ODIN WORKSHOP · STRASBOURG · 27 SEPTEMBER 2026

Current and Future Applications of XR and AI in Dentistry

Roberto Mangano
MSc Computer Engineering
Digital Dentistry Society Certified Speaker

www.digital-dentistry.org

Digital
Dentistry
Society

Virtual Reality

Augmented Reality

AI Glasses

Mixed Reality

TODAY'S QUESTIONS

What can we do today with these technologies?

How to navigate the current market?

Where does AI fit into it?

Current and Future Applications of XR and AI in Dentistry

01

Key concepts

- AR / VR / MR
- How to navigate the current market

02

Current applications

- VR Training
- VR Simulation
- Virtual Desktop
- University education

03

Mixed Reality in Dentistry

- The HoloImplant case study

04

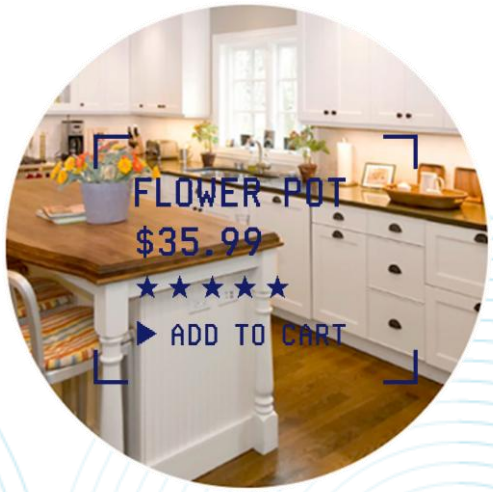
Dynamic Navigation with Mixed Reality

- In vitro and in vivo studies

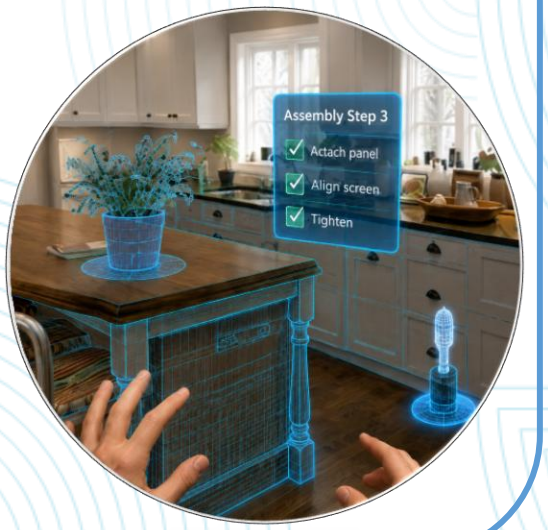
REALITY–VIRTUALITY CONTINUUM

AUGMENTED REALITY (AR)

REALITY



MIXED REALITY (MR)

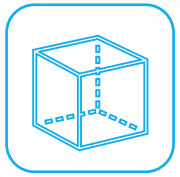


VIRTUAL REALITY (VR)

REALITY — EXTENDED REALITY CONTINUUM — **VIRTUALITY**

REALITY
What we see and experience naturally

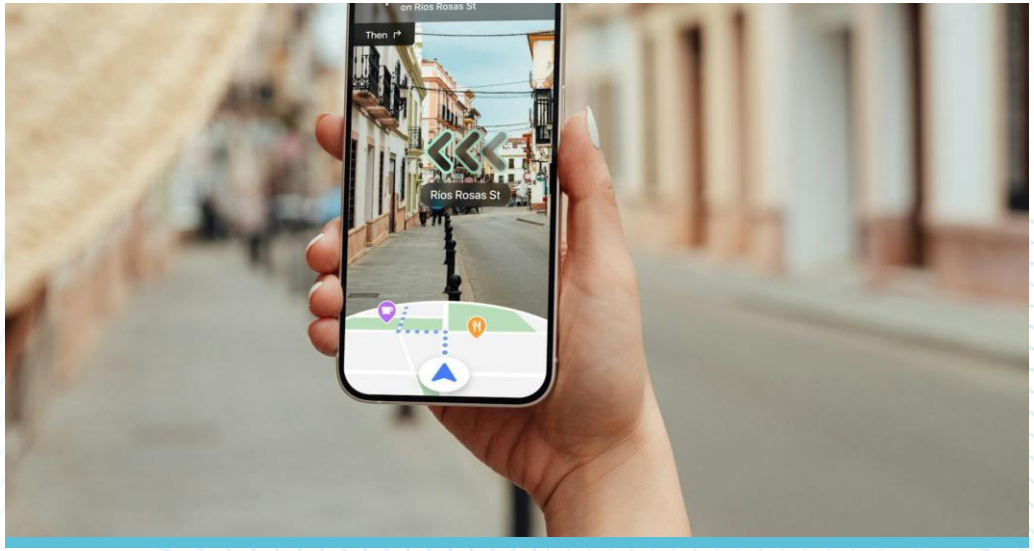
AUGMENTED REALITY
Adds digital information, images, text on top of the real world



MIXED REALITY
Digital objects exist and interact with the real world in real time

VIRTUAL REALITY
A complete immersive virtual environment with no real-world visuals

AR vs. VR: Key Differences



AR Augmented Reality

- Adds digital elements to a live view through a smartphone or AR glasses
- Interactive: overlays information onto the real world

VR Virtual Reality

- Immerses the user in a fully virtual environment, cut off from the real world
- Used for simulation, training and gaming

AR: See-through glasses

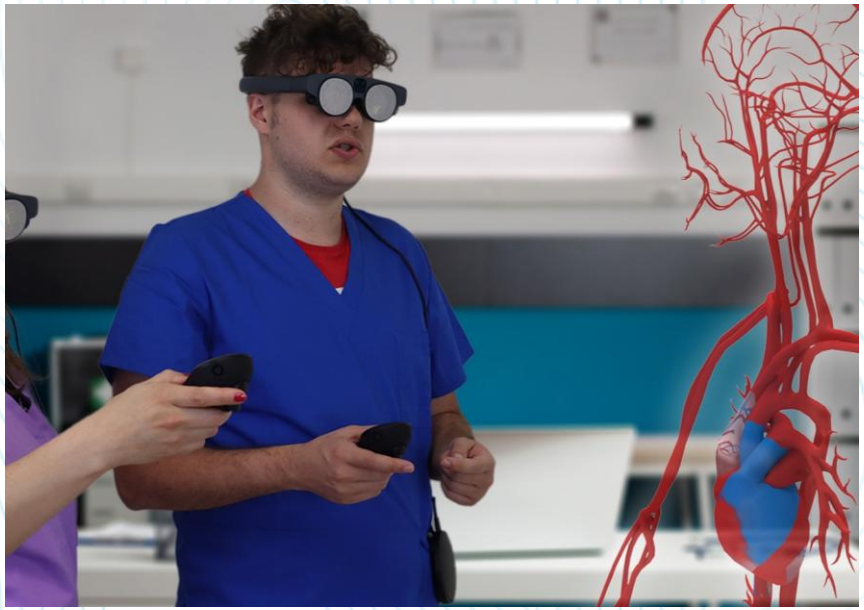
This technology allows users to see the real world directly through a transparent lens, onto which digital content is overlaid.

EXAMPLES

- HoloLens 2, Magic Leap 2, Xreal

ADVANTAGES

- Natural view of reality
- Lightweight and comfortable
- Limited brightness of virtual elements



Xreal

HoloLens 2

Magic Leap 2

AR/AI Glasses

Integrate AI for real-time understanding of the environment (pictures, videos), contextual assistance, and natural interaction through voice, vision and sensors.

EXAMPLES

- Ray-Ban Meta Smart Glasses, Alibaba Qwen, HTC Vive Eagle, Meta Display

FEATURES

- Computer Vision & AI integration (Gemini, OpenAI, Meta AI)
- Audio answers, automatic translation, music playback
- Always require internet connectivity
- Newer generations feature a display

Meta Ray-Ban

Meta Display AI Glasses

HTC Vive Eagle

TCL X2

AR: Pass-through headsets

Pass-through technology uses **external cameras** to capture the real world, which is then displayed on **opaque screens** inside a VR headset.

EXAMPLES

- Meta Quest, HTC Vive, Apple Vision Pro

ADVANTAGES

- Full control over displayed content
- Better integration of virtual and real
- Versatility and better contrast

Meta Quest 3

Apple Vision Pro

Meta VR

See-through vs. pass-through

APPLICATION SCENARIOS

See-through

Preferred where the real world must be seen clearly, without distortion

BEST FOR

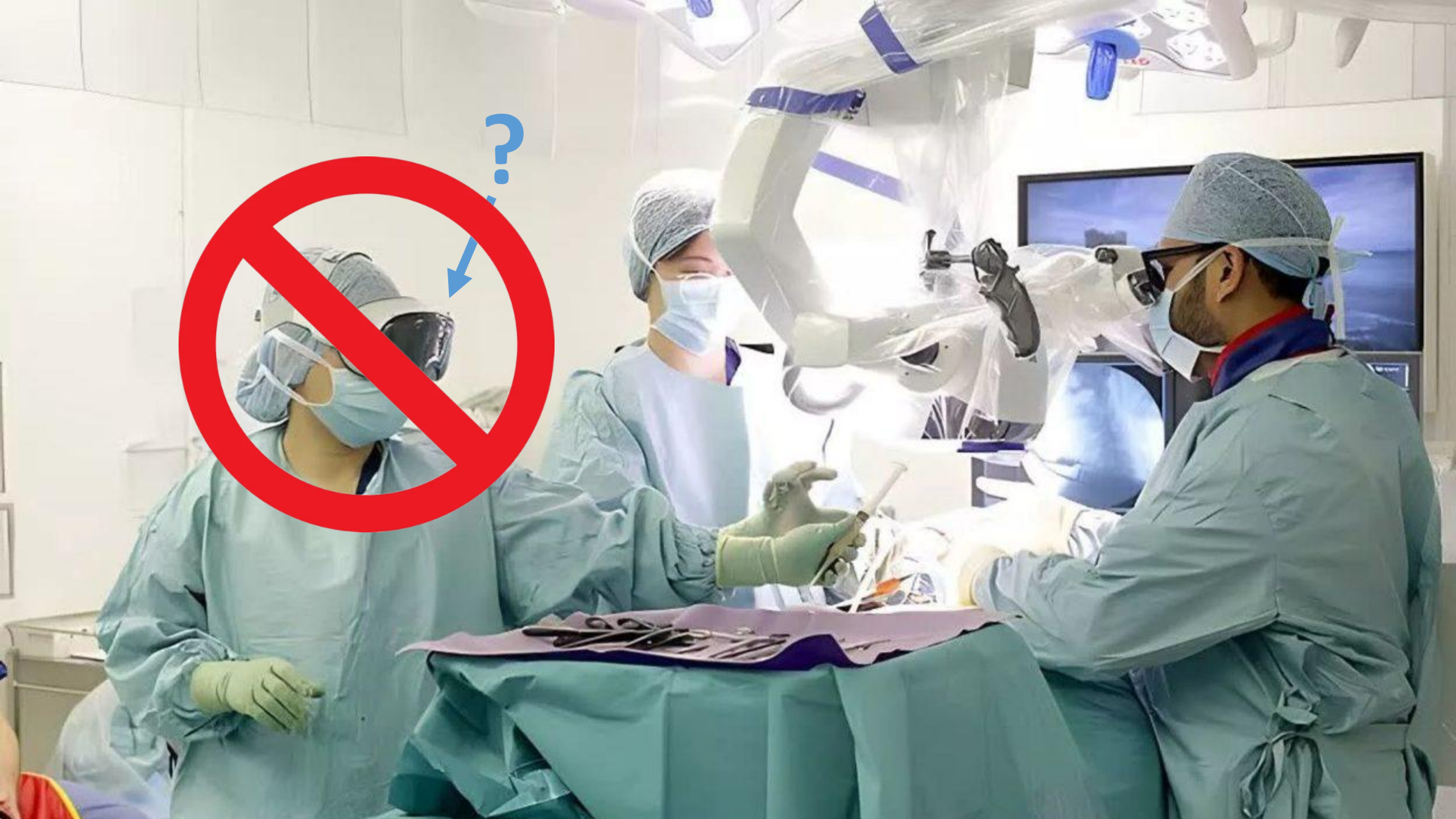
- **Medical AR**
- **Military**
- **Industrial applications**

Pass-through

Ideal for mixed reality that needs a seamless transition between AR and VR

BEST FOR

- **Training and simulations**
- **Immersive gaming**
- **Creative design**



Current and Future Applications of XR and AI in Dentistry

01

Key concepts

- AR / VR / MR
- How to navigate the current market

02

Current applications

- **VR Training**
- **VR Simulation**
- **Virtual Desktop**
- **University education**

03

Mixed Reality in Dentistry

- The HoloImplant case study

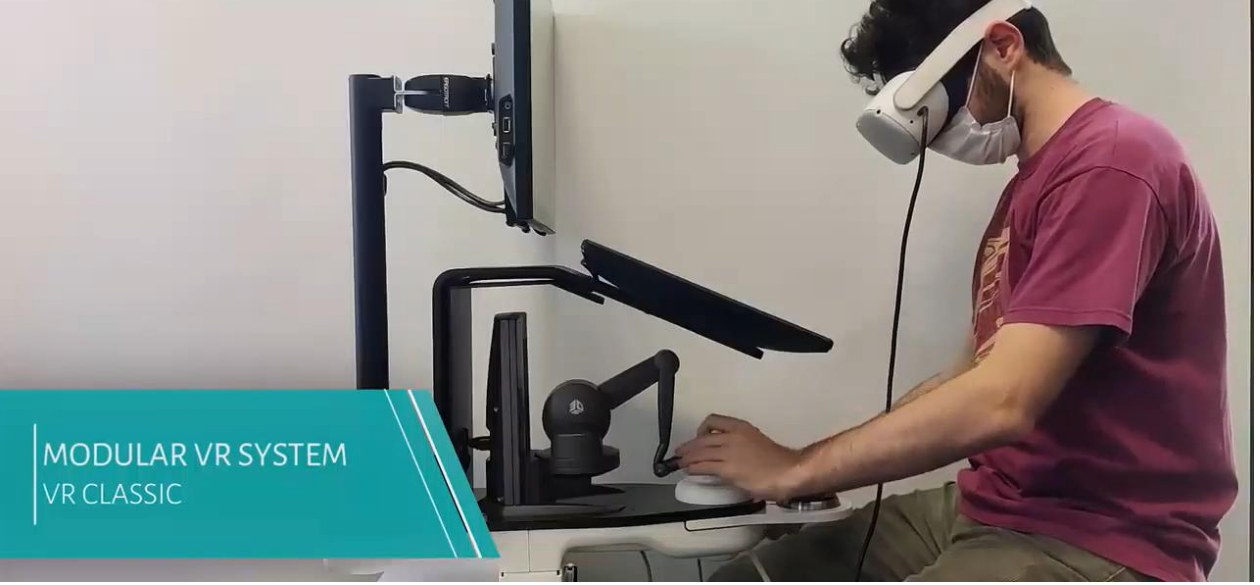
04

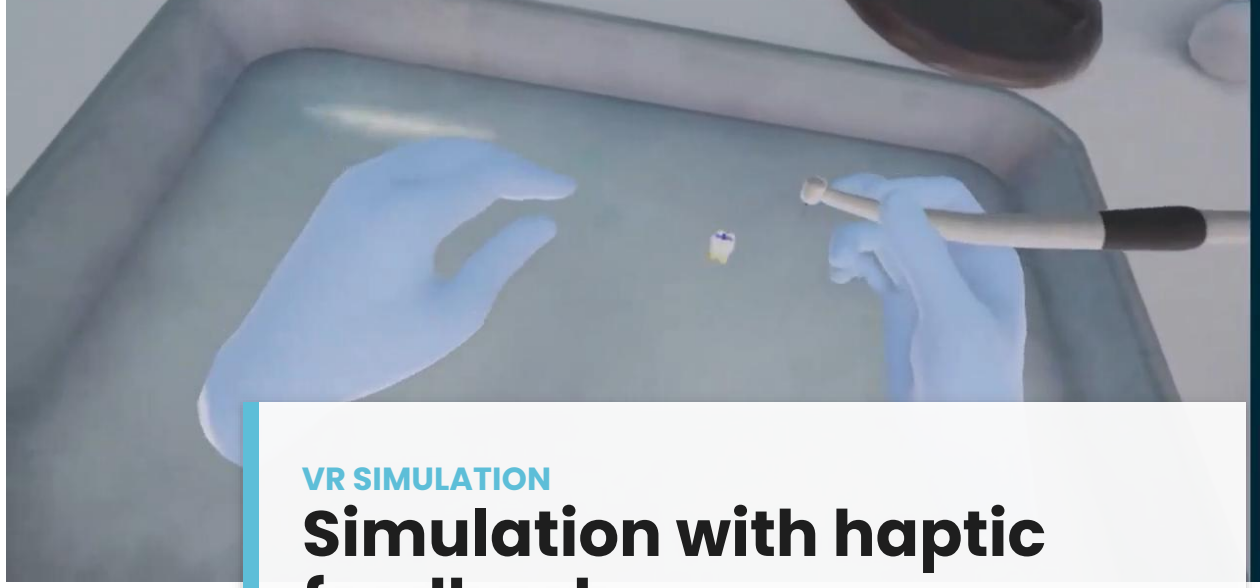
Dynamic Navigation with Mixed Reality

- In vitro and in vivo studies

VR TRAINING

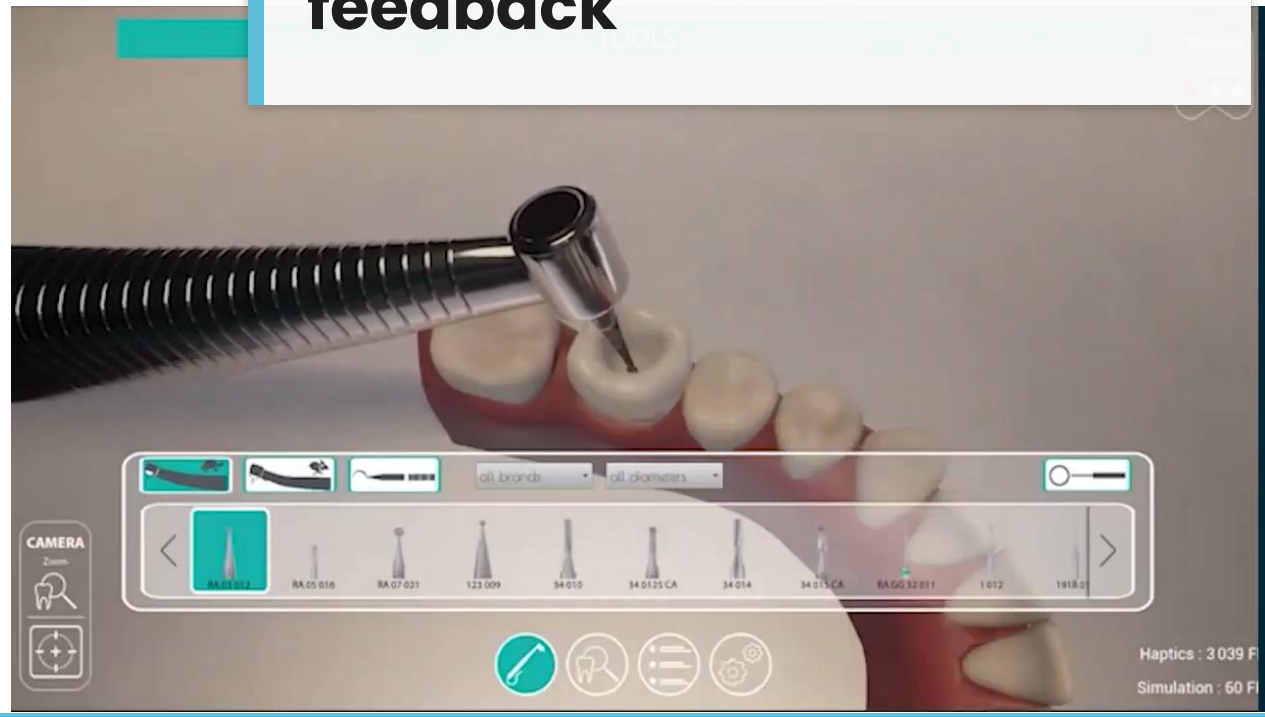
Life-saving procedures





VR SIMULATION

Simulation with haptic feedback



MIXED REALITY

Intraoral scanner + Virtual Desktop

TINALP

University education (Link)

The Digital Dentistry Ecosystem

#SCAN!
Data Acquisition
From real to virtual

- Intraoral Scanners (IOS)
- Face Scanners (FS)
- Cone Beam Computed Tomography (CBCT)
- Mandibular Motion Tracking

#PLAN!
Data Processing
Software & apps

- **Artificial Intelligence (AI)**
- **Virtual / Augmented / Mixed Reality (VR/AR/MR)**

#MILL! #MAKE!
Production
From virtual to real

- Milling units
- 3D Printers
- Selective Laser Melting (SLM)

#DONE!
Clinical Application
Chairside

- **Mixed Reality-based Dynamic Navigation**
- Robotics

Current and Future Applications of XR and AI in Dentistry

01

Key concepts

- AR / VR / MR
- How to navigate the current market

02

Current applications

- VR Training
- VR Simulation
- Virtual Desktop
- University education

03

Mixed Reality in Dentistry

- **The HoloImplant case study**

04

Dynamic Navigation with Mixed Reality

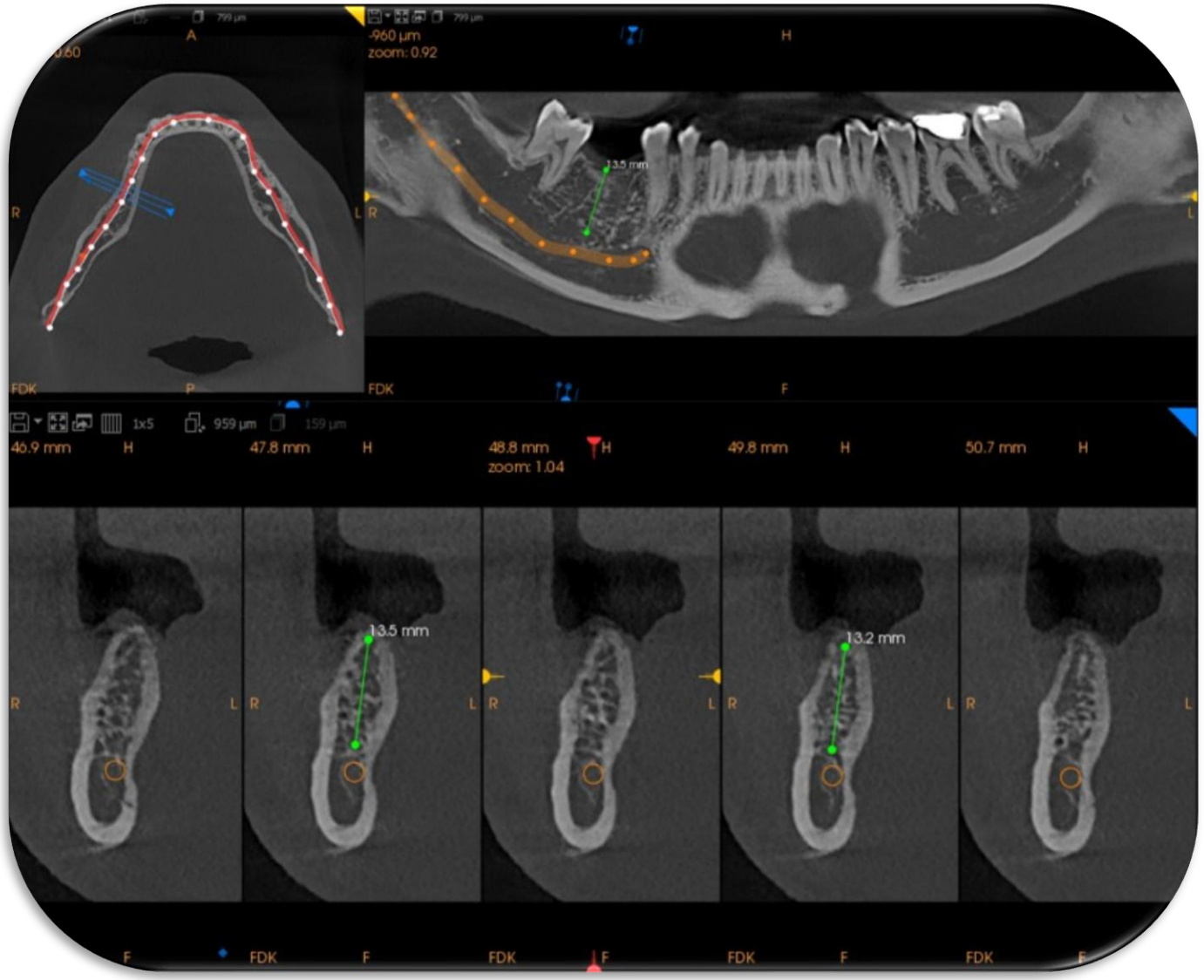
- In vitro and in vivo studies

Our Protocol

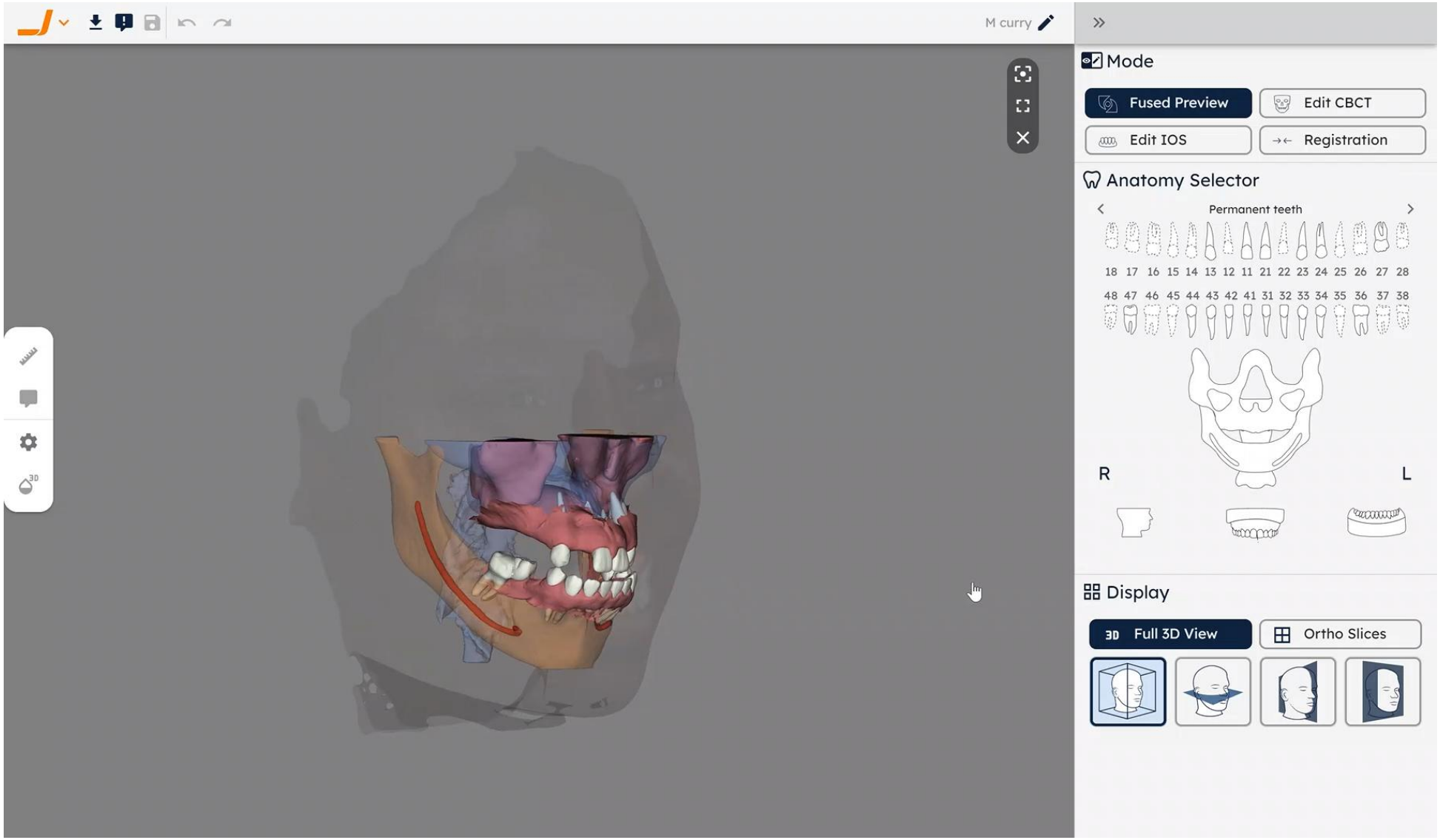
1. Intraoral Scan (IOS) + Cone Beam Computed Tomography (CBCT)
2. Artificial Intelligence (AI) for automated file alignment and segmentation
3. Virtual Diagnostic Waxing
4. **Implant Planning with Mixed Reality (MR)**
5. Case Validation Implant Planning Software (2D/3D)
6. Design and Fabrication of the Surgical Guide
7. Surgery on Patient
8. Prosthetic Phase: Intraoral Scan (IOS)
9. Computer-Assisted-Design (CAD) of Prosthetic Restorations
10. Delivery of the Prosthetic Restorations

F Mangano, K R Yang, H Lerner, O Admakin, C Mangano
Artificial Intelligence and Mixed Reality for Dental Implant Planning: a technical note
Clinical Implant Dentistry & Related Research, 2024;26:942–953

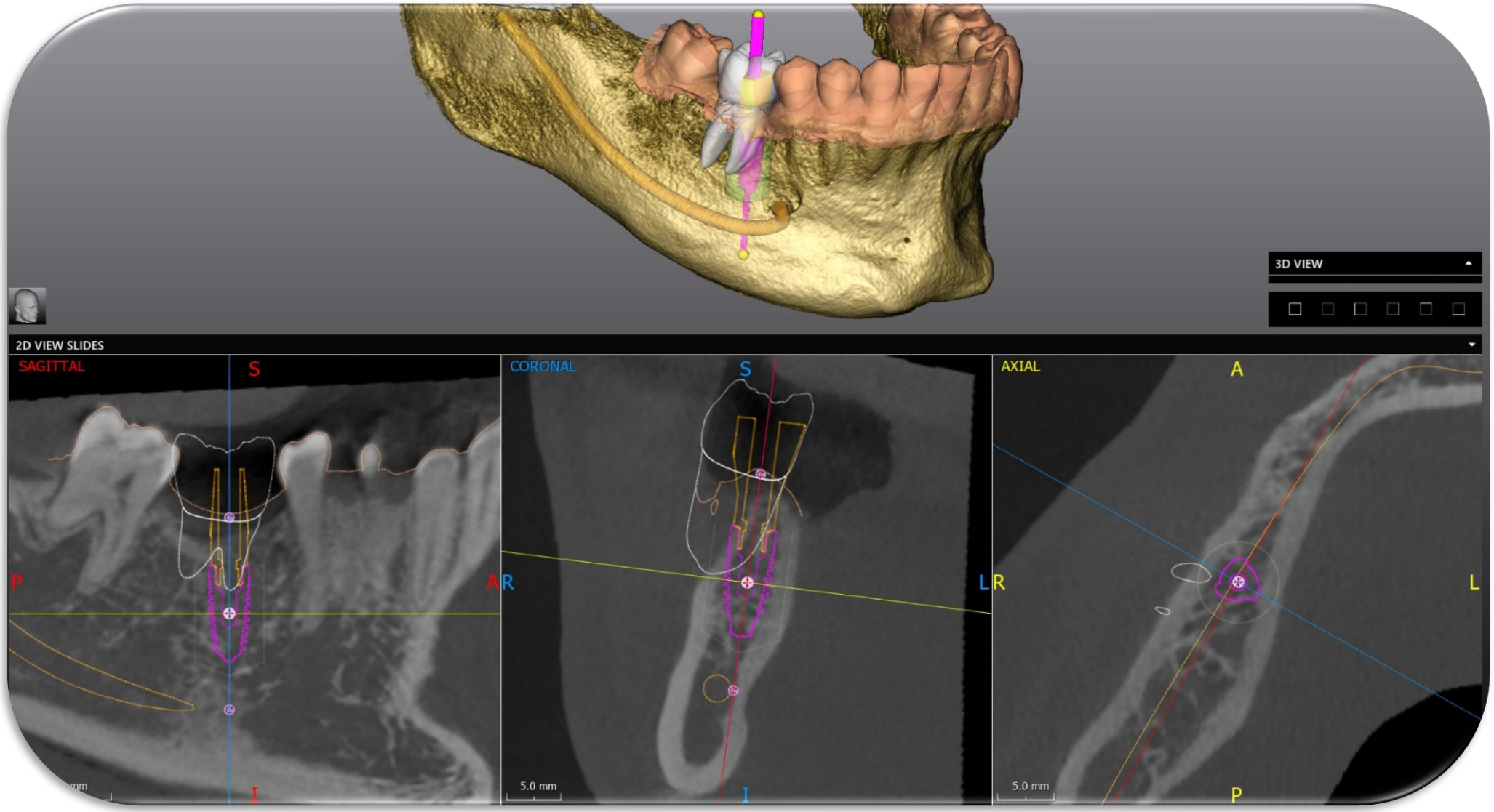
Cone Beam Computed Tomography (CBCT)



Relu segmentation & alignment



The standard process



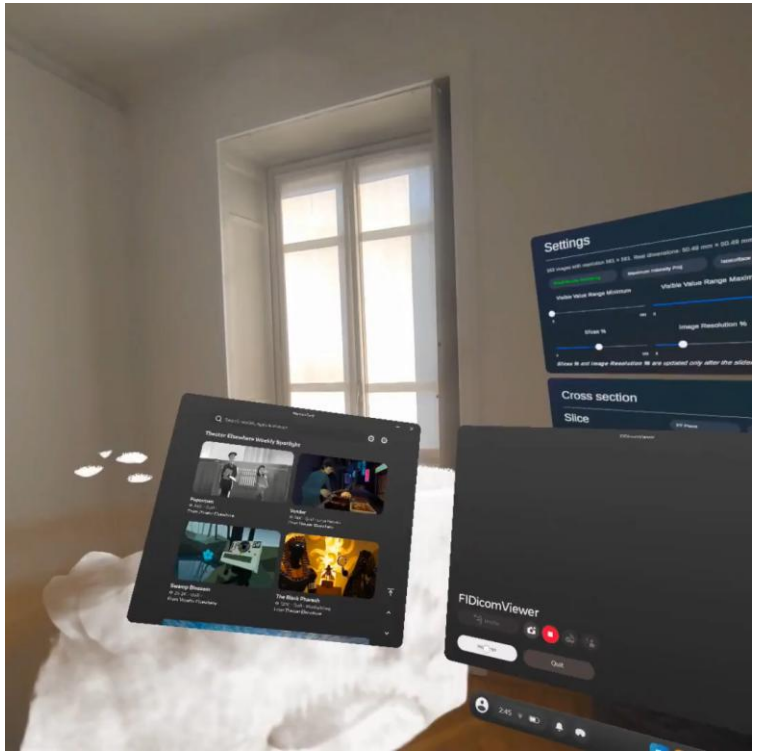
Implant Planning with Mixed Reality (MR)

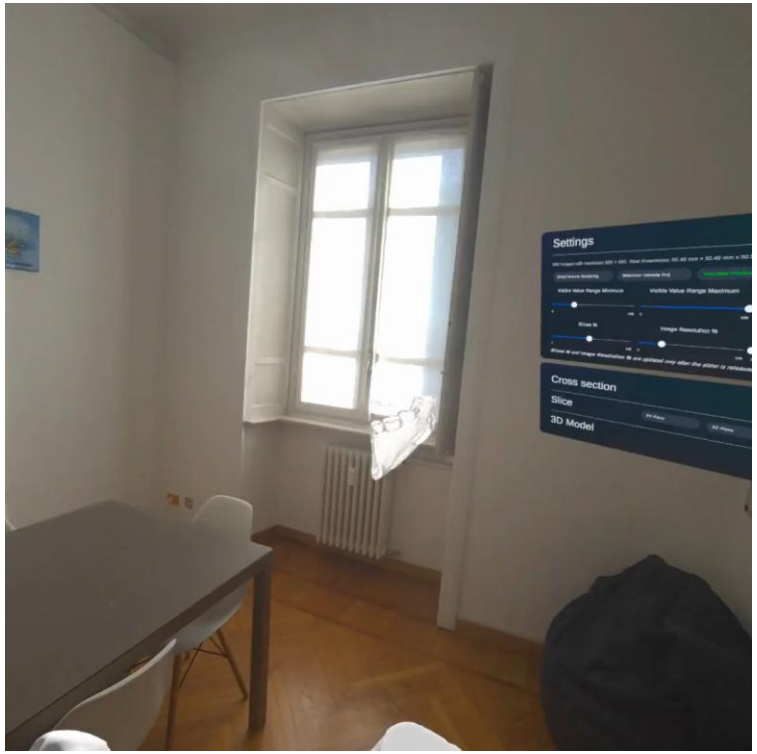
STEP 2B

The complete set of **STL files** is uploaded in the HoloImplant software

HoloImplant

Achieved results and research products in the period



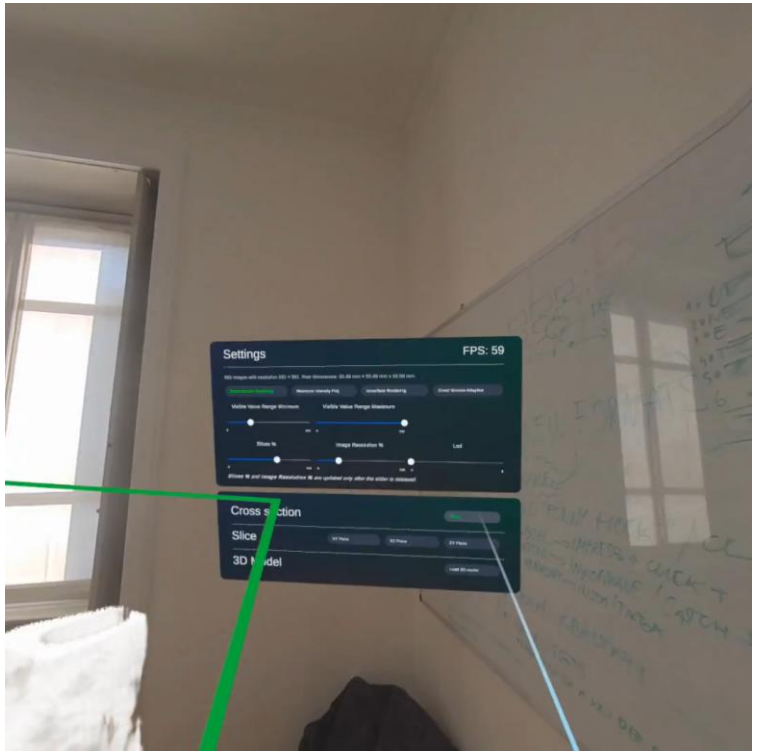


HoloImplant

FEATURES

- Multiple rendering modes for DICOM files
- Manage DICOM and 3D files at the same time

Development of XR-Optimized Rendering Techniques



HoloImplant

FEATURES

- Slicing planes to explore inside DICOM files
- Generate new slices to explore DICOM data
- Optimized AMV3D file for volume rendering

Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA
SAPIENZA UNIVERSITÀ DI ROMA

Scientific basis for our alignment and segmentation

Our IOS–CBCT pipeline is built on these peer-reviewed methods:

ALIGNMENT

Besl & McKay · IEEE TPAMI 1992
A method for registration of 3-D shapes
Original ICP: our automatic fit step

Chetverikov et al. · Image Vis Comput 2005
Robust Euclidean alignment of 3D point sets: the trimmed ICP algorithm
Trimmed ICP: robust when the scan covers only part of the CT

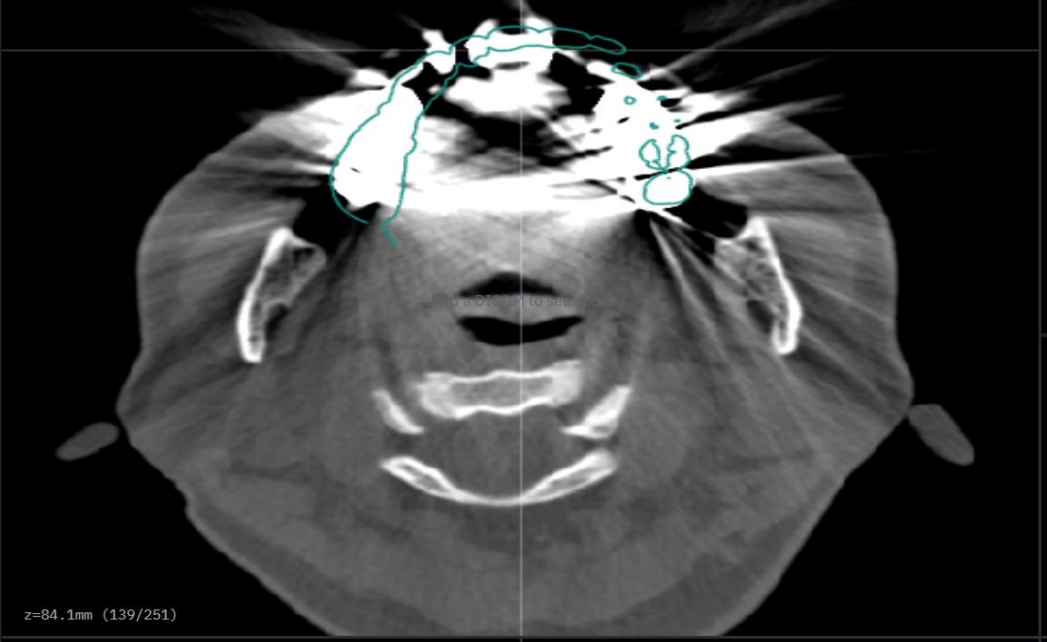
Horn · JOSA A 1987
Closed-form solution of absolute orientation using unit quaternions
Rigid fit from landmark pairs

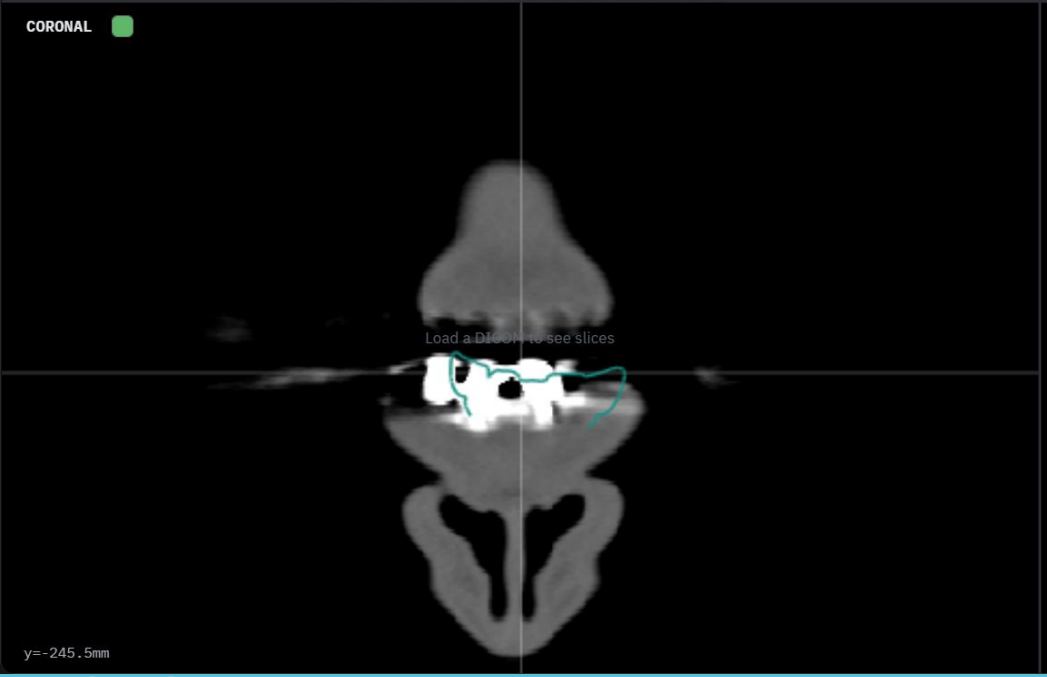
Flügge et al. · Clin Oral Implants Res 2017
Registration of CBCT data and intraoral surface scans: a prerequisite for guided implant surgery
Why registration accuracy matters clinically

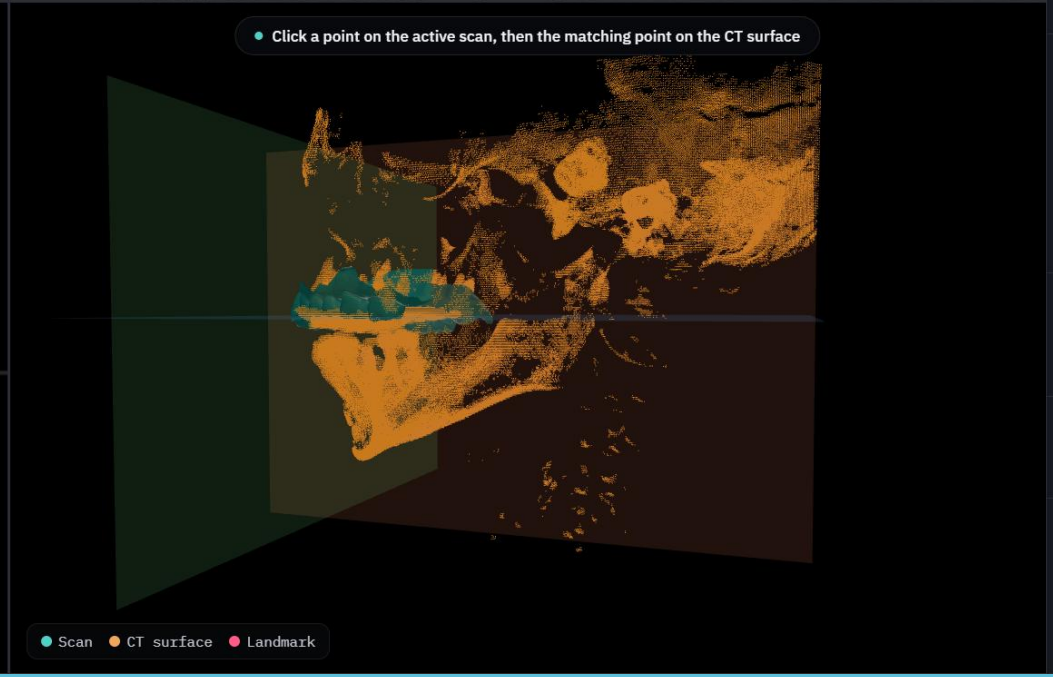
SEGMENTATION

Pauwels et al. · Dentomaxillofac Radiol 2015
CBCT-based bone quality assessment: are Hounsfield units applicable?
CBCT grey values are not true HU

Pauwels et al. (SEDENTEXCT) · Br J Radiol 2013
Variability of dental cone beam CT grey values for density estimations
Grey values vary across 13 CBCT devices, so one fixed threshold does not transfer







Load scan(s)...

STL, PLY, OBJ(+MTL+textures), GLB — select all files for one scan together.

Case 3_Maxilla_scan.stl (229,885 tris)

Load DICOM file...

Load DICOM folder...

251 slices, 512x512, spacing 0.352/0.352/0.500mm

LAYERS

CT surface (3D view)

Point size

HU threshold

1500 HU — 183,154 points

Window center

Window width

Cut planes (3D)

PICK LANDMARKS (ACTIVE SCAN)

Click a point on the **active scan** (3D view), then the matching point on the **CT surface**. Repeat for at least 3 pairs for a stable fit.

Undo last click

Clear all pairs

PAIRS (0)

No pairs yet.

LANDMARK FIT (REFERENCE)

Pick at least 3 pairs to compute a fit.

MANUAL TRANSFORM (ACTIVE SCAN — THE REAL ANSWER)

Mean distance, scan → CT surface: 1.537 mm (2360/2508 sample pts matched)

State of the art: the Relu process

01
Segment the CBCT
A 3D U-Net segments the jaw bones and labels each tooth individually.

39 s vs 133 min manually [1,2]
Dice 92.6% (bone)

02
Isolate the crowns
Crowns are segmented before matching, so metal artefacts from restorations are ignored.

0.03 mm surface deviation [3]
Dice 0.91, heavy artefacts

03
Register IOS onto CBCT
The intraoral scan is fitted automatically onto the segmented teeth.

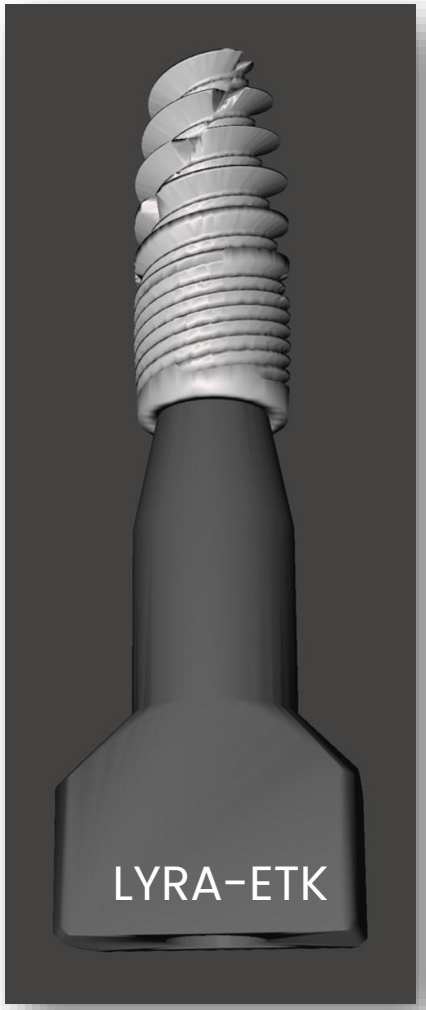
51 s, median 0.04 mm [4,5]
7.3× faster than experts

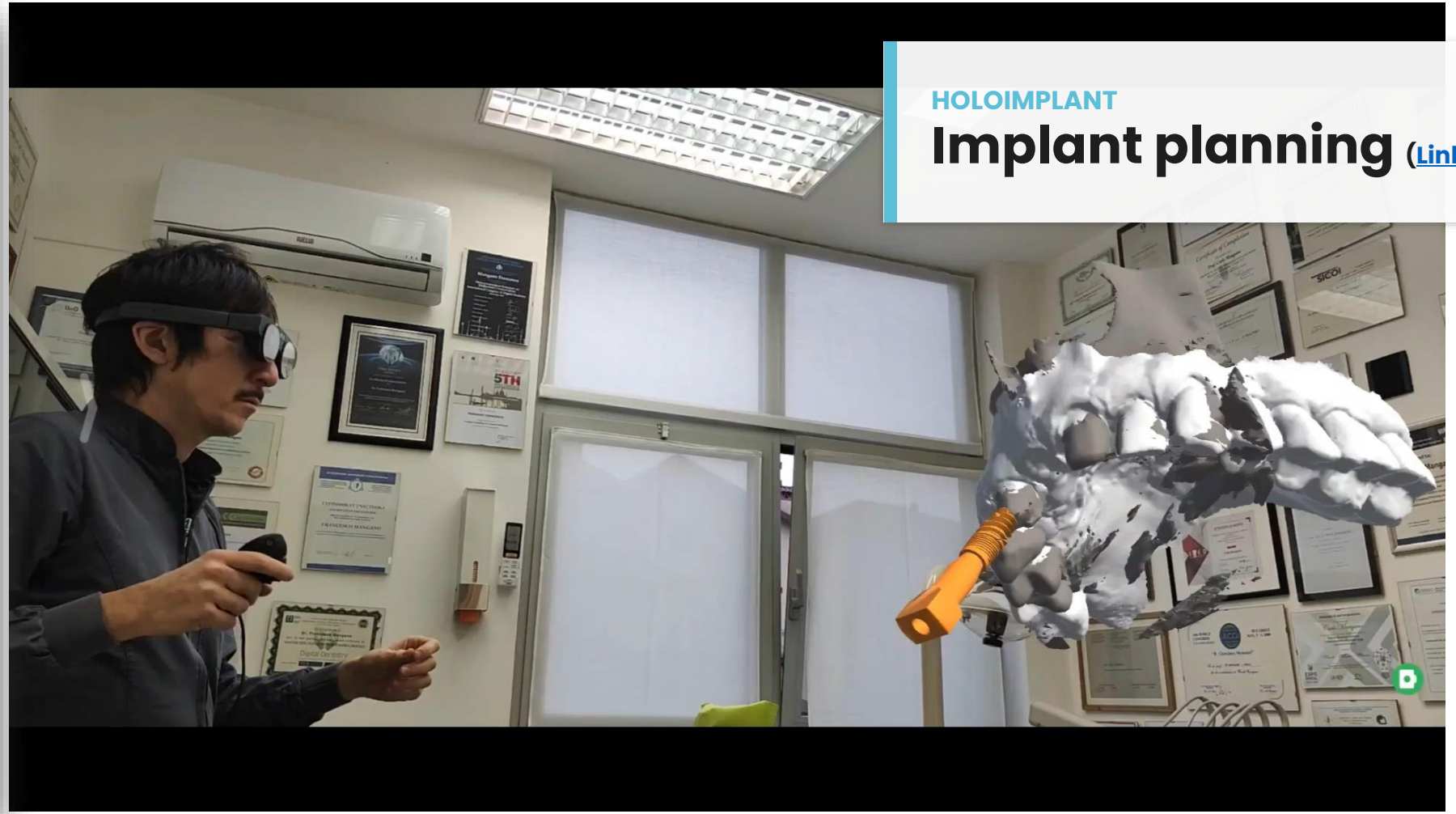
Result: ≈0.03–0.2 mm vs expert registration, in under 1 minute

SOURCES

1. Preda F et al. *Automated segmentation of the maxillofacial complex from CBCT.* **J Dent 2022**
2. Shaheen E et al. *Multi-class tooth segmentation and classification on CBCT.* **J Dent 2021**
3. Elgarba BM et al. *AI crown segmentation for IOS-to-CBCT registration in high-artifact scenarios.* **J Prosthet Dent 2025**
4. Elgarba BM et al. *AI-based automated multimodal registration of CBCT and intraoral scan.* **Clin Oral Implants Res 2024**
5. Preda F et al. *Validation of automated registration of intraoral scan onto CBCT.* **J Dent 2024**

Implant Planning with Mixed Reality (MR)





HOLOIMPLANT

Implant planning (Link)

HOLOIMPLANT

Mixed reality at the chair

What’s next?

COVERED TODAY

01 Key concepts
AR/VR/MR · How to navigate the current market

02 Current applications

03 Mixed Reality in Dentistry: The HoloImplant case study

04

NEXT

Dynamic Navigation with Mixed Reality

MR in Implant-Guided Surgery

We have **three different** guided surgery options:

01

Static guided surgery

02

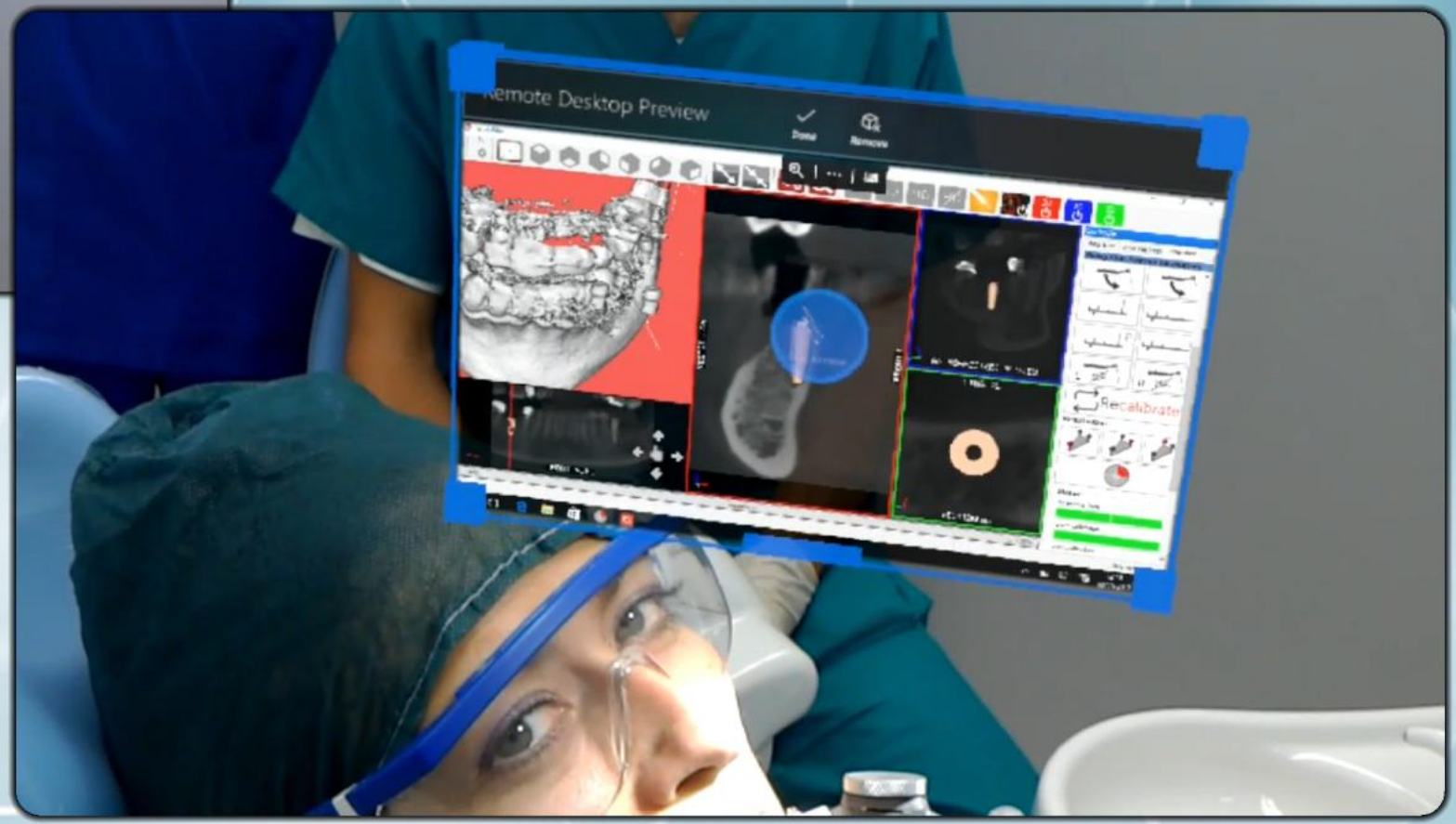
Dynamic navigation

03

Mixed Reality-based Dynamic Navigation

HOLOLENS 1 TESTING – CUSTOM SOFTWARE

DNS integration (2016)



Pellegrino *et al. BMC Oral Health* (2019) 19:158
https://doi.org/10.1186/s12903-019-0853-y

BMC Oral Health

CASE REPORT Open Access

Augmented reality for dental implantology: a pilot clinical report of two cases

Gerardo Pellegrino[1*], Carlo Mangano[2], Roberto Mangano[3], Agnese Ferri[1], Valerio Taraschi[4] and Claudio Marchetti[5]

Our Protocol with MR-based Dynamic Navigation

SURGICAL PHASE

#SCAN!	1. Intraoral Scan (IOS) + Cone Beam Computed Tomography (CBCT)
#PLAN!	2. **Artificial Intelligence (AI)** for File Alignment/Segmentation and Implant Planning
#DONE!	3. Surgery on Patient with **Mixed Reality-based Dynamic Navigation**

PROSTHETIC PHASE

#SCAN!	4. Prosthetic Phase: Intraoral Scan (IOS)
#PLAN!	5. Computer-Assisted-Design (CAD) of Prosthetic Restorations
#MILL!	6. Manufacturing of the Restorations
#DONE!	7. Delivery of the Prosthetic Restorations

Elgarba M, Fontanele R, Mangano F, Jacobs R.
Novel AI-based automated virtual implant placement: Artificial versus Human Intelligence
Journal of Dentistry 2024

Shusterman A, Nashef R, Tecco S, Mangano C, Lerner H, Mangano F.
Accuracy of Implant Placement using a Mixed Reality-Based Dynamic Navigation System versus Static Computer-Assisted and Freehand Surgery: an in Vitro Study.
Journal of Dentistry 2024

Shusterman A, Nashef R, Tecco S, Mangano C, Mangano F.
Implant placement using Mixed Reality-Based Dynamic Navigation: a proof of concept.
Journal of Dentistry 2024

MR-DN: *in vitro* study design

STUDY DESIGN

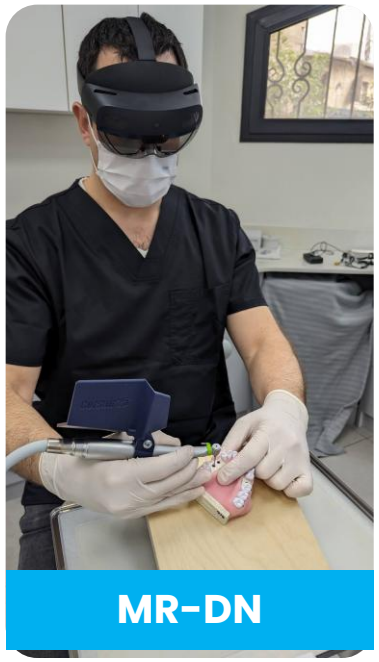
In Vitro Methodology & Study Design

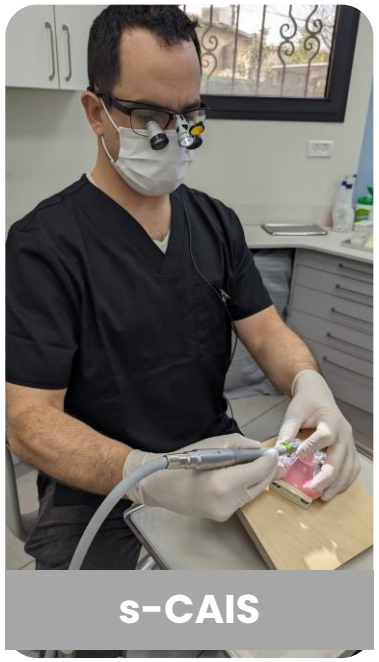
45 Partially Edentulous Maxillary Models
Teeth missing at #15, #16, #25. Preoperative CBCT and Intraoral Scans merged in Implant Planner software.

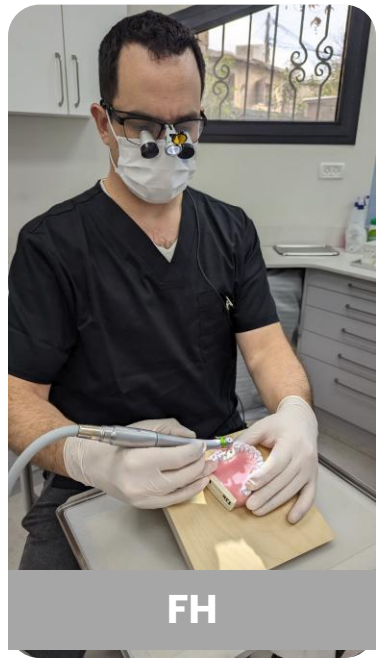
- **Group 1 (MR-DN)** — 15 models
- **Group 2 (s-CAIS)** — 15 models
- **Group 3 (Freehand)** — 15 models

135 Total Dental Implants Placed
All osteotomies performed by the same experienced clinician to eliminate variable operator skill. 3.75 × 10 mm MIS Lance+ implants used.

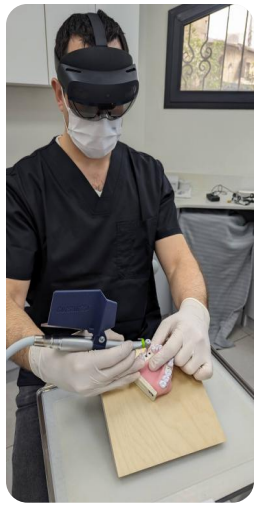
THREE SURGICAL TECHNIQUES

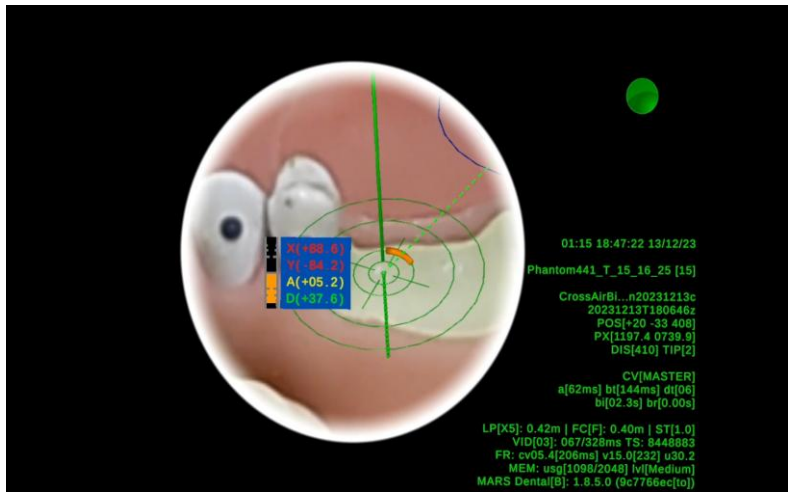






MR-DN: *in vitro* setup and results





The Diagnostic Scorecard (Statistical Significance)

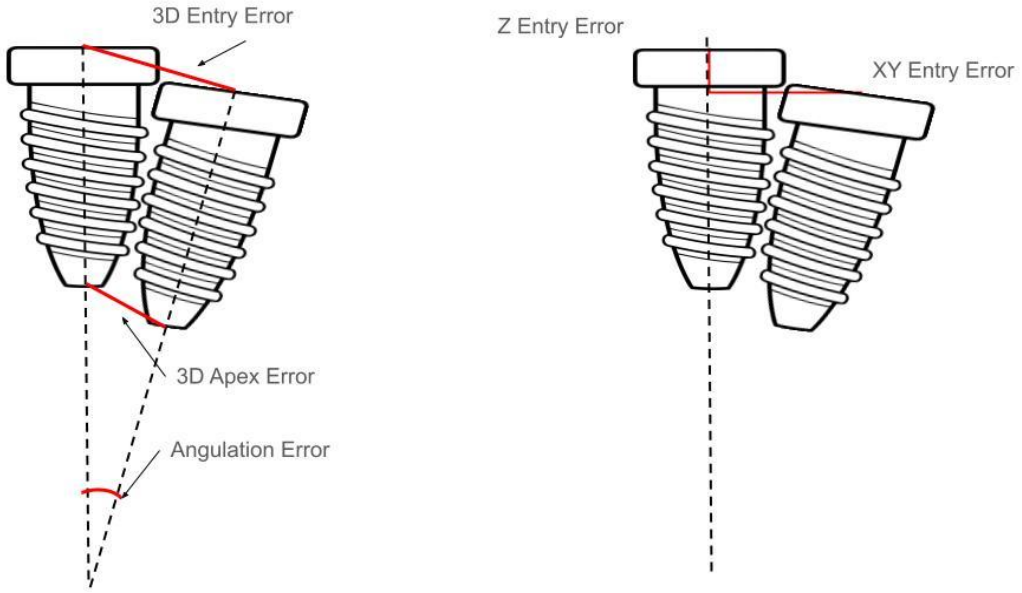
	MR-DN vs. Freehand	MR-DN vs. s-CAIS
XY Shift	MR-DN Superior (P < 0.05)	s-CAIS Superior
Z Depth	MR-DN Superior (P < 0.05)	MR-DN Superior
3D Entry	MR-DN Superior (P < 0.05)	Statistically Equivalent
3D Apex	MR-DN Superior (P < 0.05)	MR-DN Superior
Angulation	MR-DN Superior (P < 0.05)	MR-DN Superior

The Metrics of Deviation

3D Entry Error (En)
The linear coronal deviation at the implant platform.

3D Apex Error (Ap)
The linear deviation at the most apical point of the implant.

Angulation Error (An)
The 3D angular discrepancy between the planned longitudinal axis and the actual placed axis.

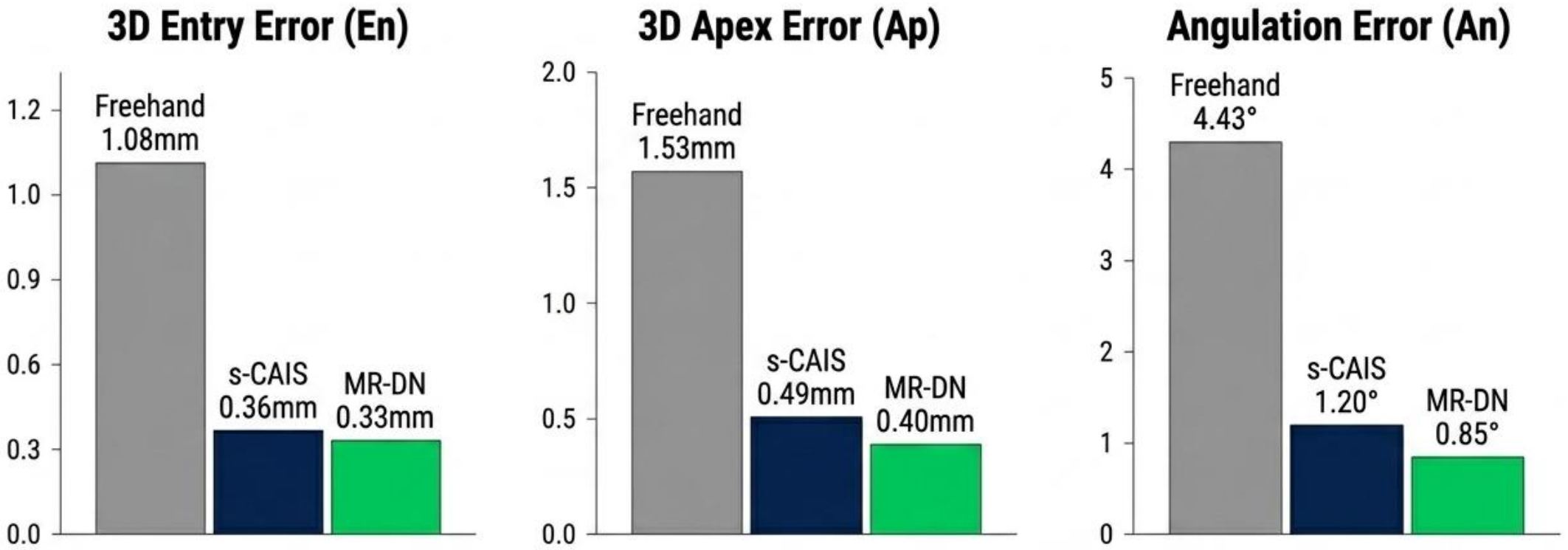


PUBLISHED STUDY

Accuracy of Implant Placement using a Mixed Reality-Based Dynamic Navigation System versus Static Computer-Assisted and Free-hand Surgery: an in Vitro Study.

Shusterman A, Nashef R, Tecco S, Mangano C, Lerner H, Mangano F. **Journal of Dentistry** 2024

Average Implant Deviation: The Macroscopic View



STUDY RESULTS

Across all three spatial metrics, **MR-DN dramatically outperformed Freehand placement**, while matching or slightly exceeding the precision of static guides.

The accuracy scorecard

MR-DN vs. Freehand

Is Mixed Reality statistically superior to human estimation?

3D Entry Deviation (En)	Mean difference -0.75mm	P < 0.0001
3D Apex Deviation (Ap)	Mean difference -1.12mm	P < 0.0001
Angulation Deviation (An)	Mean difference -3.58°	P < 0.0001
Z-Axis (Depth)	Mean difference -0.43mm	P < 0.0001

MR-DN demonstrates **absolute statistical superiority** over the **Freehand method** across every measured parameter, effectively eliminating the human variance associated with analog site preparation.

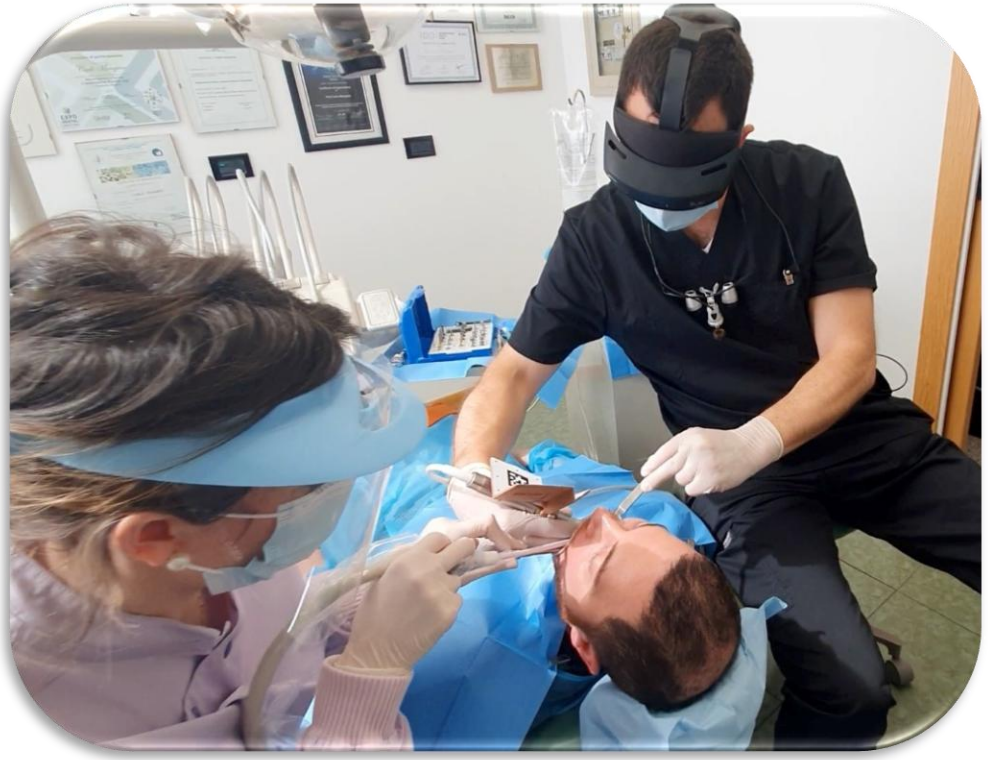
MR-DN vs. Static Guides

Does Mixed Reality match the rigid control of physical templates?

3D Entry Deviation (En)		= Equivalent (P = 0.6536) No statistical difference.
3D Apex Deviation (Ap)	Mean difference -0.09mm	✓ **MR-DN Superior** (P = 0.0896 T-Test / 0.0327 Wilcoxon)
Angulation Deviation (An)	Mean difference -0.35°	✓ **MR-DN Superior** (P = 0.0134)
Z-Axis (Depth)	Mean difference -0.20mm	✓ **MR-DN Superior** (P < 0.0001)
XY-Axis (Lateral)	Mean difference +0.14mm	✓ **s-CAIS Superior** (P = 0.0040)

MR-DN achieves clinical parity with **static guides** at the **platform**, while offering **statistically significant improvements in depth control**, **apical positioning**, and **trajectory angle**.

MR-DN: *in vivo* study



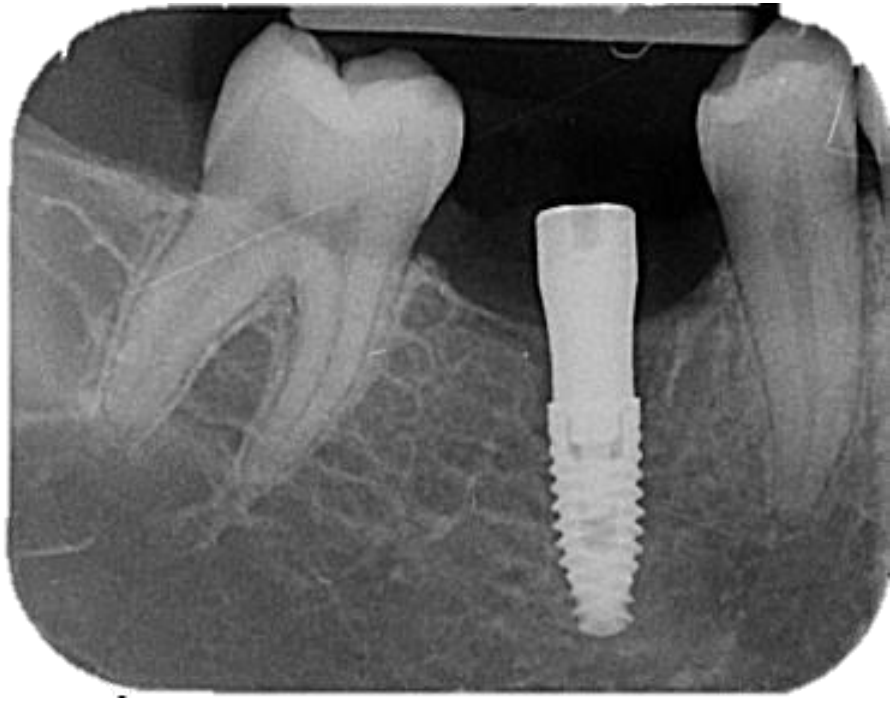
PUBLISHED STUDY

Implant placement using Mixed Reality-Based Dynamic Navigation: a proof of concept

Shusterman A, Nashef R, Tecco S, Mangano C, Mangano F. **Journal of Dentistry** 2024

MARS Dental 1.10.4.0
23:10 14:02:08 06/04/24
CohenIdan_T_46 [46]
Px[--.-] Py[--.-] A[--.-]
crossairV1_idan46_1a [2]
PX[1142.5 0837.8] Z[406]
OFS[0.00 0.00 0.00]
CV[BDRECOVER] [00]
i[00.7s] t[099ms] r[0.82s] a[165ms]
LP[X5]: 0.43m | FC[F]: 0.40m | ST[1.0]
VID[04]: 058/266ms TS: 48752278
FR: cv08.7[264ms] v15.0[7084] u30.4
MEM: usg[934/2048] lvl[Low]
MARS Dental 1.10.4.0
33:34 14:12:32 06/04/24
CohenIdan_T_46 [46]
Px[--.-] Py[--.-] A[--.-]
crossairV1_idan46_1a [2]
PX[0000.0 0000.0] Z[000]
OFS[0.00 0.00 0.00]
CV[BDTRACKING] [07]
i[00.5s] t[103ms] r[1.09s] a[25ms]
LP[X5]: 0.43m | FC[F]: 0.40m | ST[1.0]
VID[03]: 063/224ms TS: 49376297
FR: cv11.1[128ms] v15.0[10479] u31.2
MEM: usg[958/2048] lvl[Low]
MARS Dental 1.10.4.0
40:07 14:19:05 06/04/24
CohenIdan_T_46 [46]
Px[--.-] Py[--.-] A[--.-]
crossairV1_idan46_1a [5]
PX[0000.0 0000.0] Z[000]
OFS[0.00 0.00 0.00]
CV[BDRECOVER] [00]
i[00.9s] t[120ms] r[0.17s] a[78ms]
LP[X5]: 0.44m | FC[F]: 0.40m | ST[1.0]
VID[04]: 058/166ms TS: 49768751
FR: cv13.9[198ms] v15.1[12524] u30.5
MEM: usg[973/2048] lvl[Low]
MARS Dental 1.10.4.0
46:02 14:25:00 06/04/24
CohenIdan_T_46 [46]
Px[--.-] Py[--.-] A[--.-]
crossairV1_idan46_1a [5]
PX[0000.0 0000.0] Z[000]
OFS[0.00 0.00 0.00]
CV[BDRECOVER] [00]
i[00.9s] t[107ms] r[0.32s] a[44ms]
LP[X5]: 0.40m | FC[F]: 0.40m | ST[1.0]
VID[02]: 061/132ms TS: 50124533
FR: cv12.3[151ms] v14.9[13743] u30.3
MEM: usg[985/2048] lvl[Low]

MR-DN: a real alternative to guided surgery



MERGED WITH THE REAL ENVIRONMENT

Implant planning	**3D models**
Computer screens	**Calibrated surgical instruments**

These are superimposed on the patient, so the surgeon can follow the real-time information from the MR-DN system and the surgical site simultaneously.

> *The use of Mixed Reality Dynamic Navigation can change the perspectives of guided dental implant surgery as an alternative to the classic static and dynamic guided surgical techniques*

Mirela Feraru, Ariel Shusterman, Carlo Mangano, Francesco Guido Mangano
Clinical Integration of Artificial Intelligence and Mixed Reality-Based Dynamic Navigation for Implant Placement in the Anterior Maxilla
Journal of Dentistry 2026

State of the Art Conference
See you at the Antwerp Congress 2026!
Antwerp | October 16-17th, 2026
Digital Dentistry Society

ODIN WORKSHOP · STRASBOURG · 27 SEPTEMBER 2026

Thank you

for your attention!

Current and Future Applications of XR and AI in Dentistry

Roberto Mangano

MSc Computer Engineering

Digital Dentistry Society Certified Speaker

www.digital-dentistry.org

Digital Dentistry Society