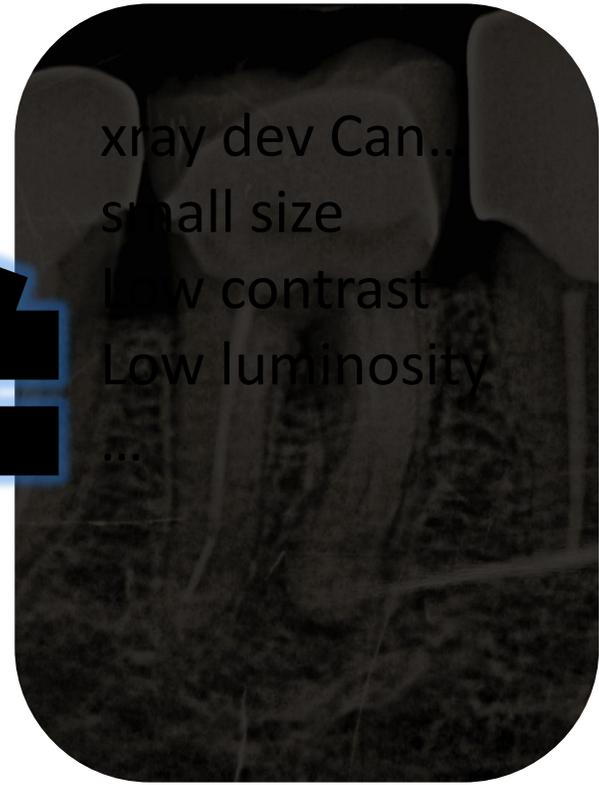


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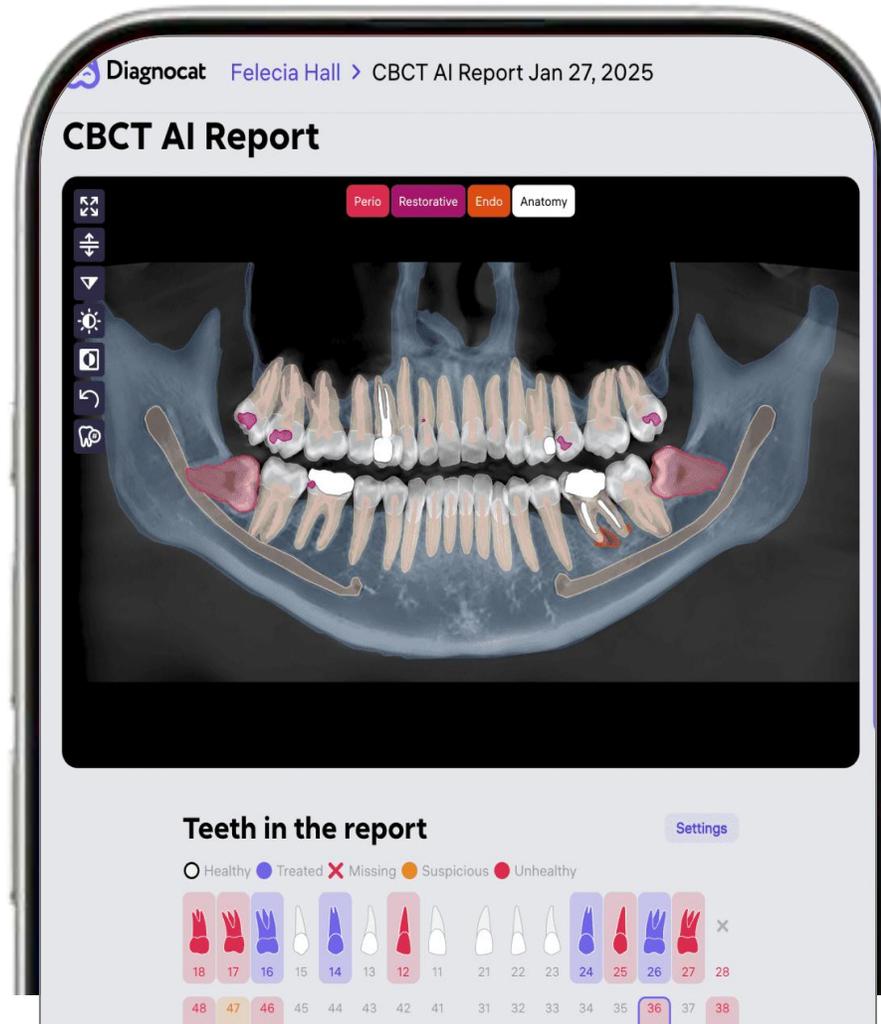
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# Origin



...but 3 three different stories for

# Origin





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## Evaluation of artificial intelligence for detecting periapical pathosis on cone-beam computed tomography scans

K. Orhan<sup>1</sup> , I. S. Bayrakdar<sup>2</sup> , M. Ezhov<sup>3</sup> , A. Kravtsov<sup>3</sup>  & T. Özyürek<sup>4</sup> 

<sup>1</sup>Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Ankara University, Ankara; <sup>2</sup>Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Eskisehir Osmangazi University, Eskişehir, Turkey; <sup>3</sup>Diagnocat Inc, San Francisco, CA, USA; and <sup>4</sup>Department of Endodontics, Faculty of Dentistry, Istanbul Medeniyet University, Istanbul, Turkey

### Abstract

**Orhan K, Bayrakdar IS, Ezhov M, Kravtsov A, Özyürek T.** Evaluation of artificial intelligence for detecting periapical pathosis on cone-beam computed tomography scans. *International Endodontic Journal*, 53, 680–689, 2020.

**Aim** To verify the diagnostic performance of an artificial intelligence system based on the deep convolutional neural network method to detect periapical pathosis on cone-beam computed tomography (CBCT) images.

**Methodology** Images of 153 periapical lesions obtained from 109 patients were included. The specific area of the jaw and teeth associated with the periapical lesions were then determined by a human observer. Lesion volumes were calculated using the manual segmentation methods using Fujifilm-Synapse 3D software (Fujifilm Medical Systems, Tokyo, Japan). The neural network was then used to determine (i)

(Diagnocat Inc., San Francisco, CA, USA) methods were compared using Wilcoxon signed rank test and Bland–Altman analysis.

**Results** The deep convolutional neural network system was successful in detecting teeth and numbering specific teeth. Only one tooth was incorrectly identified. The AI system was able to detect 142 of a total of 153 periapical lesions. The reliability of correctly detecting a periapical lesion was 92.8%. The deep convolutional neural network volumetric measurements of the lesions were similar to those with manual segmentation. There was no significant difference between the two measurement methods ( $P > 0.05$ ).

**Conclusions** Volume measurements performed by humans and by AI systems were comparable to each other. AI systems based on deep learning methods can be useful for detecting periapical pathosis on CBCT images for clinical application.

**Keywords:** artificial intelligence, cone beam com-

puted tomography, deep learning, diagnosis, exact type of periapical pathosis must be specified using a separate deep CNN. Once trained, the model is utilized to identify the presence of apical periodonti-

### Patient selection

CBCT scans for test data sets taken for various diagnostic purposes were obtained from the CBCT archive of Eskisehir Osmangazi University Faculty of Dentistry. A total of 153 periapical lesion images obtained from 109 patients were included in this study. The research protocol was approved by the Non-interventional Clinical Research Ethical Committee of Eskisehir Osmangazi University (decision date and number: 28.05.2019/48) and was performed in accordance with the principles of the Declaration of Helsinki.

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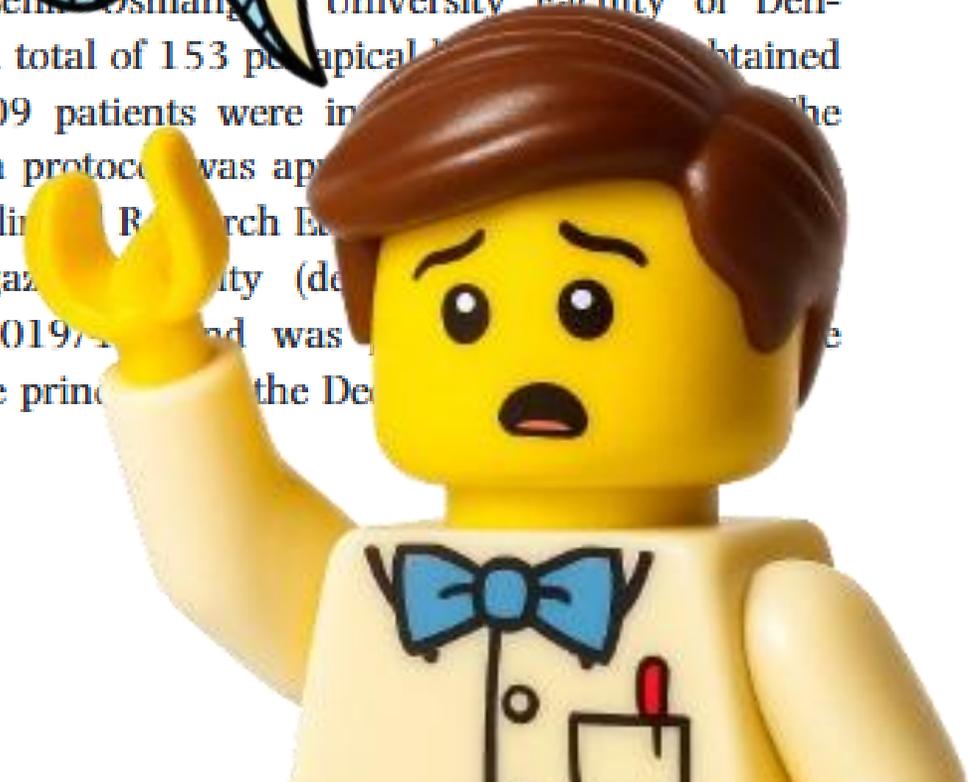
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On which  
data is AI  
trained?

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### Conflict of interest

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

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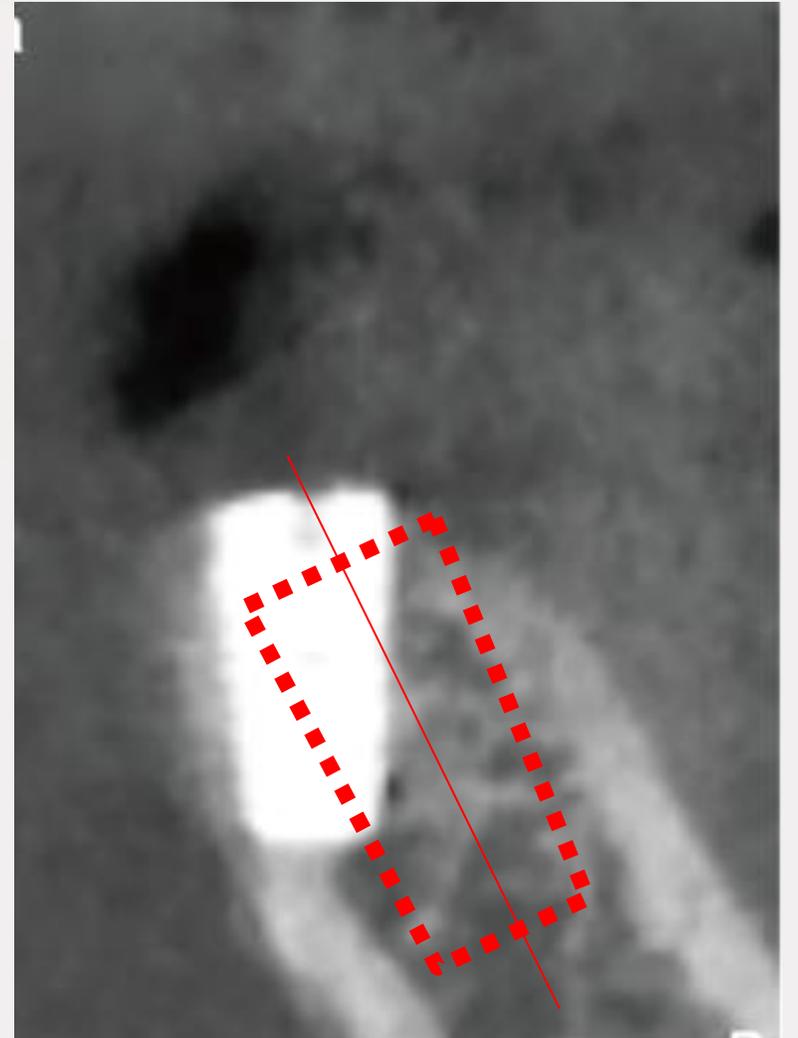


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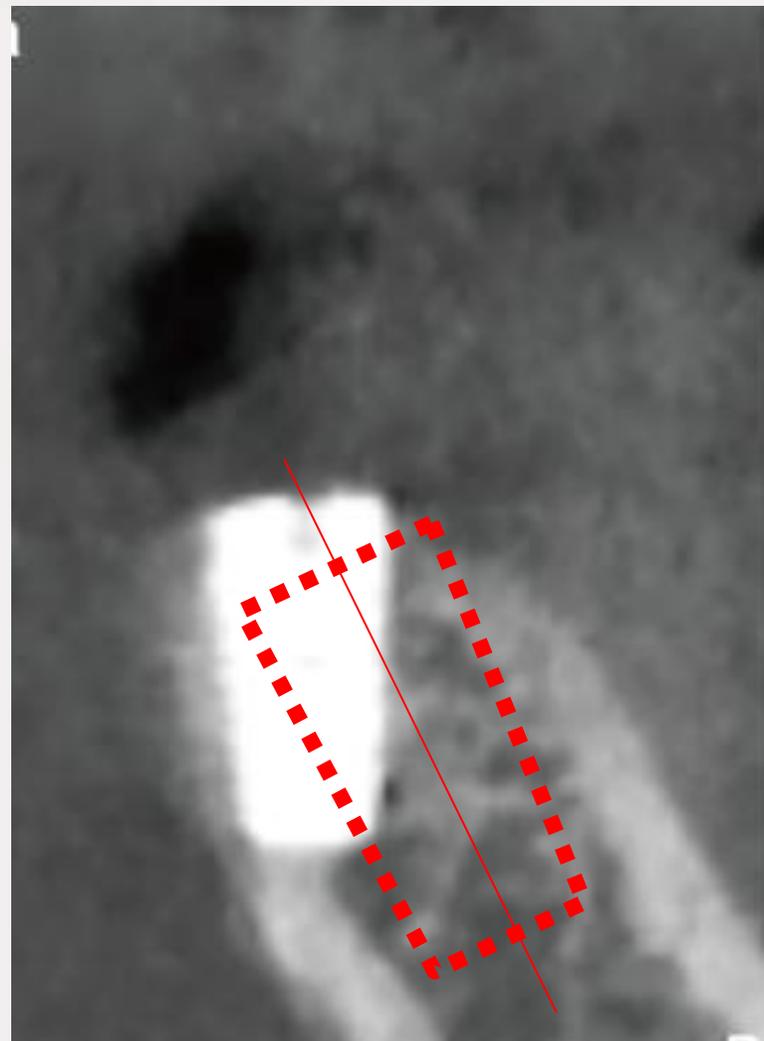




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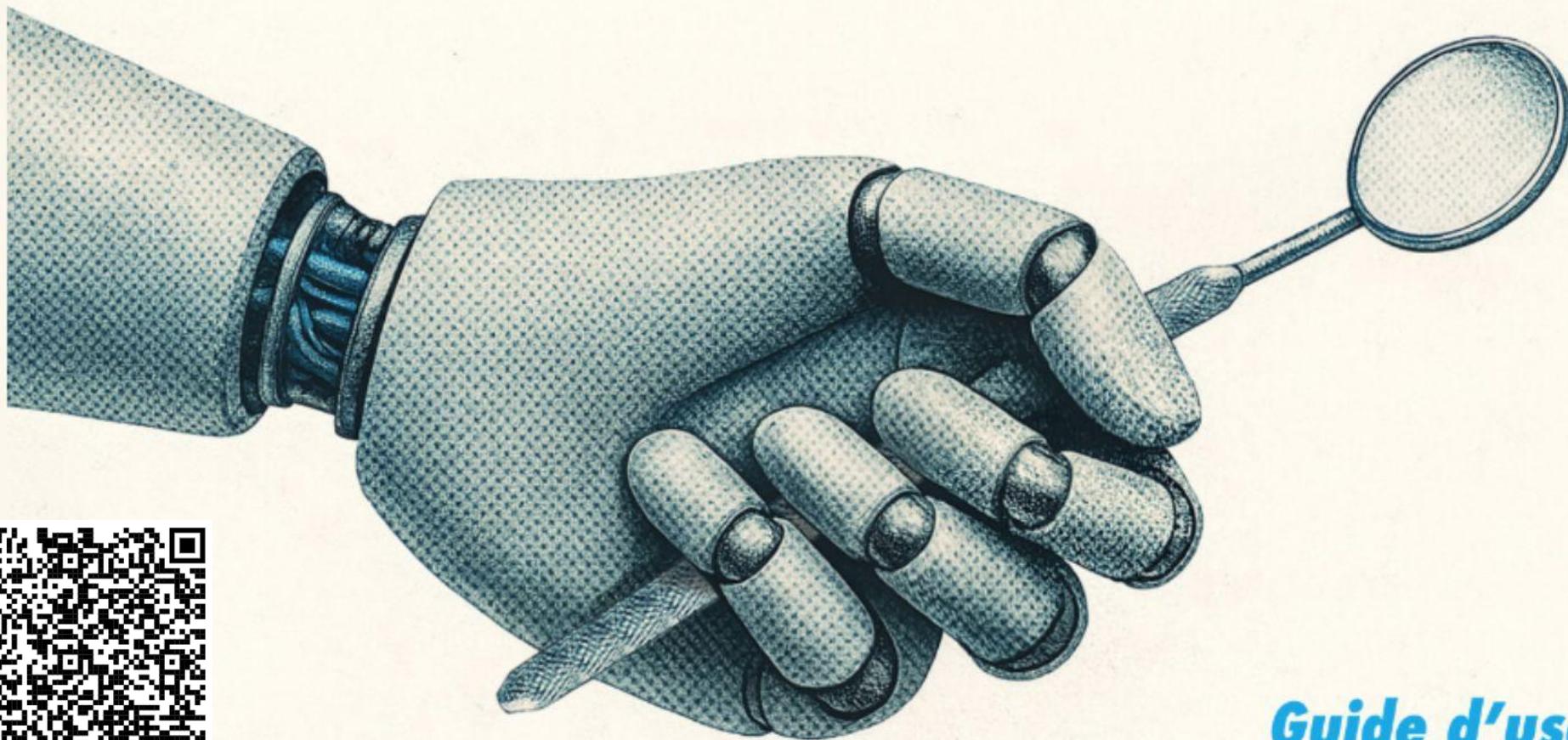
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1. Quelle est l'origine des données utilisées pour entraîner l'IA ?	Origine des données totalement transparente (nombre et diversité).	Origine des données partiellement transparente.	Origine des données inconnue.
2. Comment les données sont-elles utilisées et protégées (RGPD) ?	Usage transparent et conformité au RGPD.	Usage transparent, mais absence de cadre relatif au RGPD.	Usage non transparent et hors cadre du RGPD.
3. Que vaut la performance du dispositif ?	Données de performance validées par des études indépendantes.	Données de performance validées uniquement en interne, rapportées par le fabricant.	Absence d'information.
4. Le fonctionnement de l'IA est-il clair ?	Fonctionnement clair et explication claire.	Fonctionnement clair mais absence d'explication.	Fonctionnement peu clair et absence d'explication.
5. Y a-t-il une garantie humaine pour vérifier les décisions ?	Mécanisme en place automatiquement sur l'ensemble de la chaîne et vérifié en externe.	Mécanisme facultatif.	Aucun mécanisme.
6. Le dispositif est-il mis à jour	Mise à jour fréquente (3 à 6 mois) et	Mise à jour rare (> 6 mois), peu	Aucune mise à jour.



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*Guide d'usage*

# L'INTELLIGENCE ARTIFICIELLE EN ODONTOLOGIE

# Les jumeaux numériques pour de meilleurs soins



Lecture



00:03



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