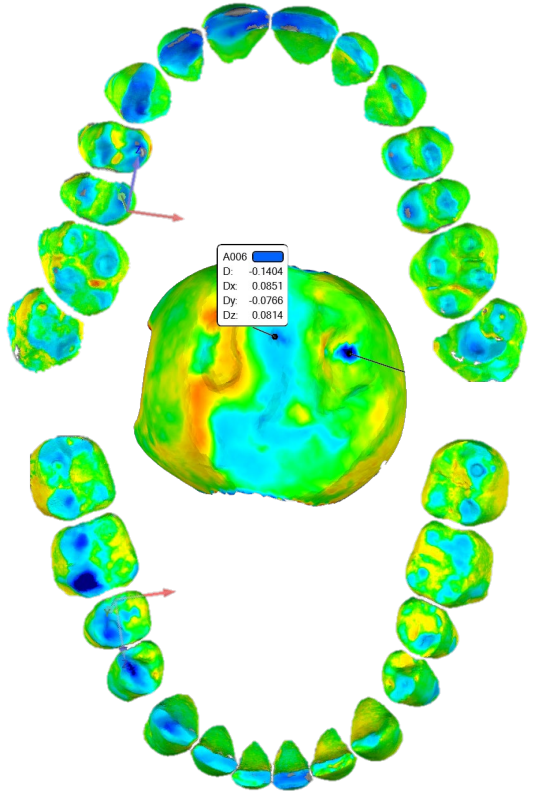
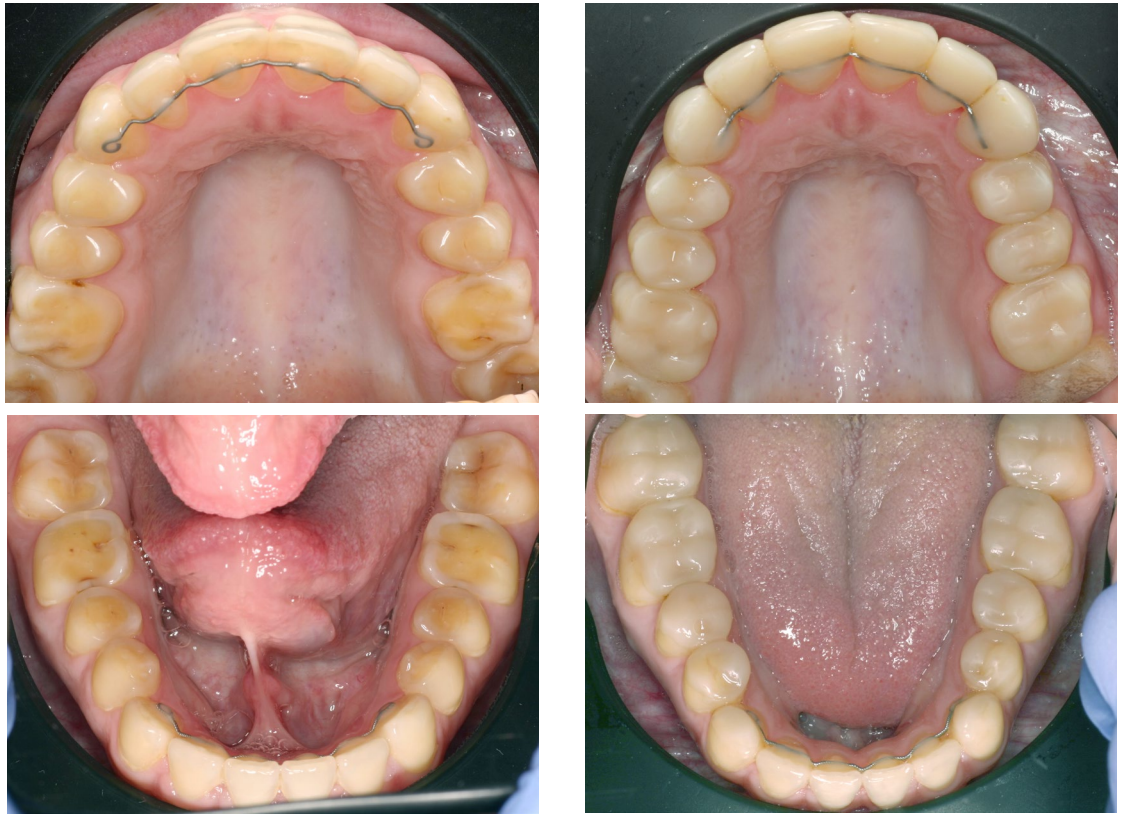
Digital Dentistry:
Data, Detection & Decisions



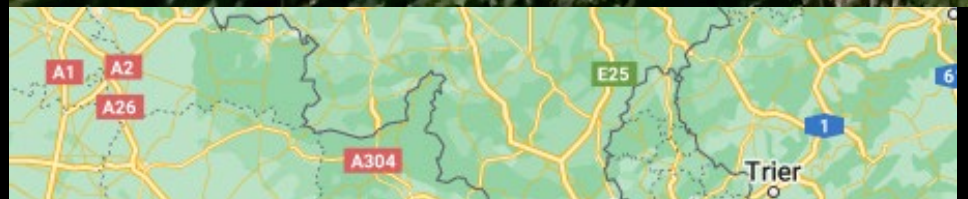


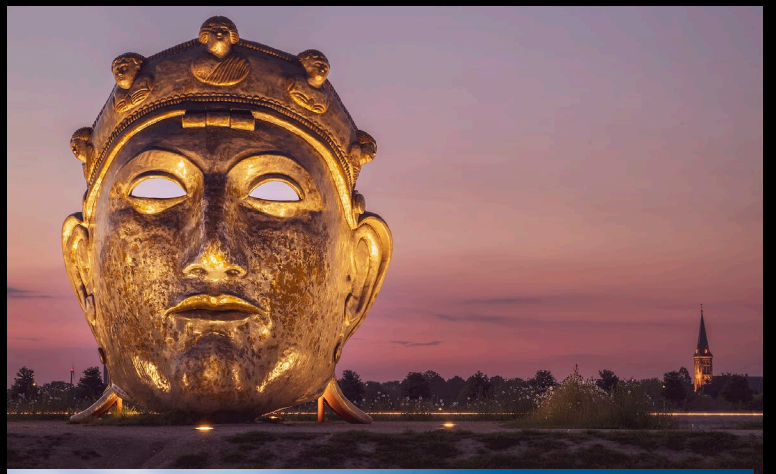
Bas Loomans

Professor Oral Function and Restorative Dentistry

MICCAI 2026

Radboudumc


A1
A2
A26
E25
A304
1
Trier



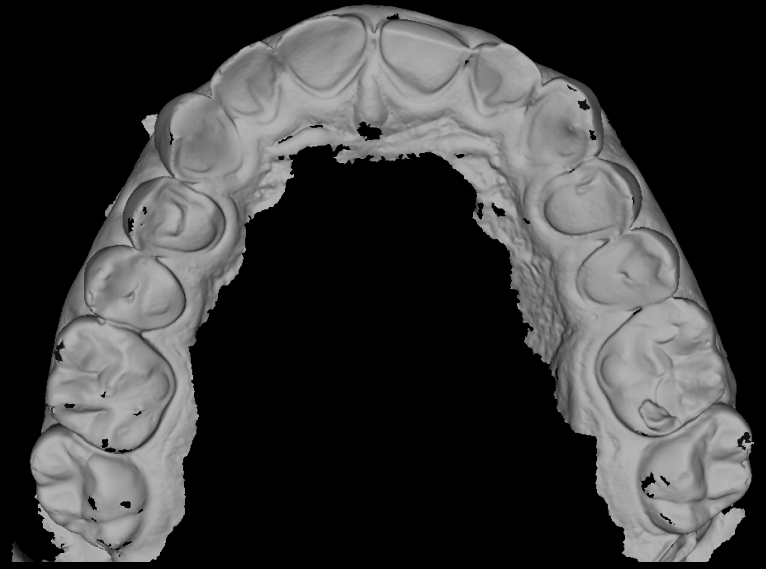
Conflict of Interest Disclosure

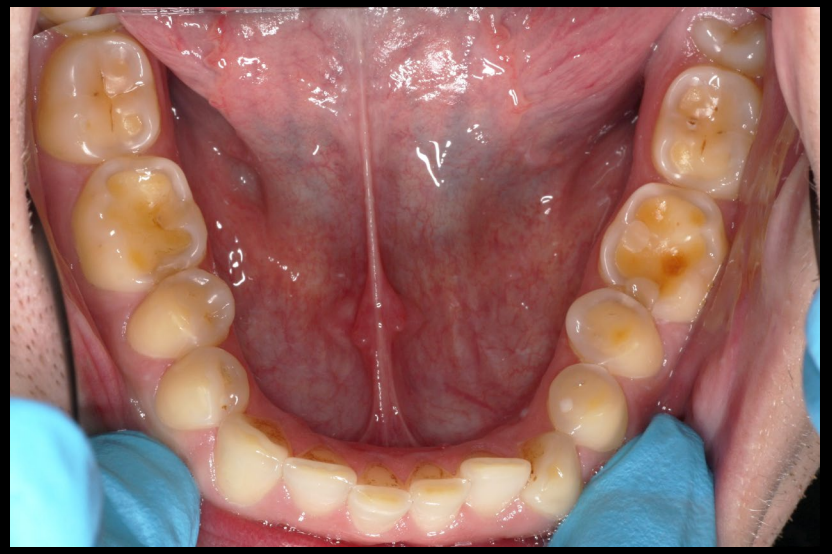
I have no conflicts of interest to declare.

My participation in this symposium is supported by ODIN

Topics on this early Sunday morning

- How I became involved in AI
- What we are doing with AI and clinical decision support
- What we have learned so far: opportunities, challenges, and risks
- Where do we go from here?





How often do we think we know the etiology?

*... But how often **can we prove** this?*

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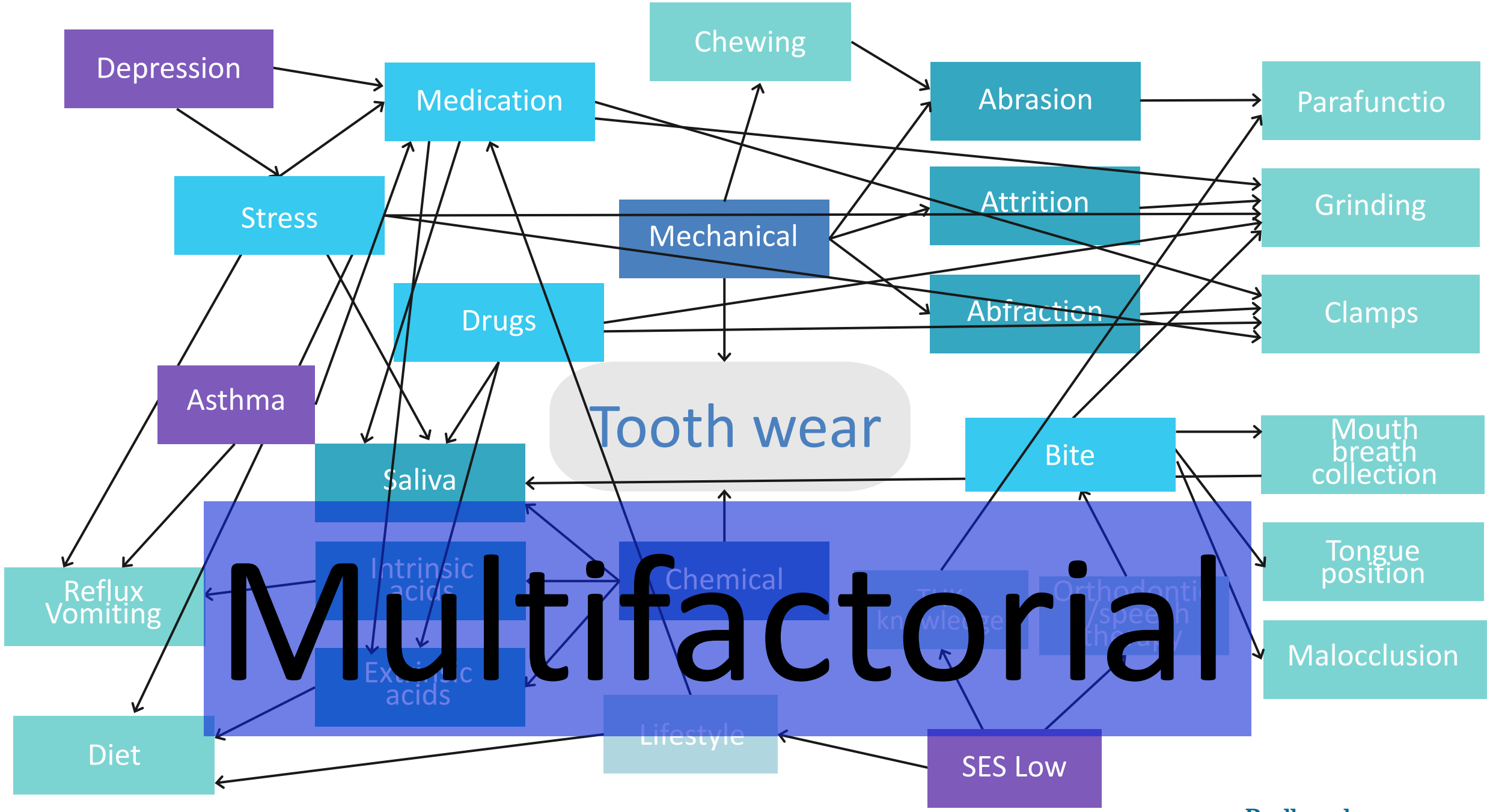
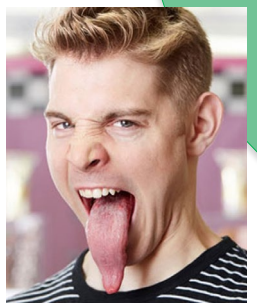
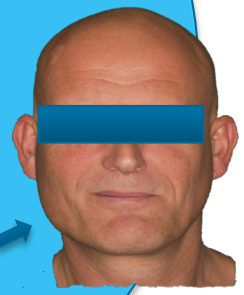

Depression
Medication
Chewing
Abrasion
Parafunctio
Stress
Attrition
Grinding
Mechanical
Drugs
Abfraction
Clamps
Asthma
Tooth wear
Saliva
Bite
Mouth breath collection
Reflux Vomiting
Intrinsic acids
Chemical
Tongue position
Extrinsic acids
Malocclusion
Diet
Lifestyle
SES Low
Multifactorial

Radboudumc

Chemical processes

Biological and individual factors

Mechanical processes

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Radboud Tooth Wear Project

Contents lists available at ScienceDirect

Journal of Dentistry

journal homepage: www.elsevier.com/locate/jdent

Review article

Evidence-based, patient-centred management of tooth wear: *15-years insights from the Radboud Tooth Wear Project*

B.A.C. Loomans [a,*], S.B. Mehta [a,b], M.C.D.N.J.M. Huysmans [a], T. Pereira-Cenci [a], N.J.M. Opdam [a]

[a] Department of Dentistry, Radboud University Medical Center, Radboud Institute for Medical Innovation, Nijmegen, the Netherlands
[b] Unit of Distance Learning, King's College London Faculty of Dentistry, Oral & Craniofacial Sciences, Guy's Campus, London, United Kingdom

15 years....

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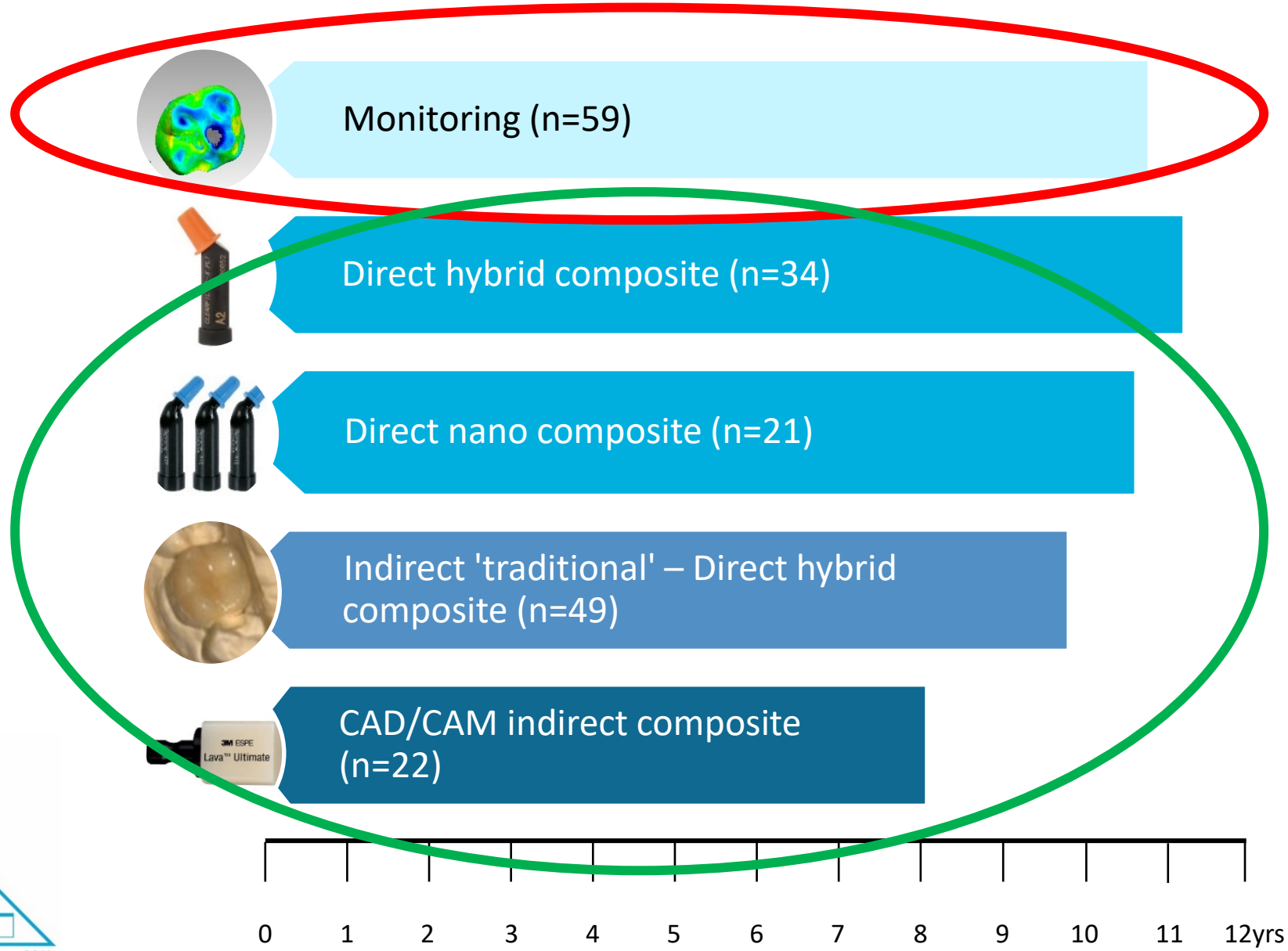
- Started in 2010
- 184 patients included
- 126 patients treated restoratively
- 75% male
- Average age: 37±10 years
- Generalized tooth wear
- No exclusion on etiological factors



RTWP

Radboud Tooth Wear Project

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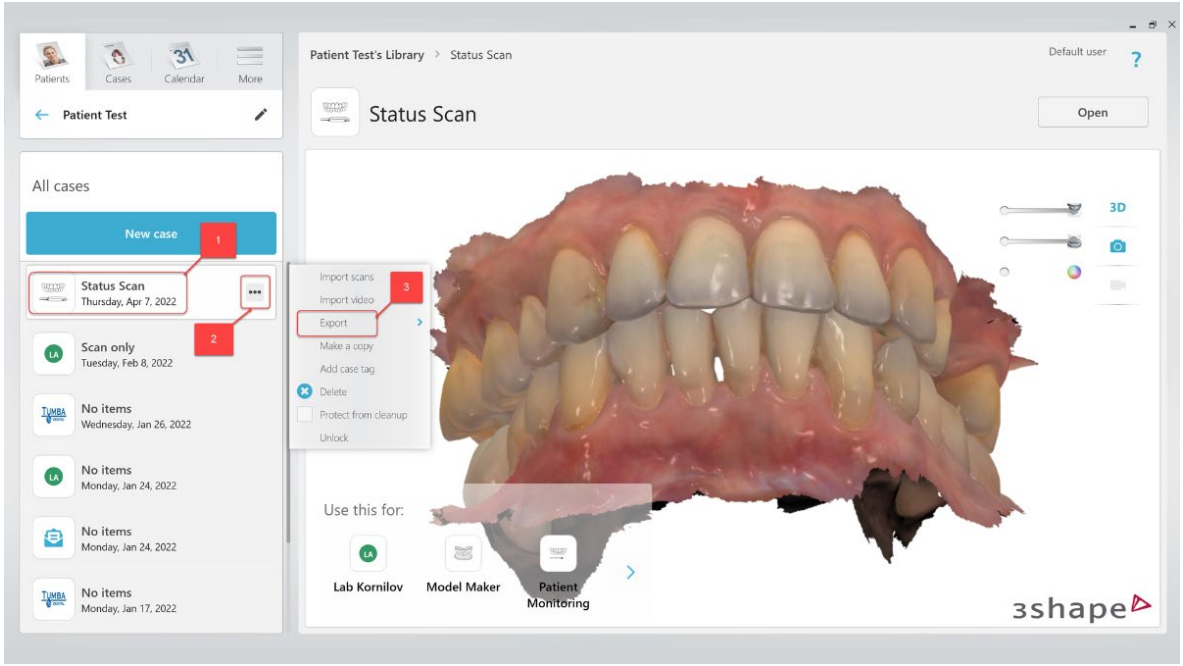
Diagnostics:
Intraoral 3D-scanning



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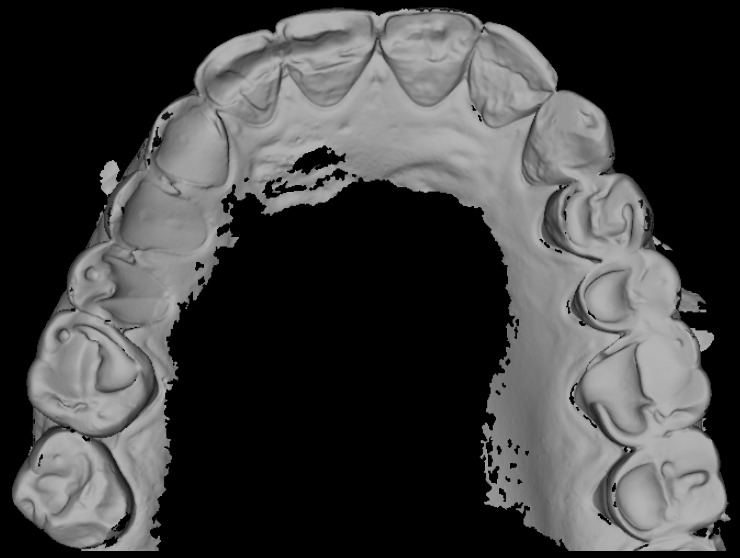
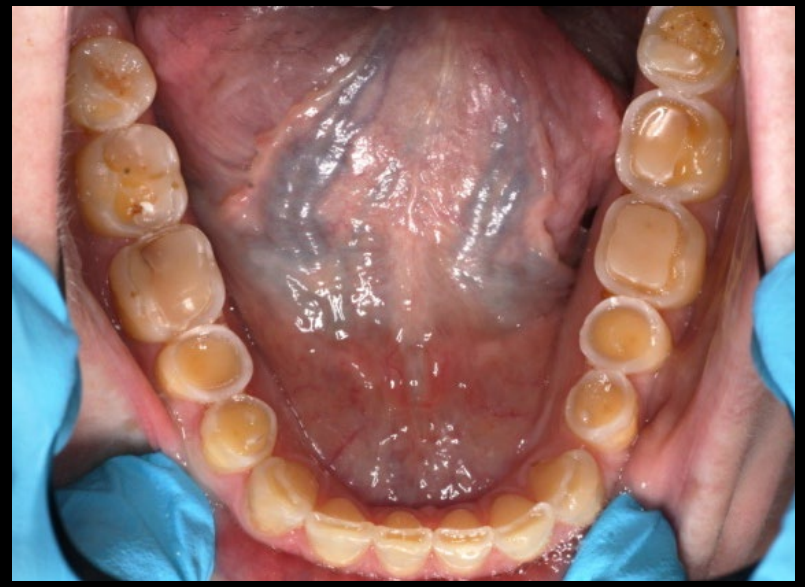
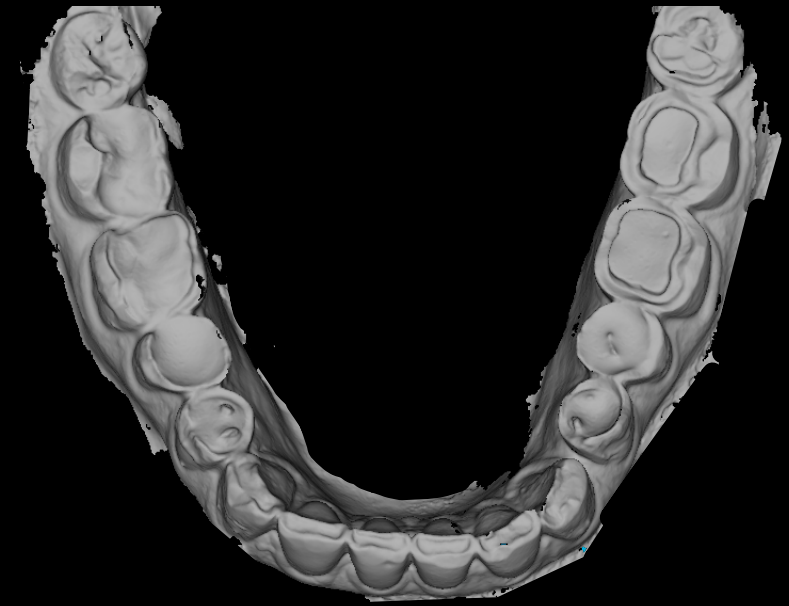


Contrast and sharpness





Digital workflow:

- Crown and Bridgework
- Tabletops
- Inlay, Onlay and Facing
- Implantology
- Telescopes
- Post & Core
- Studymodels
- Virtual Setup / Preparation
- Splints
- Denture software
- Trays
- RPD removable partial
- Orthodontics
- Drillguides
- Combination with ImplantStudio

Diagnostics!

2.28
2.27

27 Trios Scanners

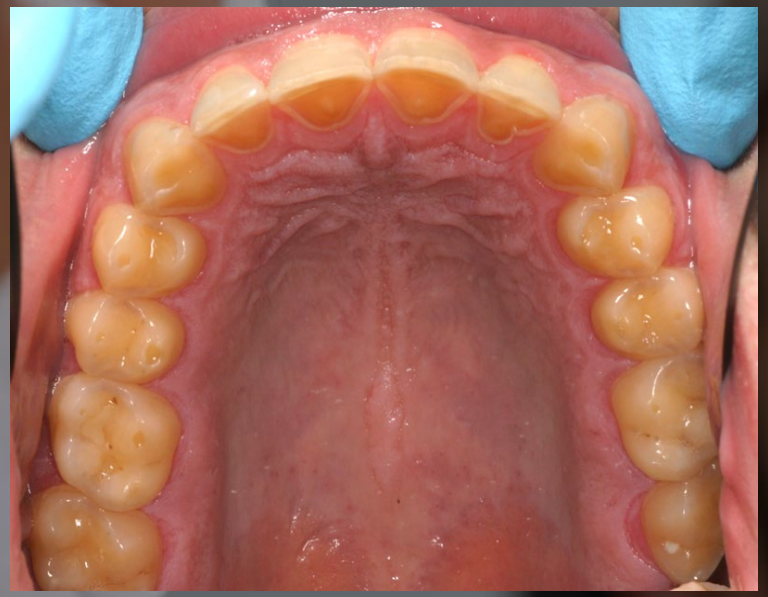
280 Chairside and Working spots

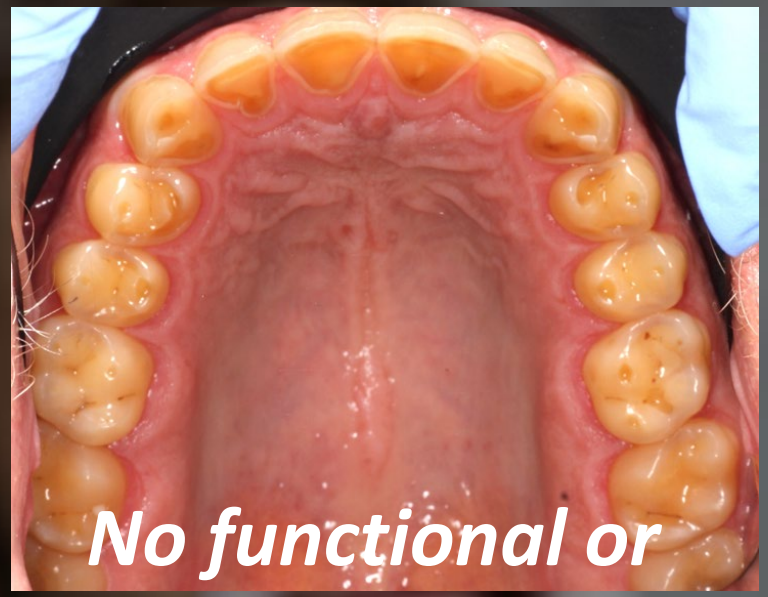
Integrated into education from the first year

Current situation:
Diagnostics
Digitization of production: crowns, onlays, frames, etc
Digital design
Digital planning (surgery, orthodontics, restorative)

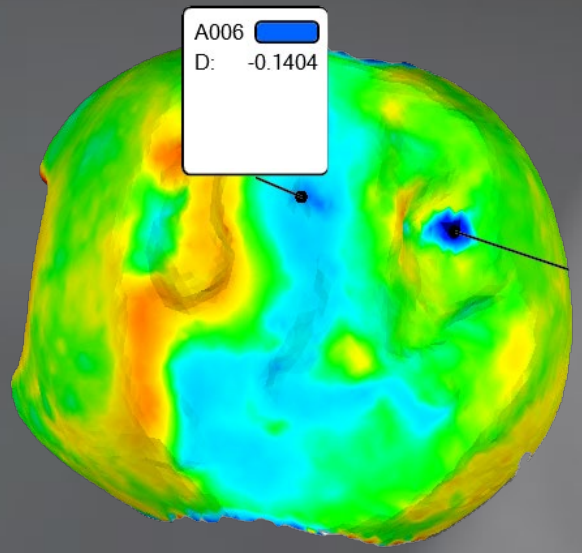
Upcoming:
Decision making processes
Prediction models

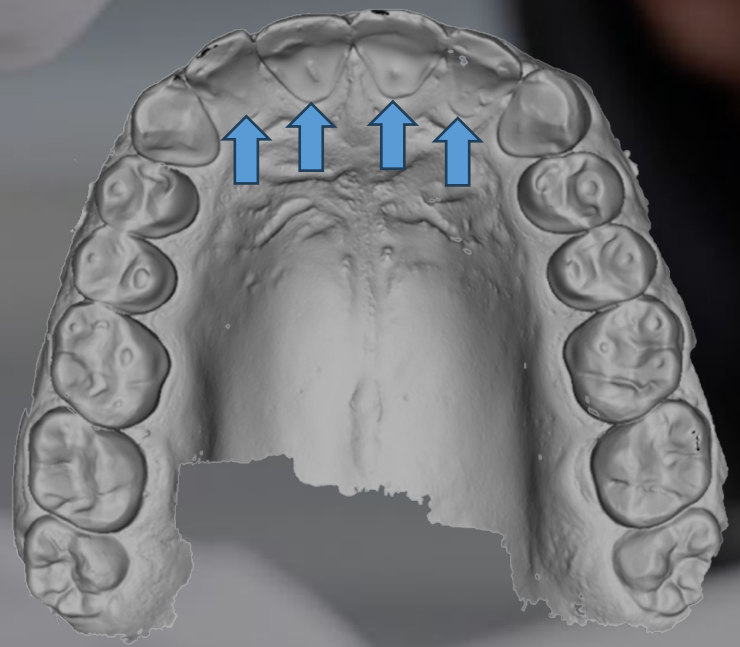
Counseling & Monitoring



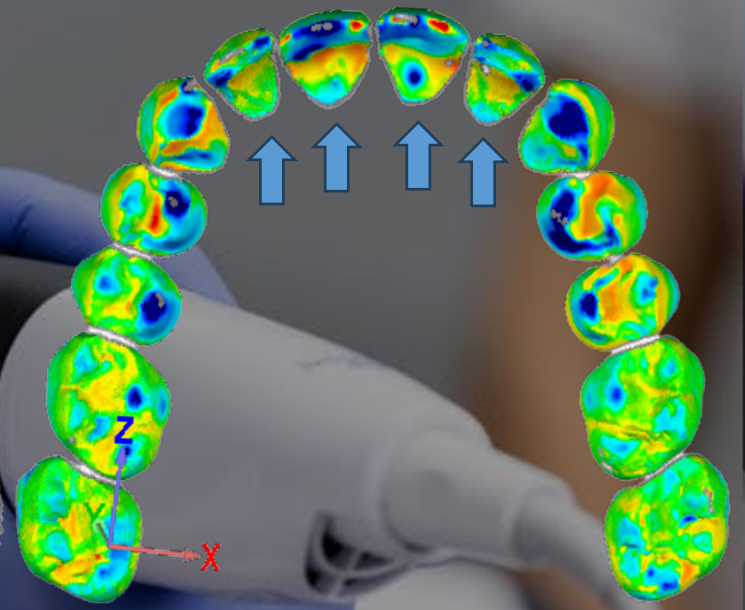


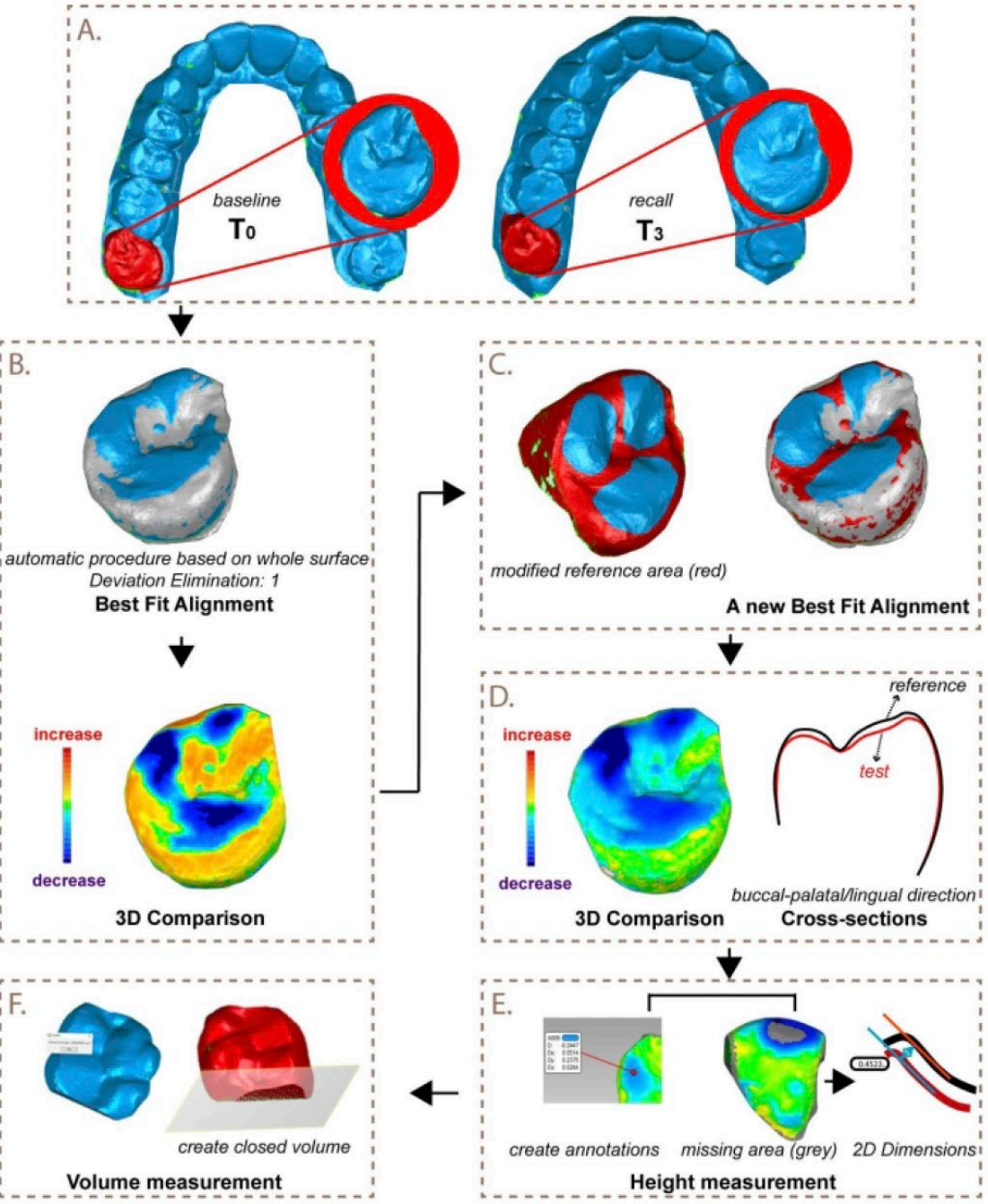
No functional or aesthetic problems





5 years





Our 'manual' algorithm

Start 2016…

8 hours per patient

jove

Precision of *In Vivo* Quantitative Tooth Wear Measurement using Intra-Oral Scans

Hilde Bronkhorst[1], Ewald Bronkhorst[1], Stanimira Kalaykova[1], Wicher van der Meer[2], Marie-Charlotte Huysmans[1], Bas Loomans[1]

[1] Department of Dentistry, Radboud University Medical Center [2] Department of Orthodontics, University Medical Center Groningen, University of Groningen

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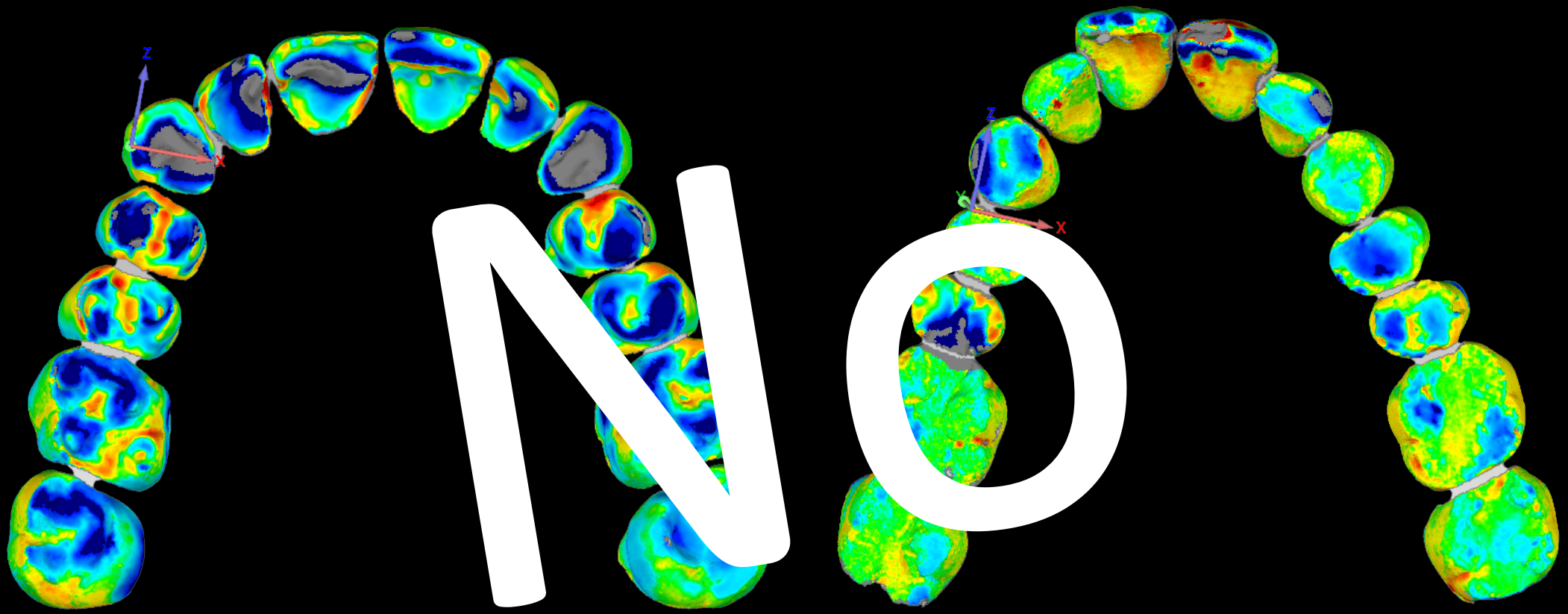
Could we have predicted the progression of wear?



Our ‘automated’ algorithm

2023

Vinayahalingam et al. BMC Oral Health (2023) 23:643
https://doi.org/10.1186/s12903-023-03362-8

BMC Oral Health

RESEARCH

Open Access

Intra-oral scan segmentation using deep learning

Shankeeth Vinayahalingam[1,2,3], Steven Kempers[1,2], Julian Schoep[4], Tzu-Ming Harry Hsu[5], David Anssari Moin[4], Bram van Ginneken[6], Tabea Flügge[7*], Marcel Hanisch[4,3†] and Tong Xi[1†]

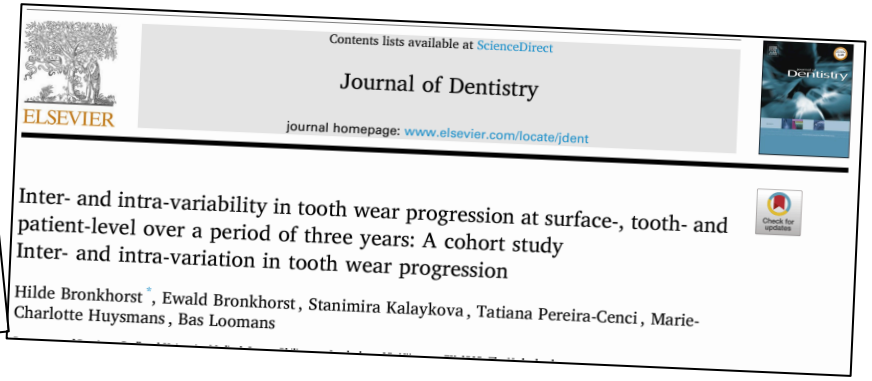
Contents lists available at ScienceDirect

Journal of Dentistry

journal homepage: www.elsevier.com/locate/jdent

Automated monitoring of tooth wear progression using AI on intraoral scans

Niels van Nistelrooij[a,b], Eva Maier[c,d], Hilde Bronkhorst[d], Luuk Crins[d], Tong Xi[a], Bas A.C. Loomans[d,1], Shankeeth Vinayahalingam[a,1,*]

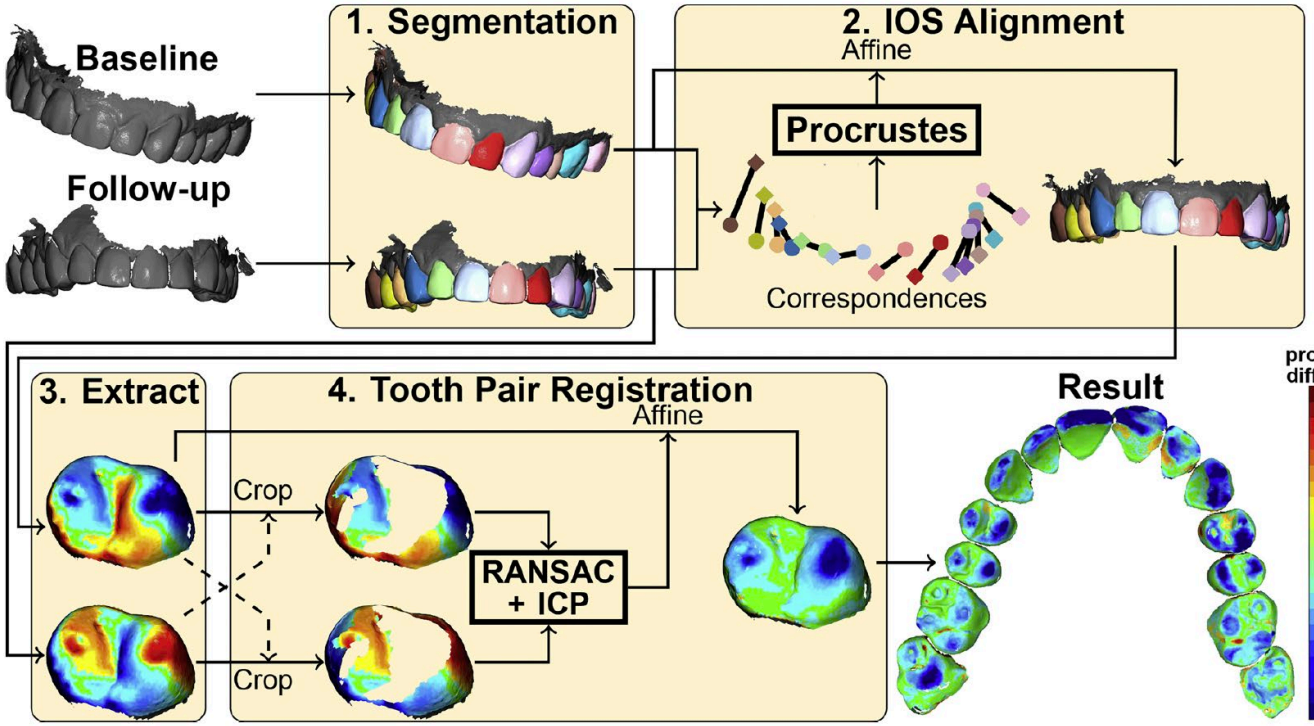

Contents lists available at ScienceDirect

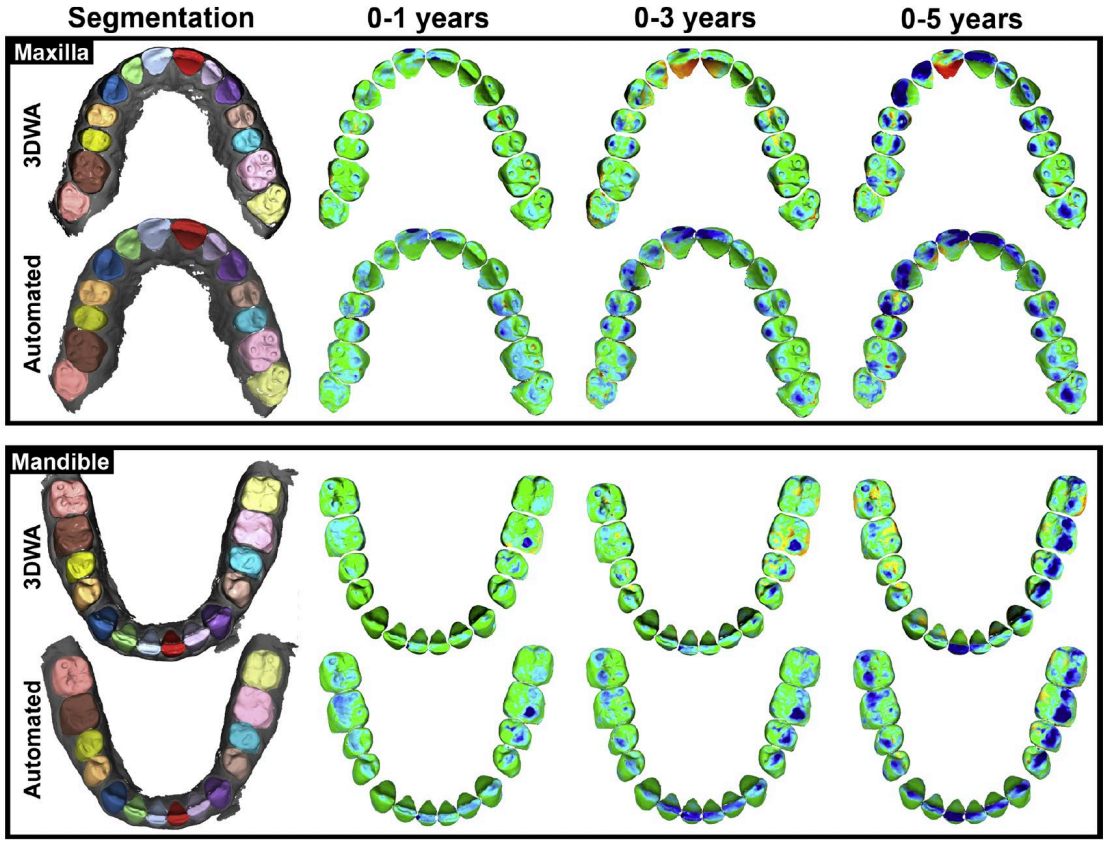
Journal of Dentistry

journal homepage: www.elsevier.com/locate/jdent

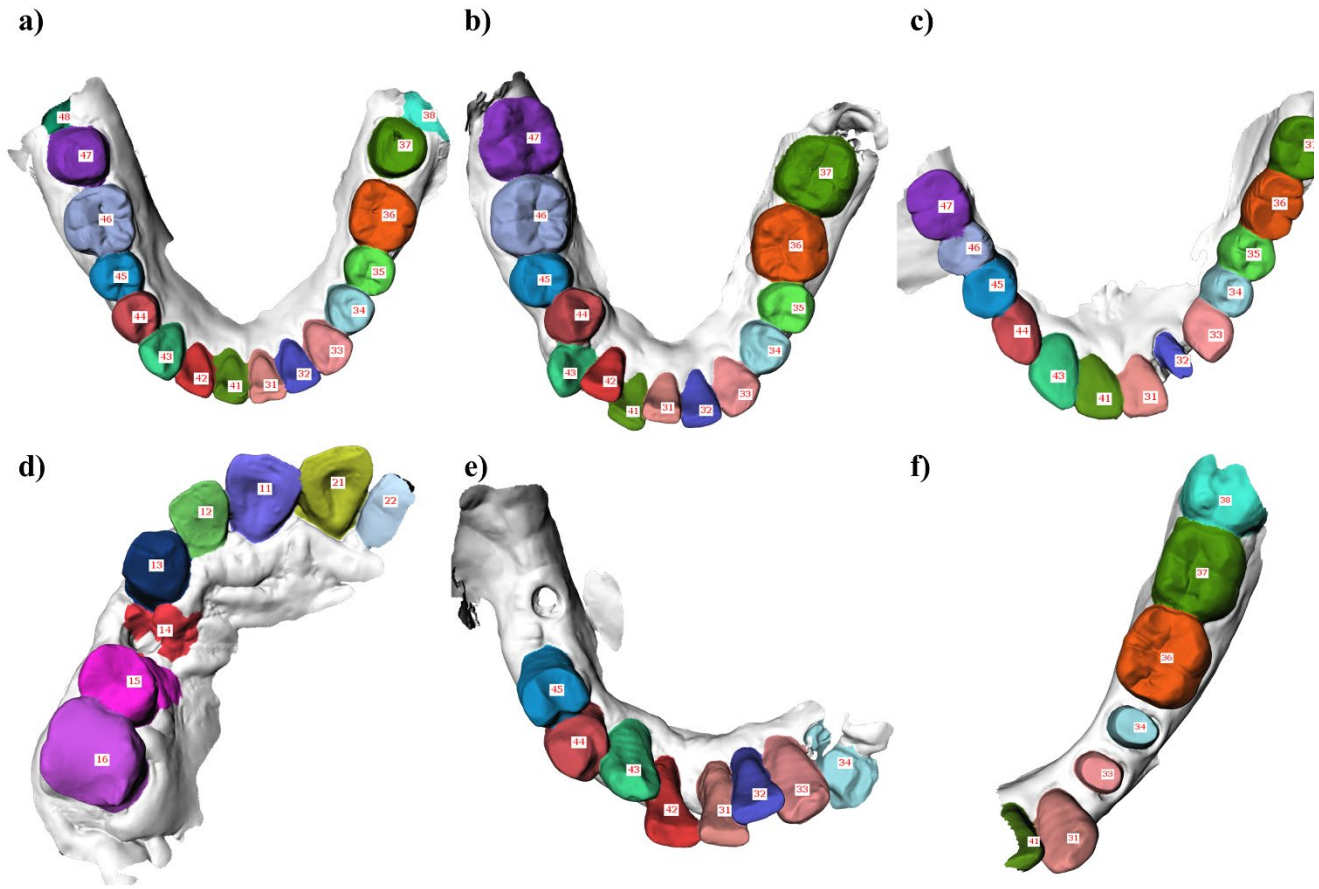
Inter- and intra-variability in tooth wear progression at surface-, tooth- and patient-level over a period of three years: A cohort study
Inter- and intra-variation in tooth wear progression

Hilde Bronkhorst*, Ewald Bronkhorst, Stanimira Kalaykova, Tatiana Pereira-Cenci, Marie-Charlotte Huysmans, Bas Loomans





Segmentation of partial scans and mixed dentitions



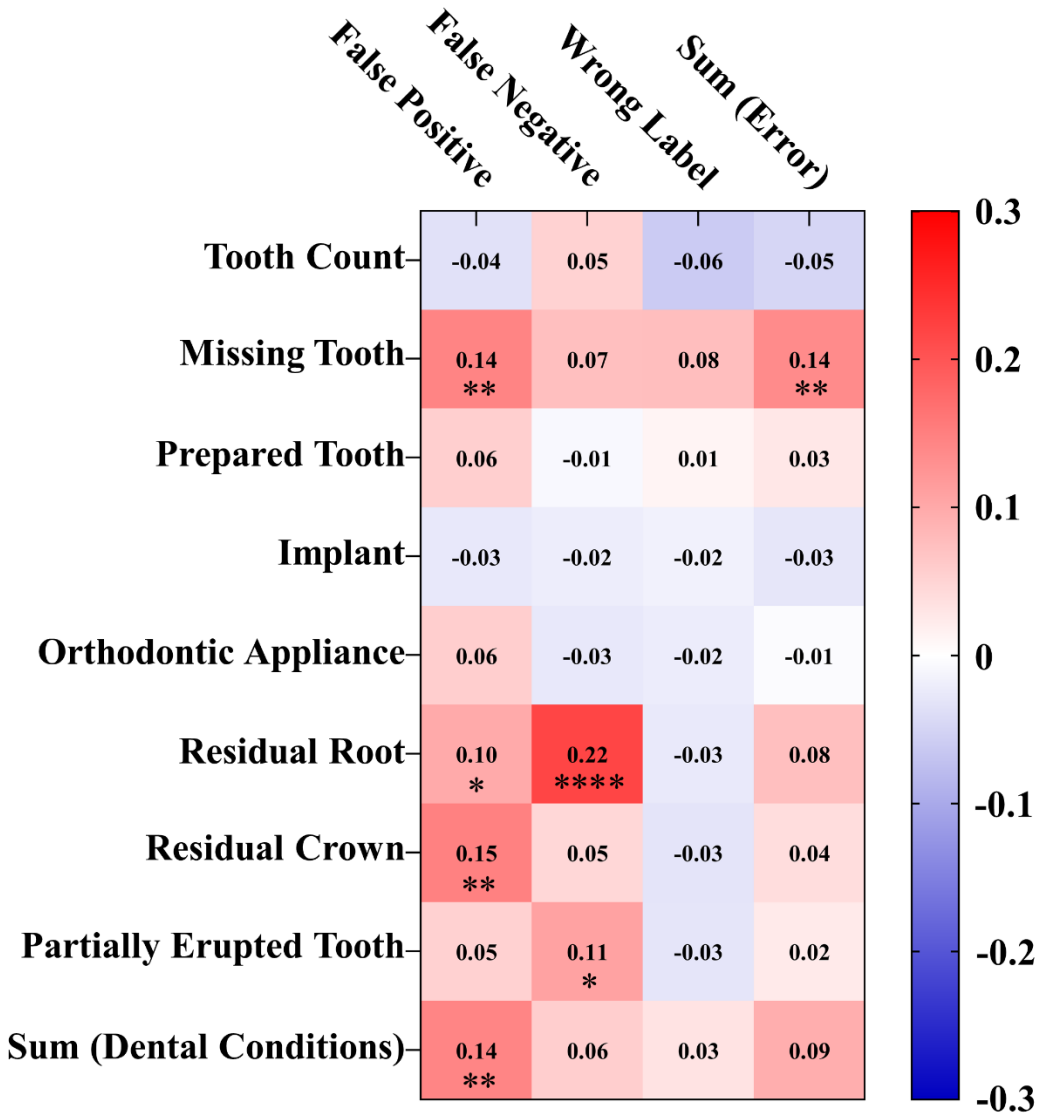
INTERNATIONAL DENTAL JOURNAL 75 (2025) 100950

Scientific Research Report

Fully Automated Tooth Segmentation and Labeling for Both Full- and Partial-Arch Intraoral Scans Using Deep Learning

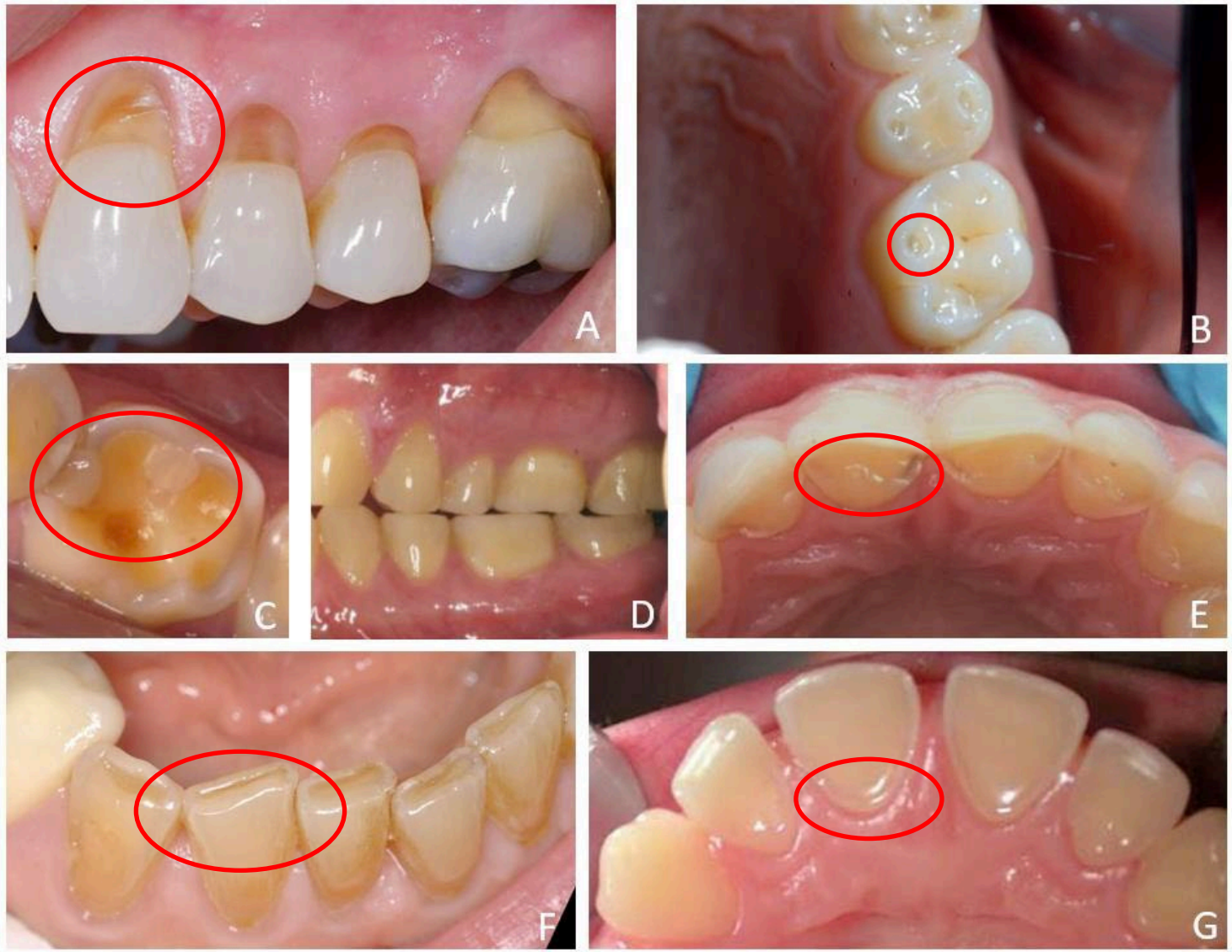
Lingyun Cao [a*], *Niels van Nistelrooij* [b], *Jiaqi Liu* [c], *Shankeeth Vinayahalingam* [b], *Maximiliano Sergio Cenci* [a], *Tong Xi* [b], *Bas A.C. Loomans* [a]

[a] Department of Dentistry, Research Institute for Medical Innovation, Radboud University Medical Center, Nijmegen, The Netherlands
[b] Department of Oral and Maxillofacial Surgery, Radboud University Medical Center, Nijmegen, The Netherlands
[c] School of Stomatology, Xiangyang Polytechnic, Xiangyang, China



Radboudumc

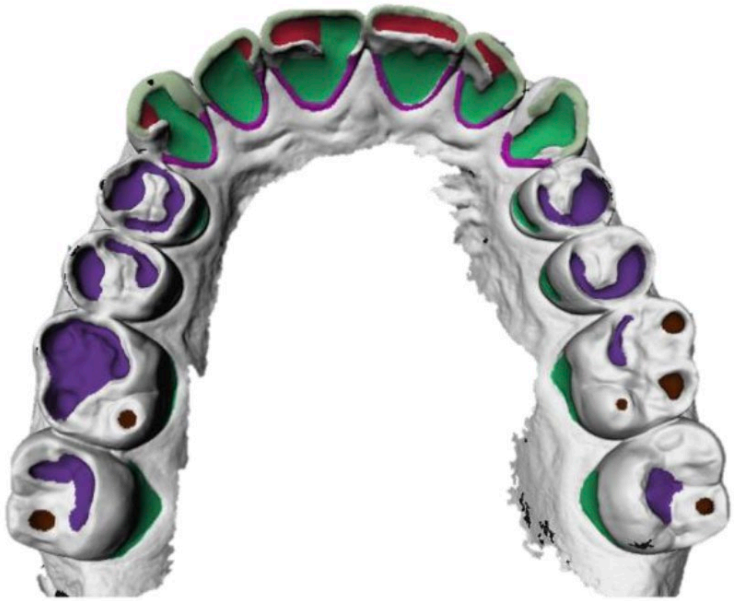
Qualitative evaluation of wear facets

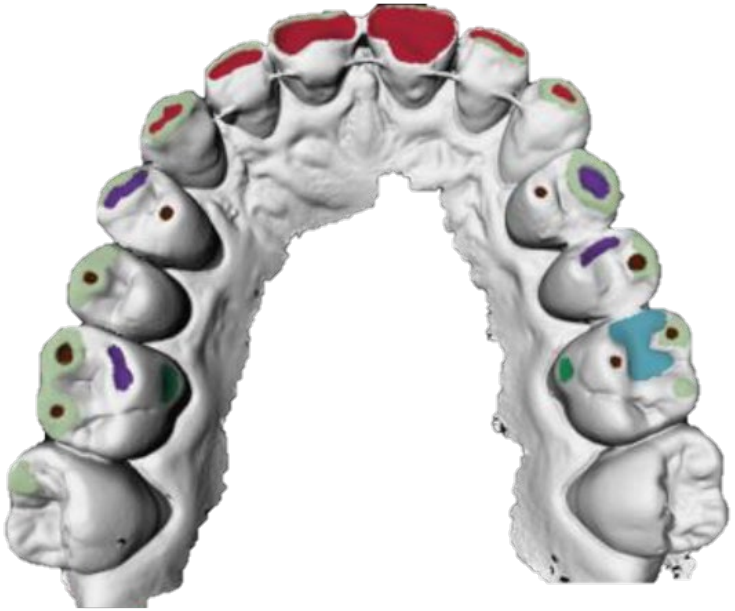


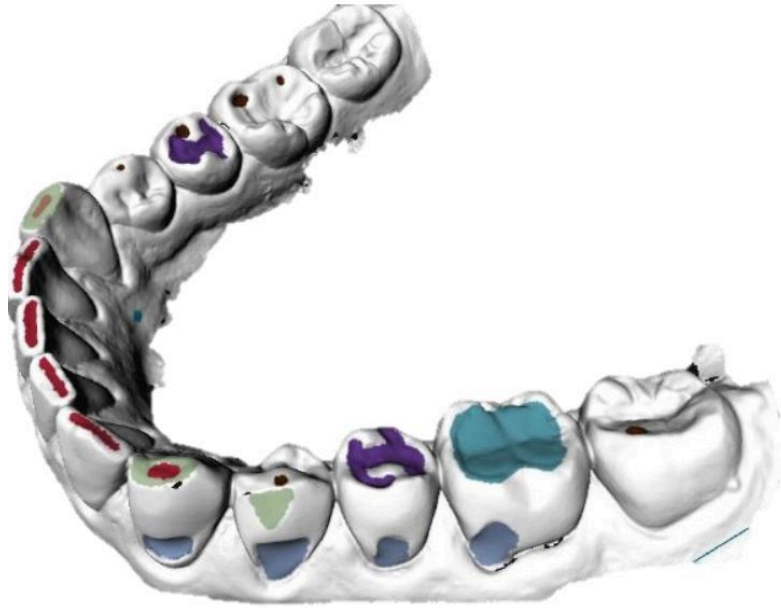
- Etiology often unclear
- Chemical and mechanical factors
- Multifactorial

Could this help in identifying the main causes of tooth wear?

Qualitative evaluation of wear facets







- Automatic detection of wear manifestations
- Next step(s): Link the progression of wear and survival of restorations
- Better prediction of the treatment
- **Individualised preventive advice**

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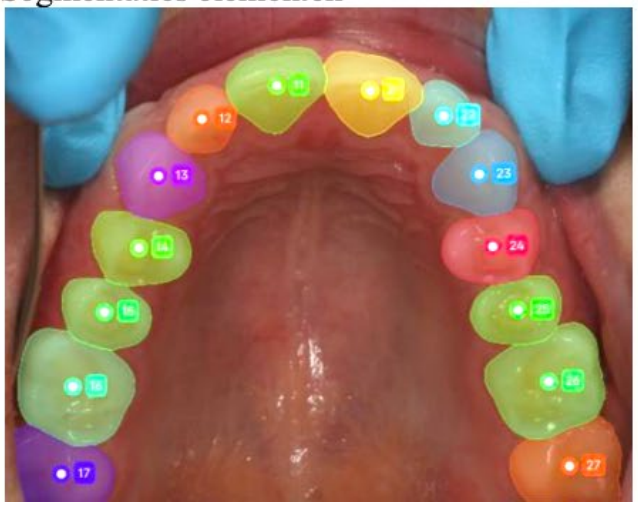
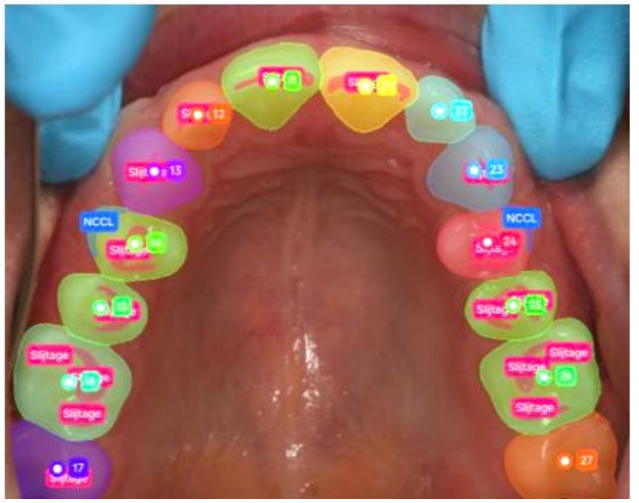
2D intra-oral images

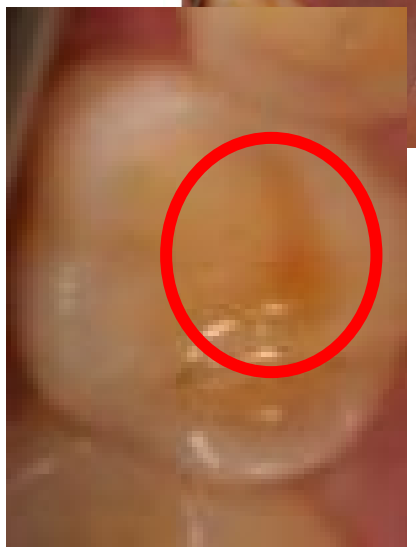
Input

Segmentaties elementen

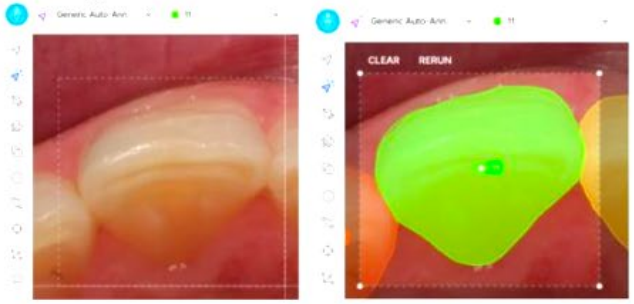


Resultaat

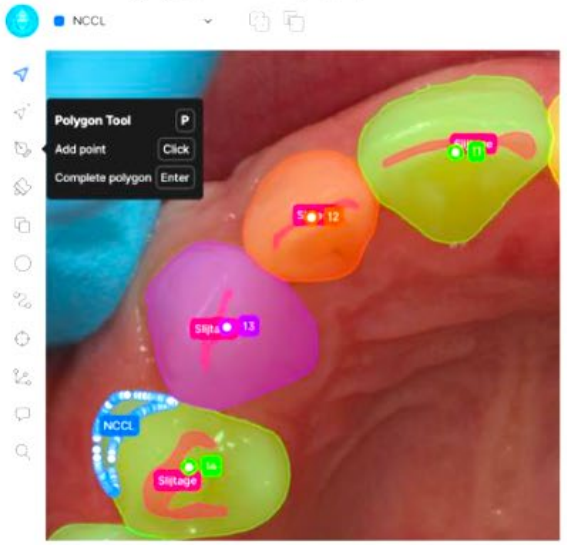




Auto-segmentatie



Annotatie slijtage; roze = slijtage, blauw = NCCL



Automated segmentation of teeth on 2D image

Automated annotations of tooth wear leasions

Detect progression over time

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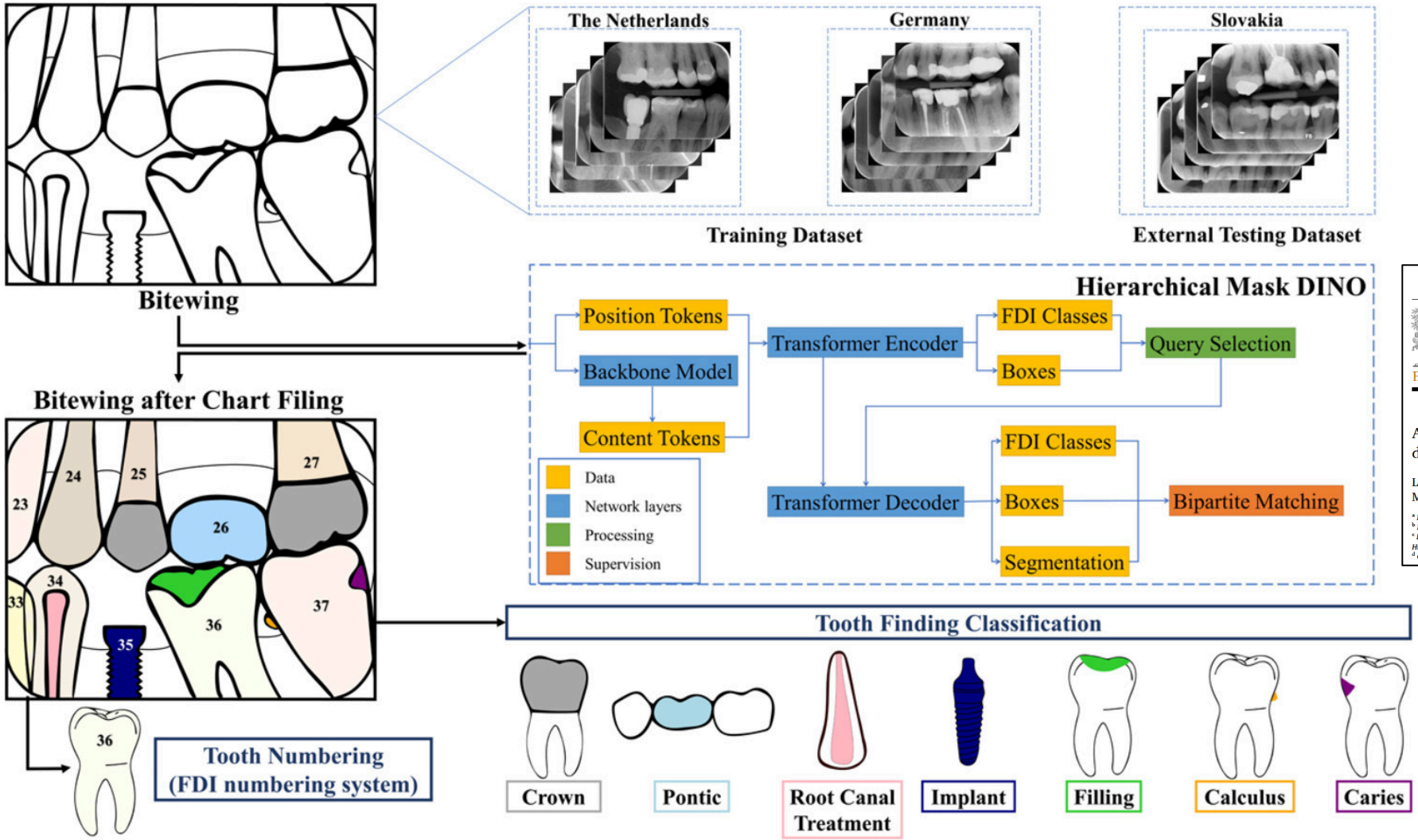
Automatic chart filling



Journal of Dentistry 161 (2025) 105919

Contents lists available at ScienceDirect

Journal of Dentistry

journal homepage: www.elsevier.com/locate/jdent

Automated chart filing on bitewings using deep learning: enhancing clinical diagnosis in a multi-center study*

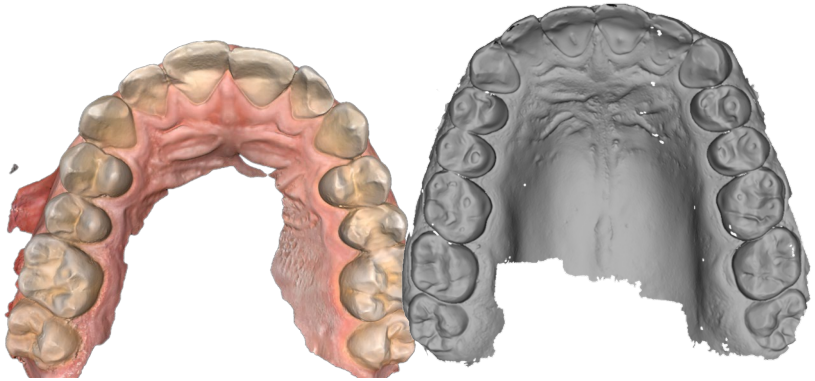
Lingyun Cao [a,1], Niels van Nistelrooij [b,c,1], Eduardo Trota Chaves [a,d], Stefaan Bergé [b], Maximiliano Sergio Cenci [a], Tong Xi [b,*], Bas Loomans [a], Shankeeth Vinayahalingam [b]

[a] Department of Dentistry, Research Institute for Medical Innovation, Radboud University Medical Center, Philips van Leydenlaan 25, 6525 EX Nijmegenthe Netherlands
[b] Department of Oral and Maxillofacial Surgery, Radboud University Medical Center, 6525 GA Nijmegenthe Netherlands
[c] Department of Oral and Maxillofacial Surgery, Charité – Universitätsmedizin Berlin, corporate member of Freie Universität Berlin and HumboldtUniversität zu Berlin, Hindenburgdamm 30, 12203 Berlin, Germany
[d] Graduate Program in Dentistry, School of Dentistry, Federal University of Pelotas, Pelotas, Brazil

Multi-modal system

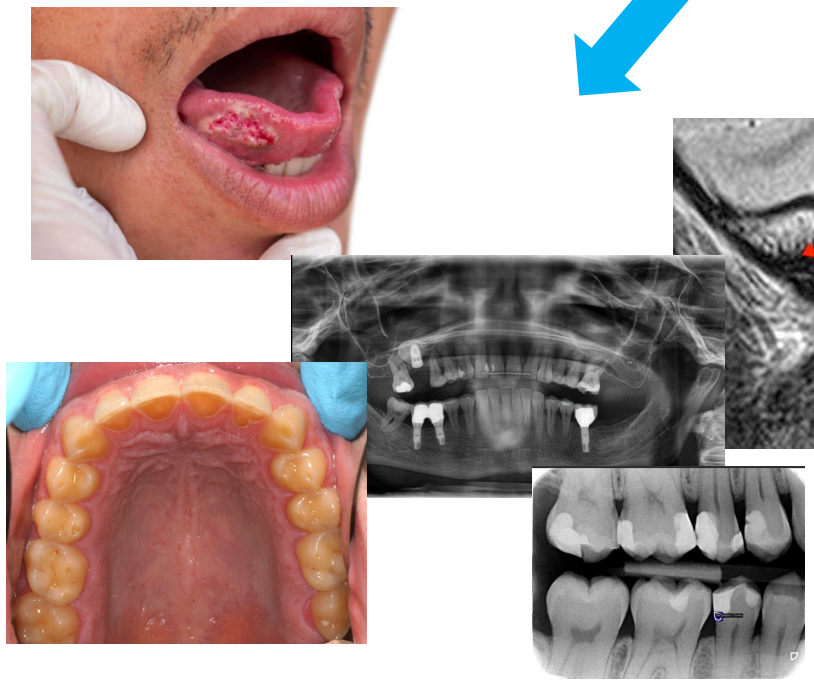
Develop:

- Prediction models
- Decision-support AI system



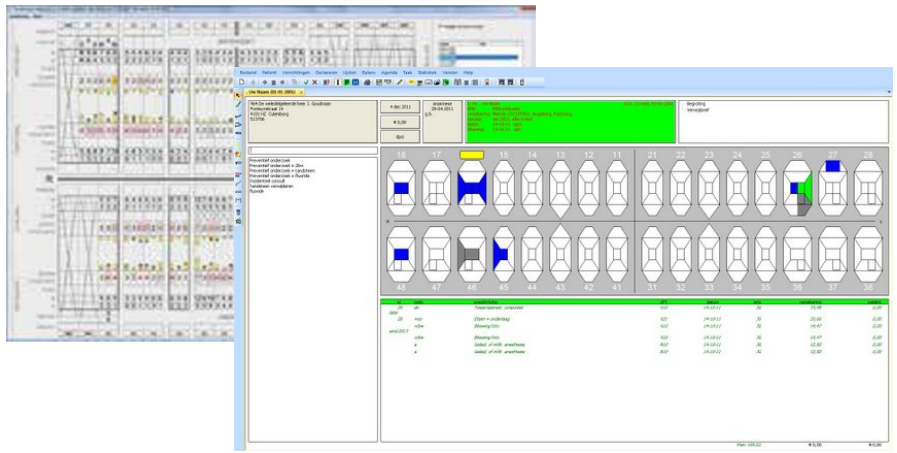
3D scans

PLY, STL, DCM, …



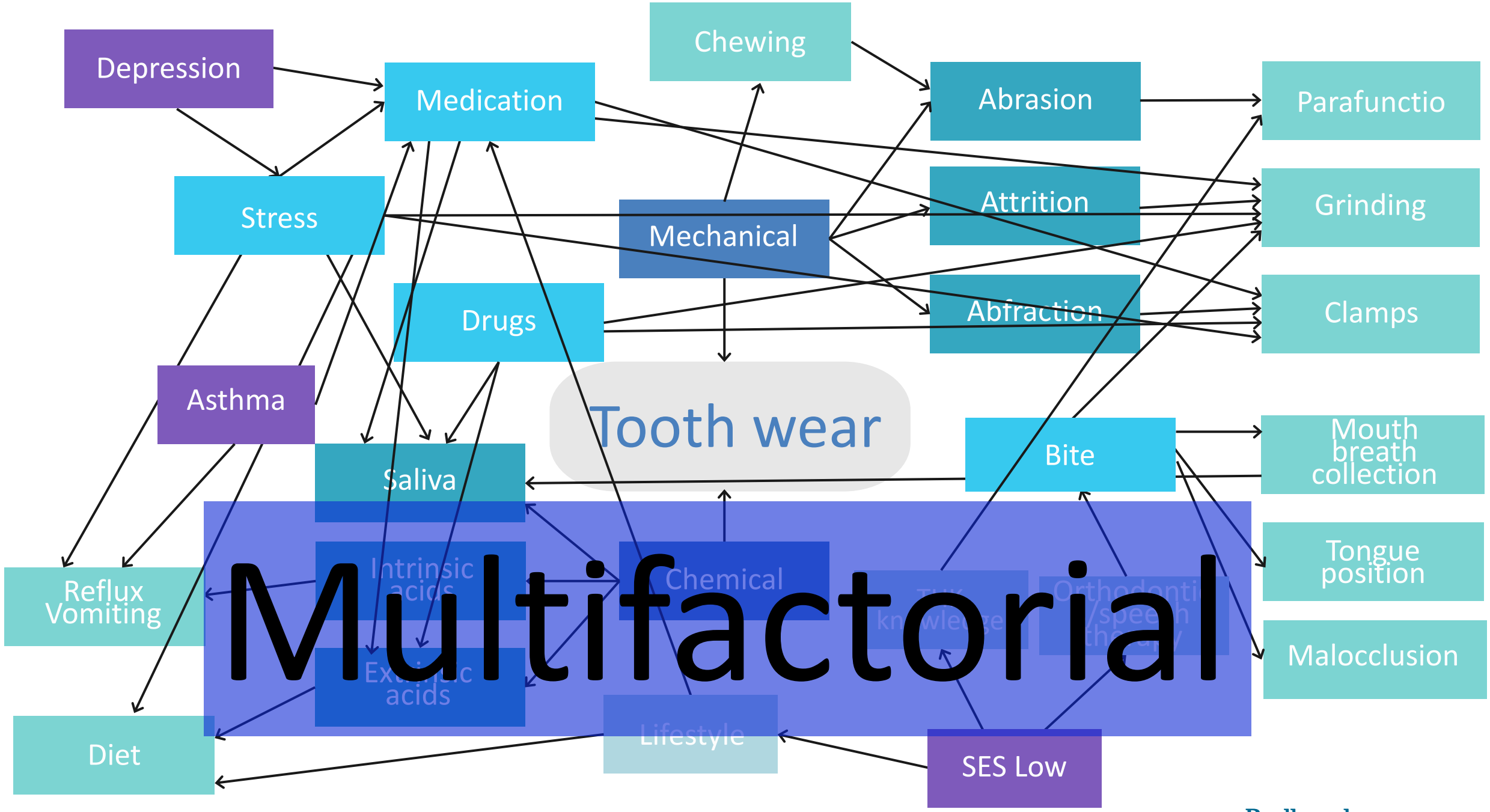
2D-photos, x-rays, MRI, echo?

JPEG, TIFF, ...



EPR

TXT, XLSX, DOCX, …


Depression
Medication
Chewing
Abrasion
Parafunctio
Stress
Attrition
Grinding
Mechanical
Drugs
Abfraction
Clamps
Asthma
Tooth wear
Saliva
Bite
Mouth breath collection
Reflux Vomiting
Intrinsic acids
Chemical
Tongue position
Extrinsic acids
Malocclusion
Diet
Lifestyle
SES Low
Multifactorial

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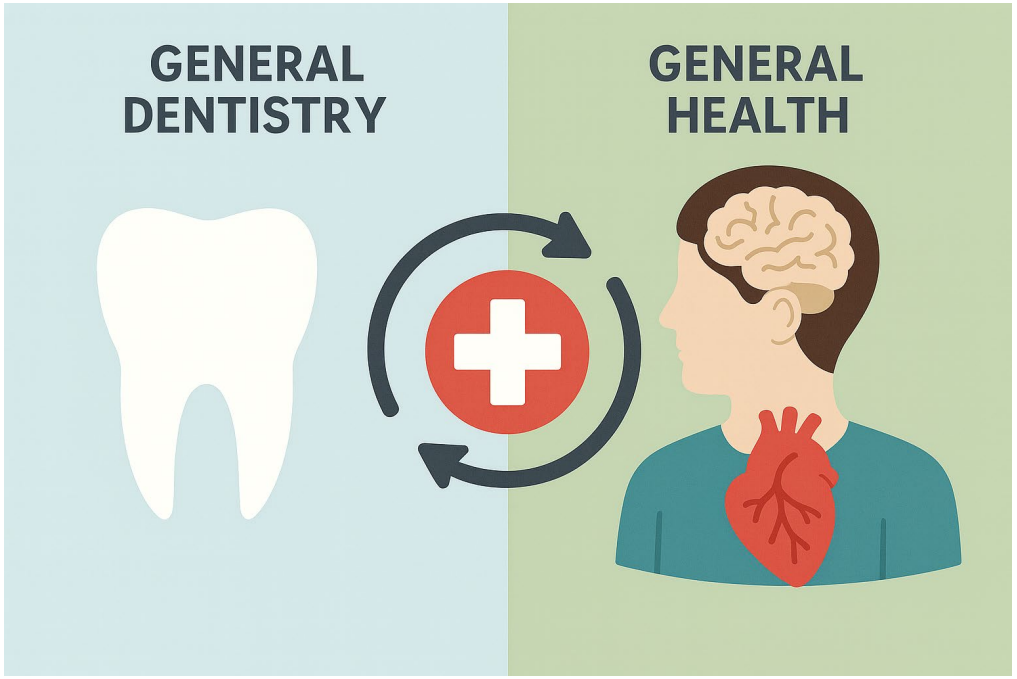
Orofacial Health

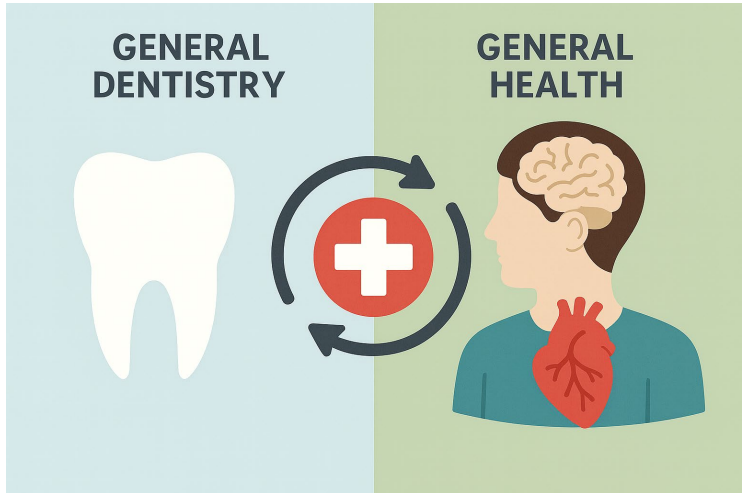


Vision:

To develop innovative solutions for orofacial health(care) problems and to contribute to a future in which everyone has optimal orofacial health.

Radboudumc

Can we transform longitudinal 3D intraoral scans from digital impressions into quantitative biomarkers of oral health and use them, together with multimodal patient data, for prediction and clinical decision support?



"3D IOS as a longitudinal digital biomarker"

Automated Chart Filling in General Dental Practice

From fragmented data → structured information → better clinical decisions

Dental X-rays (radiographs)
2D, CBCT

3D scans
Intraoral scans (STL/PLY)

2D images
Intraoral and extraoral photographs

Text from patient file
Clinical notes
Medical history
Previous treatment
Letters, referrals

Patient-specific risk factors
E.g. caries risk, periodontal risk, tooth wear, lifestyle, systemic health

Known risk factors ... → ? *... and many are still unknown*

AI PROCESSING & INTEGRATION

- Data extraction and interpretation
- Multimodal integration (X-ray, 3D, 2D, text, risk factors)
- Risk assessment and trend analysis
- Alignment with national guidelines
- Structured output for the patient record

AI

Dentist reviews & validates
Human judgement remains essential

Electronic Patient Record (EPR)

Structured. Relevant. Actionable.

Patient overview
Age: 42 ♂
Recall: 6 months
Risk profile: Moderate

Key findings (AI-assisted)
- Caries lesion 16 (R2)
- Initial enamel wear 11, 21
- Bone level reduction distal 36
- Worn restorations 46, 47
- No periapical pathology detected

Alerts / attention
- Increased caries risk
- Monitor tooth wear
- Recall according to guideline

Visual record
X-rays | 3D scan | Photos

Tooth chart (auto-filled)

Risk profile
Caries risk
Periodontal risk
Tooth wear risk
Peri-implant risk

Trends over time

Suggested next steps (based on guideline)
- ☑ Preventive measures
- ☐ Monitor (6 months)
- ☐ Consider minimally invasive treatment 16
- ☐ Patient counselling (diet, hygiene)

1. Accurate & complete record keeping

- Automatically structured and standardised
- All relevant information in one place
- Improved continuity of care

2. Decision support & prediction in general dental practice

- Evidence-based and guideline-aligned
- Early detection and risk prediction (with uncertainty)
- Supports personalised and preventive care

Aligned with national guidelines & professional standards

Routine dental checkup in 2035 ?

- Routine scanning
- Chair-side integrated 2D-photos, 3D-scans, x-rays, infrared in the EPR

- Software-based analysis of light and radiographic data:
  - Periodontal state
  - Caries detection, progression and risk
  - Dento-facial discrepancy (orthodontics)
  - Tooth wear detection and progression
  - Surgical planning
  - Detection and classification of oral diseases

- **Clinical decision and prediction models**
  - GCP, guidelines, and professional supervision

Routine digital dental checkup in 2035 !

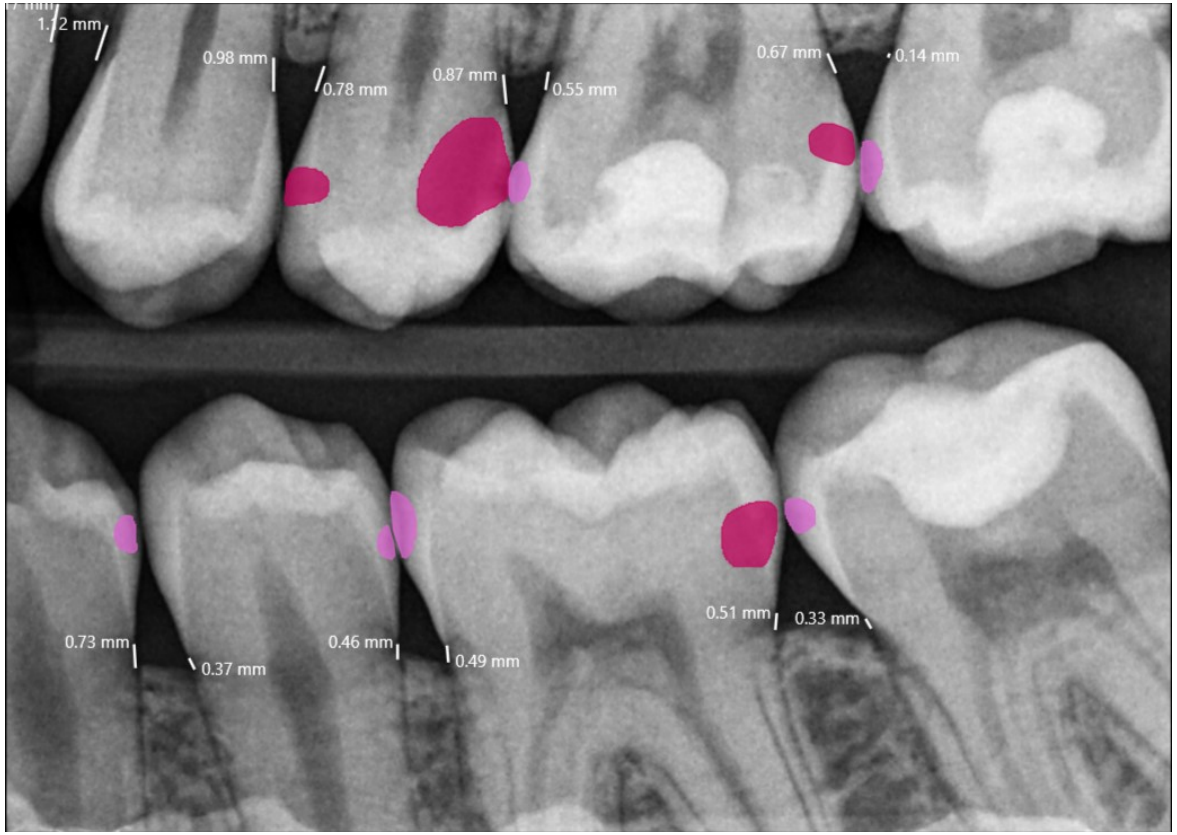
Home-based monitoring?

Legal considerations

Who makes the decisions?

Different role of the dentist/oral surgeon!

AI in dental image diagnostics



Caries Research

Review Article

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Assessing the Role of Artificial Intelligence in Caries Detection and Clinical Decision-Making: A Scoping Review

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Aim

1

Caries detection

Accuracy in identifying caries lesions

2

Treatment decisions

Choice of treatment for each proximal surface

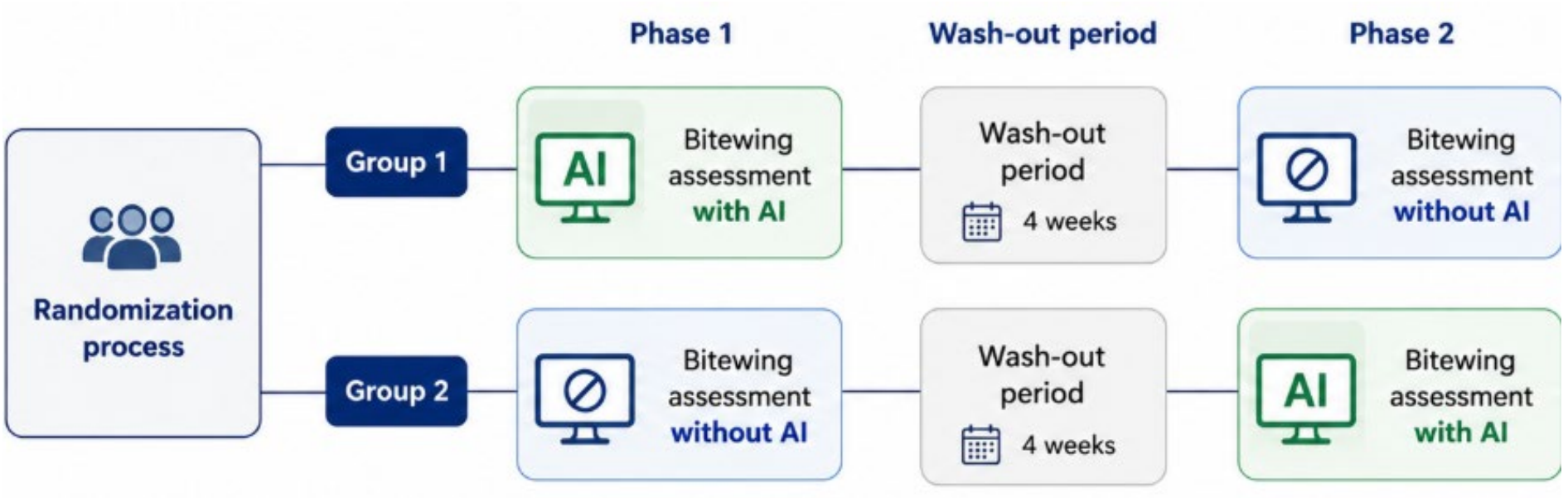
3

Confidence

Self-reported confidence in their decisions

Unpublished results

Study design



Surfaces n=2679

Participants n=19

Study design

No caries

Enamel

Outer dentin

Middle/inner dentin

No treatment | Non-invasive treatment | Restoration

Strongly insecure (1) to strongly confident (5)

Caries detection

Dentin+ threshold	Without AI	With AI	Adjusted effect of AI
Sensitivity	83.2%	95.0%	OR 6.7 95% CI 3.39-13.23 p<0.001
Specificity	92.4%	86.6%	OR 0.32 95% CI 0.24-0.43 p<0.001
Accuracy	91.0%	87.9%	OR 0.60 95% CI 0.48-0.77 p<0.001

Treatment decision

	Without AI	With AI	Adjusted effect of AI
Unsupported restoration	6.0% (153/2565)	9.7% (249/2565)	OR 2.86 95% CI 2.13-3.85 p<0.001

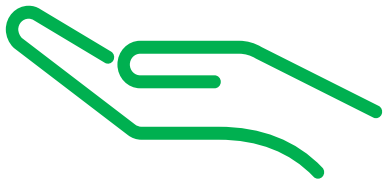
Summary

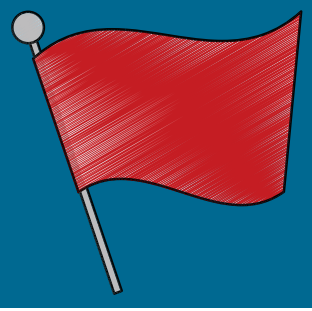
Higher sensitivity

Greater confidence

More false positives

More unsupported invasive treatment



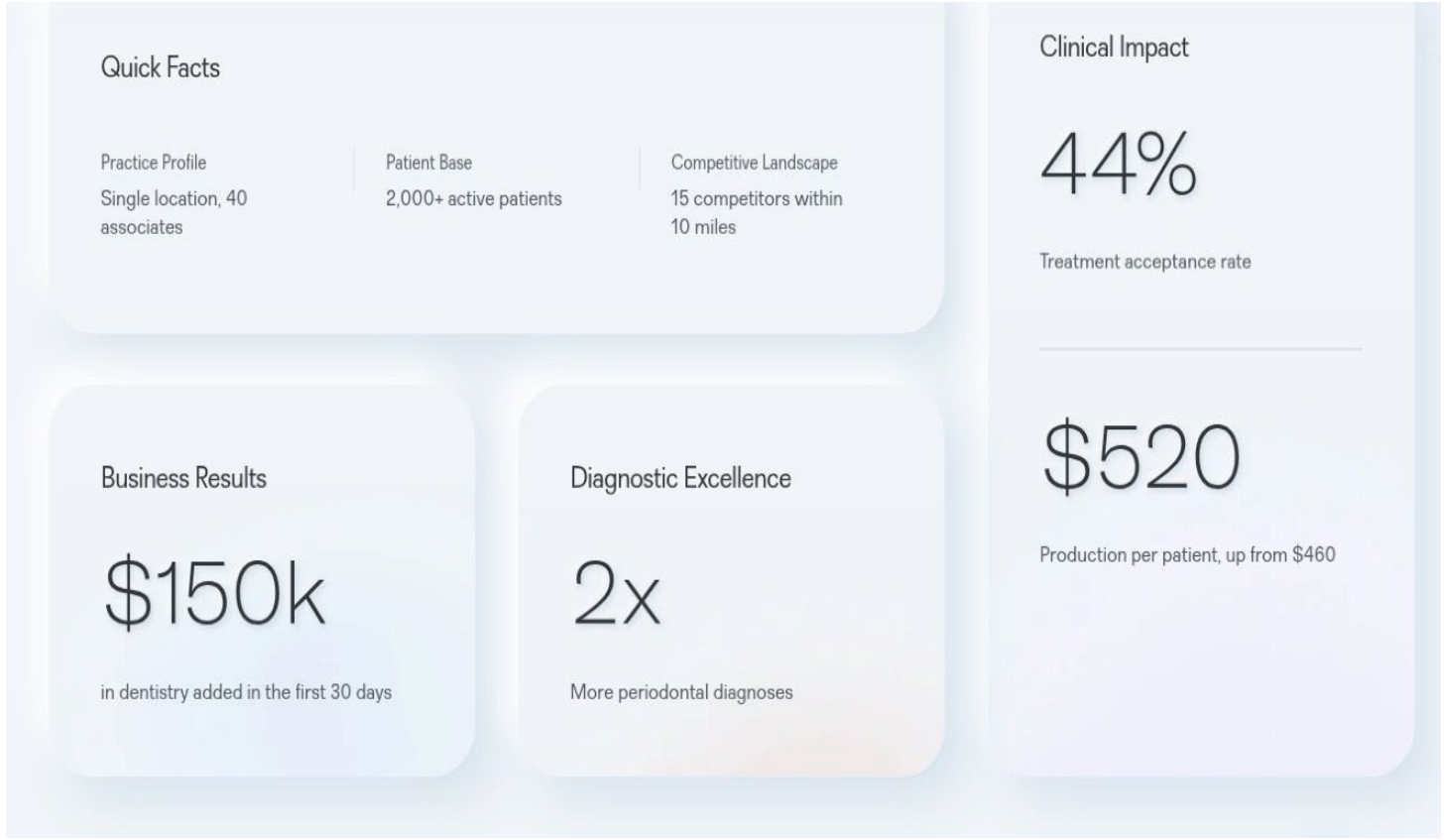


Overdiagnosis
Overtreatment

Dentists find it difficult to deal with uncertainties

The more we see, the more we do…

My aim in using AI-supported systems is to improve the quality, equity, and efficiency of (dental) healthcare



The Impact

Pearl's colour-coded radiograph overlays replaced drawn-on annotations, making it easier for patients to understand *and simpler for clinicians to align on.* Treatment surged — **57% more care was delivered after Pearl than before**.

As a result, Pearl drove double-digit growth across every major procedure:

- Hygiene: 58%↑
- Filings: 56%↑
- Crowns: 60%↑
- Root Canals: 56%↑

$150,000

Additional dentistry in the first 30 days, according to Pearl.

$460 → $520

Reported production per patient increased from 37% to 44%.

Case-study evidence

No guarantee of the same result in another practice.

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Case-study evidence

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AI-support systems: Informed consent?

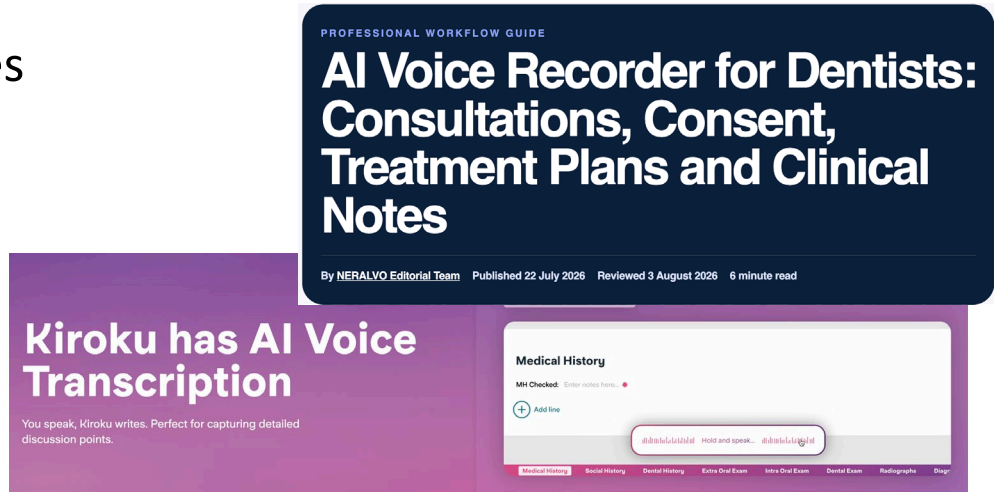
- AI-support systems will transfer (anonymous) data for processing the image
  - Is an X-ray or a 3D scan without name and date of birth really anonymous?

- What must we do with all the flagging of cavities on X-rays?
  - Should we for legal reasons comment each flag in our EPR?

- First law-suite of patients who don't want their data to be sent to AI systems

- What about voice-recording systems?
  - Long pieces of text, difficult to check on 'small' mistakes

- ***Do we oversee all the legal and ethical aspects of this?***



Let’s use AI’s potential

1. Education
- Enhances radiographic interpretation
- Increases confidence during training

2. Clinical practice
- Improves lesion detection
- Supports more consistent diagnoses
- Complements clinical judgement

Caution
- Be aware of false-positive diagnoses
- Keep minimally invasive treatment in mind
- Combine AI support with clinical examination and patient risk assessment

Take Home Messages

- ✓ AI opens up a new world of possibilities…
  …but is the (dental) world ready for these changes?
- ✓ AI is a tool to achieve our goals — not a goal in itself.
- ✓ Develop AI algorithms based on real needs in (dental) healthcare.
- ✓ Train students and dental professionals to use AI-supported systems appropriately and critically.
- ✓ Invest in infrastructure, benchmarking, and high-quality international databases.
  - ✓ Make better use of algorithms already developed and bring them into clinical practice.
- ✓ Let’s strengthen our international collaboration.

Significant impact on (oral) health and healthcare

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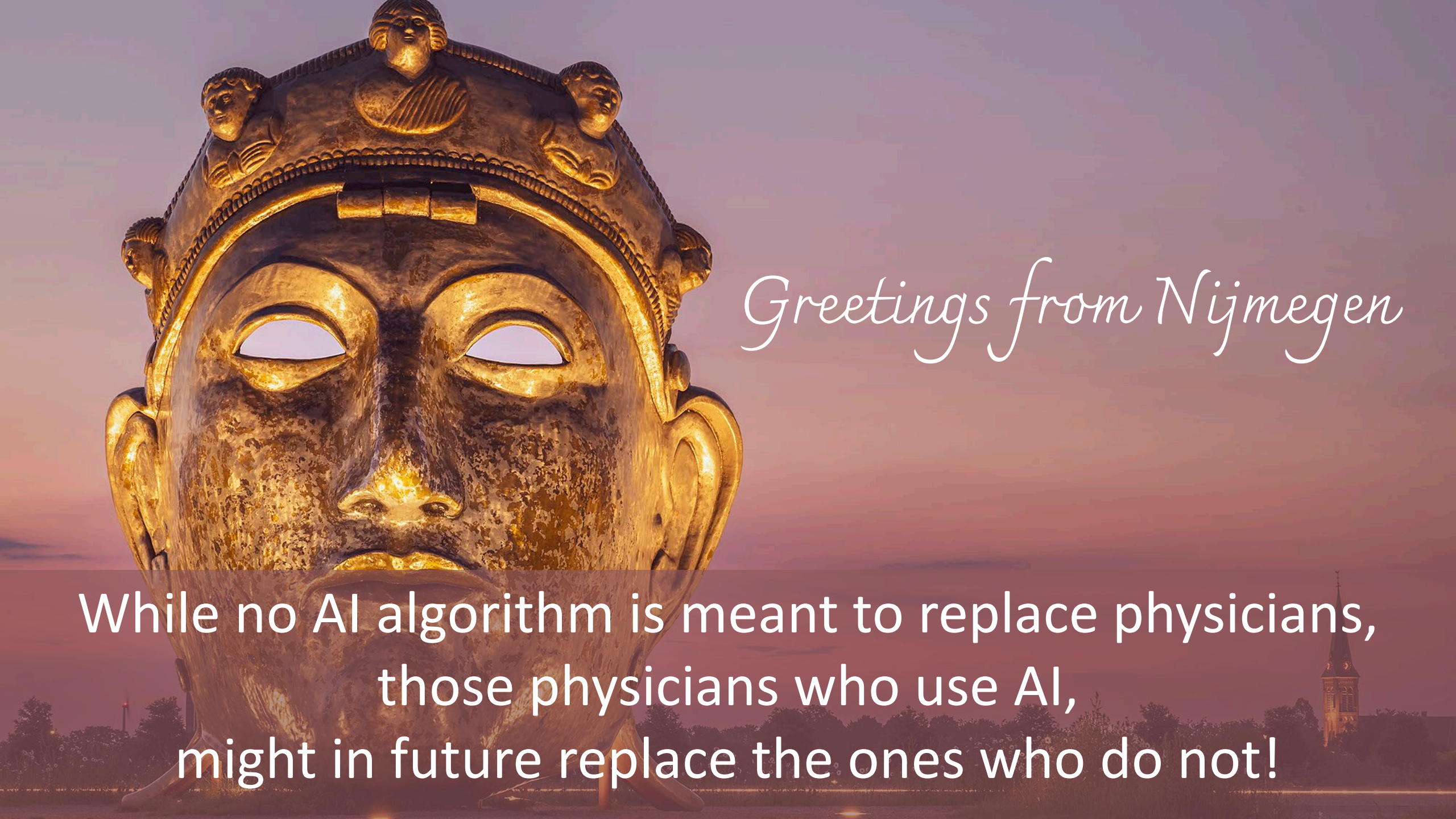

While no AI algorithm is meant to replace physicians,
those physicians who use AI,
might in future replace the ones who do not!