Planul Național de Redresare și Reziliență

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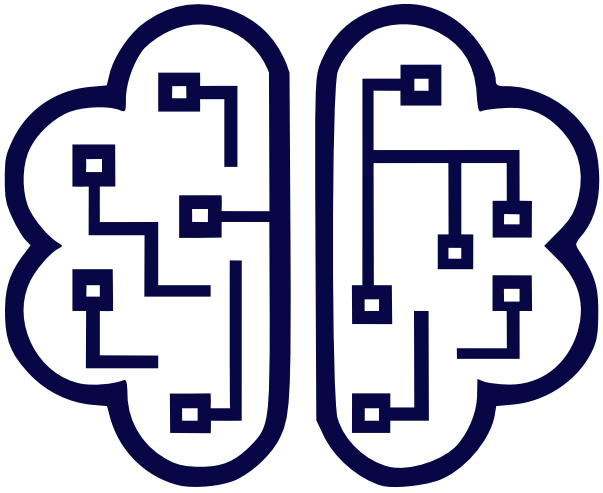

TEAM Project

Technologically Enabled Advancements in Dental Medicine

WP3 – Research activities

D3.1. Report on research activities

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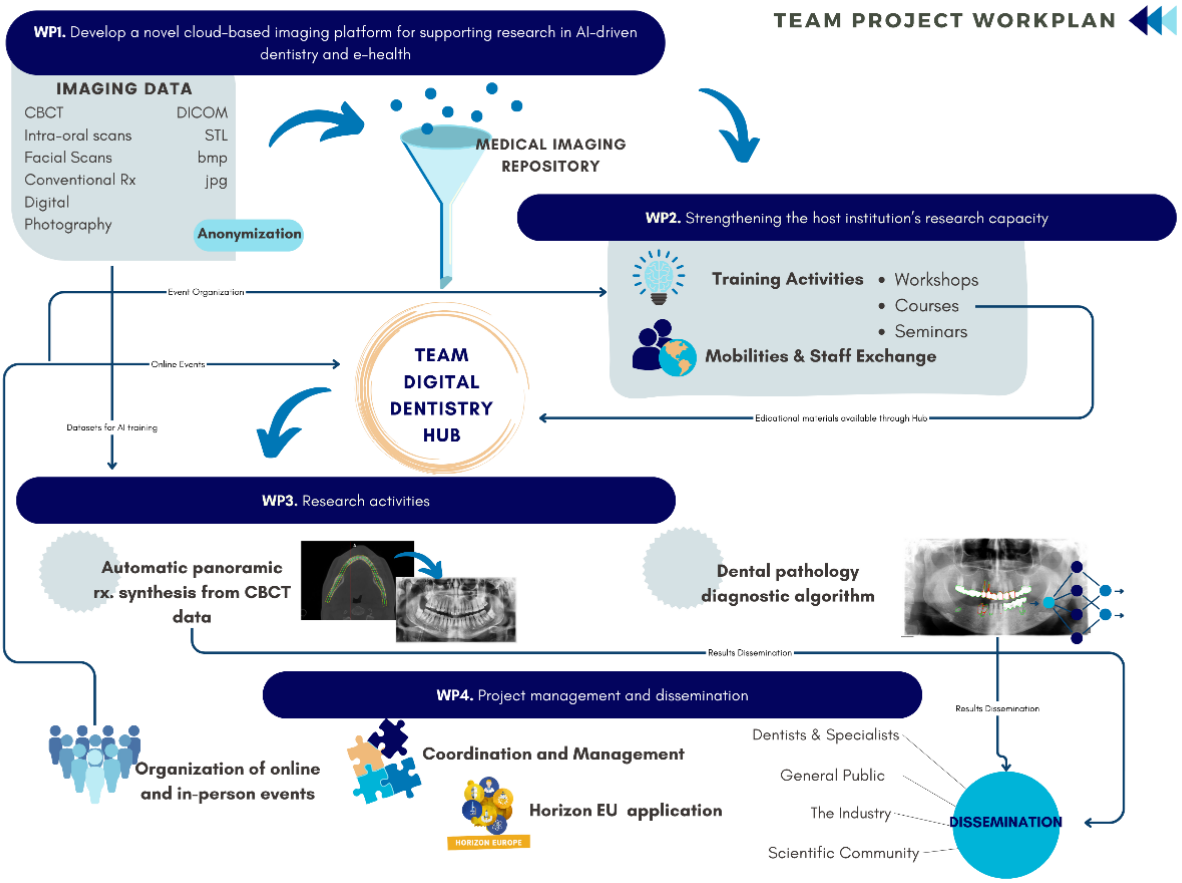
The TEAM Project aims to explore the integration of artificial intelligence (AI) into dentistry and maxillofacial surgery through the development of tools for pathology detection, clinical decision support, image segmentation, and digital surgical planning. By integrating AI into these areas, the project seeks to improve diagnostic accuracy, support personalized treatment approaches, and optimize clinical workflows.

This document presents the research activities carried out within the TEAM Project. The report summarizes the scientific activities developed within Work Package 3 (WP3), focusing on artificial intelligence applications for medical imaging and advanced computational methods for diagnosis and treatment planning.

I. Objectives

The objective of WP 3 - Research Activities was to strengthen the scientific and technological research capacity of the host institution through the development and validation of AI-based diagnostic tools and digital workflows for dentistry and maxillofacial surgery.



II. Artificial Intelligence in the Diagnosis of Temporomandibular Disorders

Research activities were conducted to develop artificial intelligence-based tools for the automated asessment of temporomandibular disorders (TMDs) using MRI. The research focused on the identification and classification of temporomandibular joint (TMJ) disc displacement on oblique sagittal and coronal MRI sections.

A pilot study was carried out on a dataset consisting of MRI scans from 50 patients diagnosed with TMD. The dataset included 300 proton density (PD) MRI sections obtained from bilateral sagittal and coronal acquisitions in open- and closed-mouth positions. The images were manually annotated by experienced clinicians and used for the development and validation of AI models.

The research team conducted an extensive review of the scientific literature to identify appropriate imaging protocols, segmentation strategies, and machine learning techniques suitable for TMJ analysis. Based on the literature review and preliminary experiments, a modified MobileNet-V2 convolutional neural network (CNN) architecture with transfer learning was selected for the classification task.

The developed AI model was trained to identify different categories of disc position abnormalities, including:

- normal disc position;
- anterior disc displacement with reduction;
- anterior disc displacement without reduction;
- medial and lateral disc displacement.

The dataset was divided into training, validation, and testing subsets. Data augmentation techniques were applied to improve model robustness. The final model achieved a training accuracy of 92% and a test accuracy of 81% for automated TMJ disc displacement classification.

In parallel, a new MRI database was collected, including anonymized TMJ imaging data intended for future AI applications. A segmentation protocol for temporomandibular joint structures was also established to support the development of automated segmentation algorithms for MRI analysis.

The research activities resulted in the publication of one scientific article:

Almășan O, Mureșanu S, Hedeșiu P, Cotor A, Băciuț M, Roman R, Team Project Group. An Examination of Temporomandibular Joint Disc Displacement through Magnetic Resonance Imaging by Integrating Artificial Intelligence: Preliminary Findings. Medicina (Kaunas). 2024 Aug 26;60(9):1396. doi: 10.3390/medicina60091396. PMID: 39336437; PMCID: PMC11433800.

The study showed the feasibility of AI-assisted TMJ evaluation and highlighted the potential of deep learning to support clinical diagnosis and educational applications in dentomaxillofacial radiology. Future research activities will focus on expanding the MRI dataset, integrating clinical parameters, and developing explainable AI models for a more comprehensive TMD diagnosis.

III. Artificial Intelligence for the Detection of Dental Conditions on Panoramic Radiographs

The TEAM Project supported the development of multiple applications for the automated detection and segmentation of dental conditions on panoramic radiographs. Research activities focused on the creation of annotated imaging datasets, development of deep learning models, external validation procedures, and preliminary evaluation of AI-assisted diagnostic tools for clinical use.

3.2.1 Teeth and Carious Lesion Segmentation

One of the main research directions focused on the automated segmentation of teeth and carious lesions on panoramic radiographs. A dedicated computer-aided detection system (CariSeg), was

developed using a two-step deep learning approach. The first stage involved teeth segmentation using a U-Net architecture, followed by carious lesion segmentation using an ensemble of three neural network architectures: U-Net, Feature Pyramid Network (FPN), and DeepLabV3.

The study included the creation and annotation of dedicated imaging datasets, including 150 panoramic radiographs for carious lesion segmentation and over 1,000 radiographs used for teeth segmentation training. Preprocessing and augmentation techniques were implemented, including automatic cropping around the dental arches, gamma correction, rotation, scaling, and contrast adjustments, to improve model generalizability and reduce overfitting.

The developed framework achieved strong performance for both teeth and carious lesion segmentation, obtaining 94.89% accuracy and an 88.5% Dice score for teeth segmentation, as well as 99.42% accuracy and a mean Dice coefficient of 68.2% for carious lesion segmentation.

The results of this research were published in the article:

Mărginean AC, Mureşanu S, Hedeşiu M, Dioşan L. Teeth segmentation and carious lesions segmentation in panoramic X-ray images using CariSeg, a networks' ensemble. Heliyon. 2024 May 10;10(10):e30836. doi: 10.1016/j.heliyon.2024.e30836. PMID: 38803980; PMCID: PMC11128823

3.2.2 Automated Detection of Multiple Dental Conditions

A second research direction focused on the automated detection of multiple dental conditions using object detection algorithms based on the YOLO architecture.

An imaging dataset consisting of 1,628 panoramic radiographs was retrospectively collected and manually annotated by calibrated examiners. An additional multicenter dataset of 180 panoramic radiographs was assembled for external validation.

The developed AI model was trained to identify a broad spectrum of dental conditions and treatments, including carious lesions, periapical lesions, periodontal bone loss, impacted teeth, root fragments, root resorption, prosthetic restorations, endodontic treatments, implants, orthodontic appliances, and surgical devices. Annotation reliability demonstrated excellent inter-observer agreement, with an ICC value of 0.91.

The final YOLOv8 model showed strong performance for the detection of implants, endodontic treatments, impacted teeth, orthodontic devices, and surgical hardware during internal validation. External validation highlighted the challenges associated with multicenter datasets and emphasized the importance of improving model generalizability for subtle lesions such as early caries and periodontal bone loss.

The research activities resulted in the following publication:

Mureșanu S, Hedeșiu M, Iacob L, Eftimie R, Olariu E, Dinu C, Jacobs R, on behalf of Team Project Group. Automating Dental Condition Detection on Panoramic Radiographs: Challenges, Pitfalls, and Opportunities. Diagnostics (Basel). 2024 Oct 21;14(20):2336. doi: 10.3390/diagnostics14202336. PMID: 39451659; PMCID: PMC11507083.

3.2.3 Detection of Maxillofacial Cysts and Tumors

The project also supported the development of AI algorithms for the identification and classification of maxillofacial cysts and tumors on panoramic radiographs and CBCT images.

A pilot dataset containing 172 patients was collected. Lesions included ameloblastomas, dentigerous cysts, radicular cysts, residual cysts, odontogenic keratocysts, simple bone cysts, odontomas, and osteomas. The lesions were manually annotated on panoramic radiographs using bounding-boxes and the dataset was divided into training, testing, and validation subsets.

Multiple deep learning experiments were conducted using MobileNet architectures, with MobileNetV3Large achieving the highest classification accuracy of approximately 0.88. In parallel, manual segmentation of lesions on CBCT images was initiated to support the future development of automated segmentation algorithms based on U-Net and nnU-Net frameworks.

A preliminary Streamlit-based user interface was developed to allow image upload, region-of-interest selection, automated lesion prediction, and retrieval of visually similar cases.

IV. Digital Dentistry and 3D Printing Applications

The project supported research activities focused on the integration of digital workflows and additive manufacturing technologies into aesthetic dental rehabilitation. The research explored the use of intraoral scanning, digital smile design, CAD/CAM systems, and 3D printing technologies for the fabrication of minimally invasive prosthetic devices.

One study investigated the use of 3D-printed Snap-On Smile devices as a short-term aesthetic rehabilitation solution. It included both a literature review and a clinical case report evaluating the indications, manufacturing techniques, advantages, and limitations of these removable prosthetic devices.

The literature review was conducted according to PRISMA-P guidelines and analyzed studies published between 2000 and 2024. The review assessed digital manufacturing workflows involving intraoral optical impressions, virtual smile planning, CAD modeling, and additive manufacturing.

A clinical case was developed within the project for a 59-year-old patient requiring immediate aesthetic rehabilitation. The complete digital workflow included intraoral scanning with Trios 3, digital smile design planning, CAD modeling in Exocad, and fabrication of the prosthetic devices through DLP 3D printing technology using Flexcera Smile Ultra+ resin.

The study ilustrates the potential of digital dentistry technologies to provide rapid, minimally invasive, and personalized aesthetic rehabilitation while preserving dental structures and reducing treatment time. These activities contributed to the implementation of advanced digital workflows within the research and educational framework of the TEAM Project.

These activities resulted in the following publication:

Burde AV, Frățilă C, Varvară EB, Varvară AV, Short-term aesthetic rehabilitation with 3d printed snap-on smile devices – literature review and a case report, Romanian Journal of Oral Rehabilitation, Vol. 16, No.2 April-June 2024, DOI: 10.6261/RJOR.2024.2.16.58