Dental-dedicated MRI—a new imaging technique in implantology?

Dr Georg Bach & Markus Bach, Germany

Fig. 1: Flexible coil of the ddMRI device.

At the 2024 European Congress of DentoMaxilloFacial Radiology in Freiburg in Germany, Dentsply Sirona and Siemens Healthineers unveiled the first MRI system specifically designed for dental applications—or dental-dedicated MRI (ddMRI), marking a significant breakthrough in dental imaging. Two key advantages of the MAGNETOM Free.Max Dental Edition MRI unit were highlighted: its complete elimination of ionising radiation and the unprecedented possibilities it provides in dentistry. Notably, it enhances soft-tissue diagnostics, offering unparalleled insights and precision. This article examines the development, advantages, limitations and clinical applications of dental MRI, giving particular focus to its role in pre-implant diagnostics, oral surgery and other dental specialties. It also discusses the technological advancements that have made MRI a viable imaging modality in dentistry and its potential impact on future clinical practice.

Although, the debut of the first dental MRI system was a landmark moment, it was the result of nearly two decades of dedicated research. By early 2023, the development process had advanced significantly, providing the first promising indications that the technology could be presented to the public. This progress culminated in a symposium in the spring of 2023, attended by approximately 50 experts, primarily from academic institutions, who gathered to review and discuss the preliminary findings.

The initial results were so compelling that both the companies involved and the panel of experts agreed to collaborate on the scientific integration of MRI in dentistry. As part of this initiative, Siemens Healthineers provided a modified version of its current low-field MRI system, MAGNETOM Free.Max, which was installed at Aarhus University in Denmark. Under the leadership of Prof. Rubens Spin-Neto from the Section for Oral Radiology and Endodontics at the Department of Dentistry and Oral Health, extensive research efforts were launched to both enhance hardware components, such as the receiving coil, and develop workflows specifically tailored for dental applications with the clear objective of establishing MRI as a viable and integral tool in dentistry.

> “Achieving truly practice-friendly device dimensions remains a challenge.”

Current status

The collaborative research efforts have yielded remarkable success. In just one year, MAGNETOM Free.Max Dental Edition was introduced. The ddMRI system differs significantly from conventional medical MRI machines. While standard MRI systems operate at field strengths of 1.5 or 3.0 T, the ddMRI utilises a reduced field strength of 0.55 T. This reduction has been achieved primarily through advanced software-based innovations in signal processing, incorporating AI-driven algorithms to enhance image quality and accelerate data acquisition.

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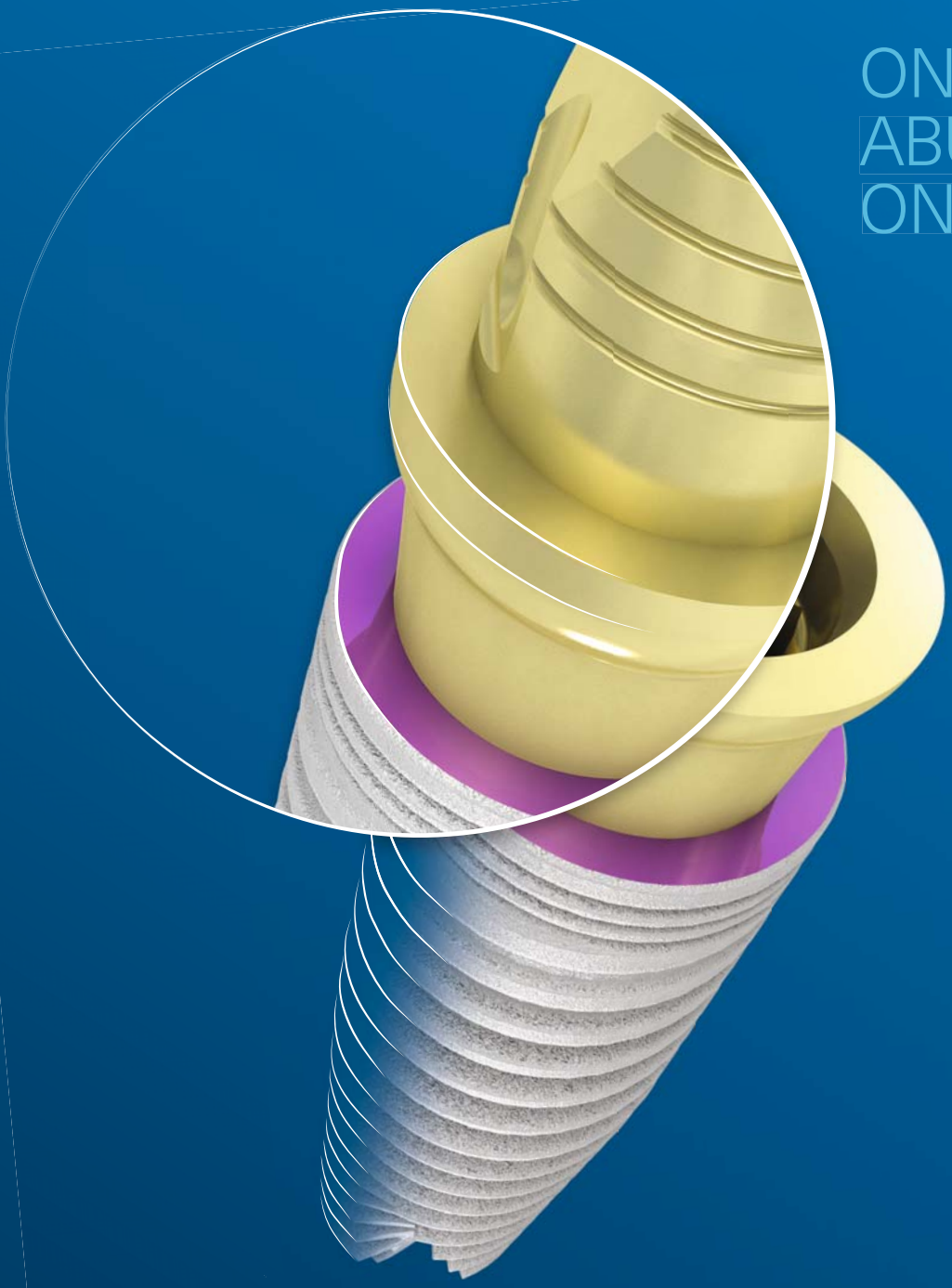

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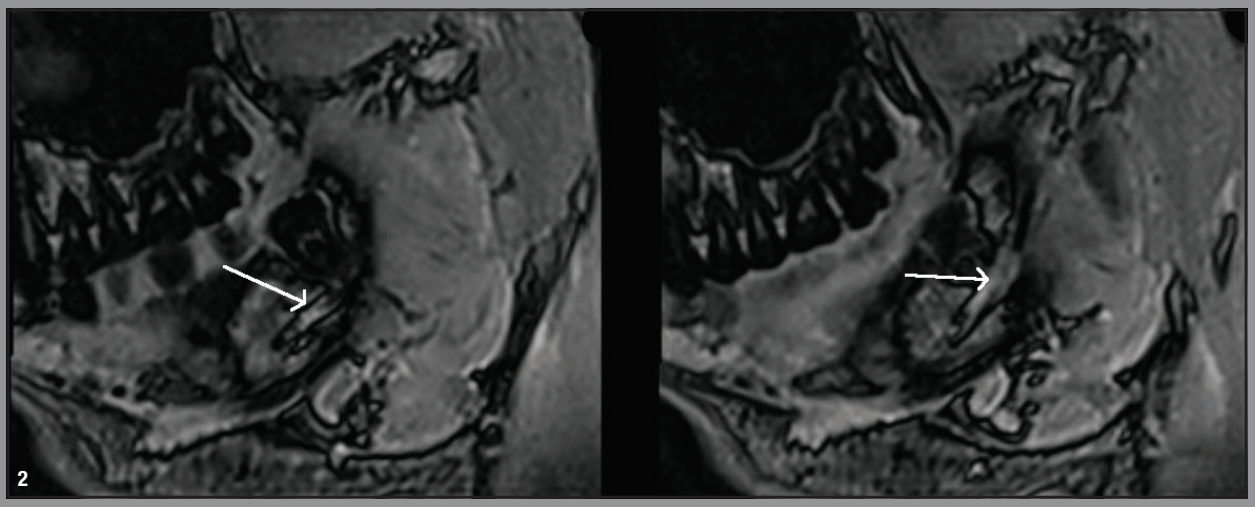
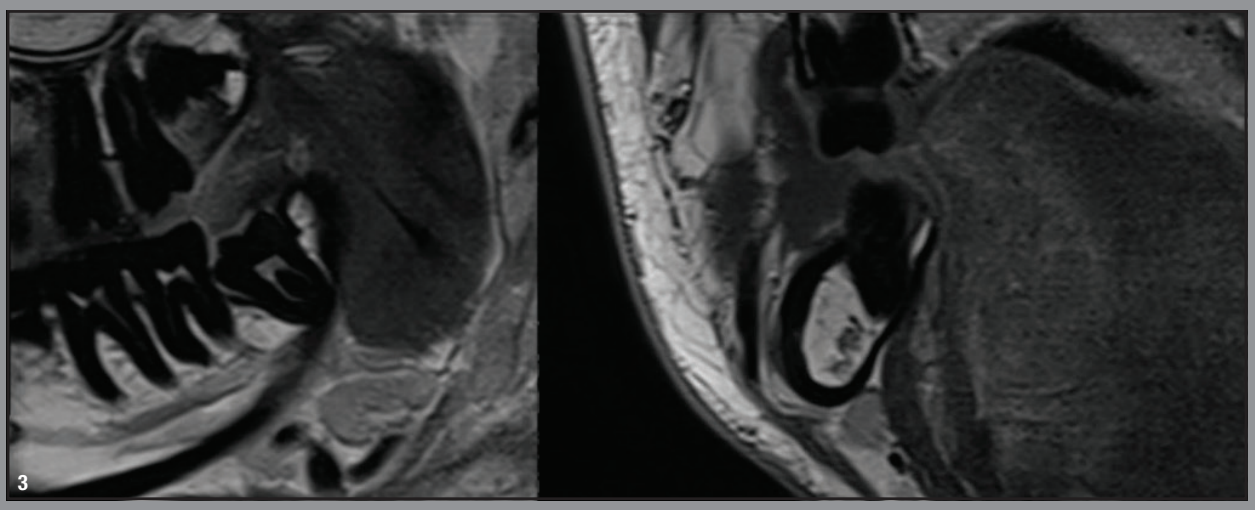




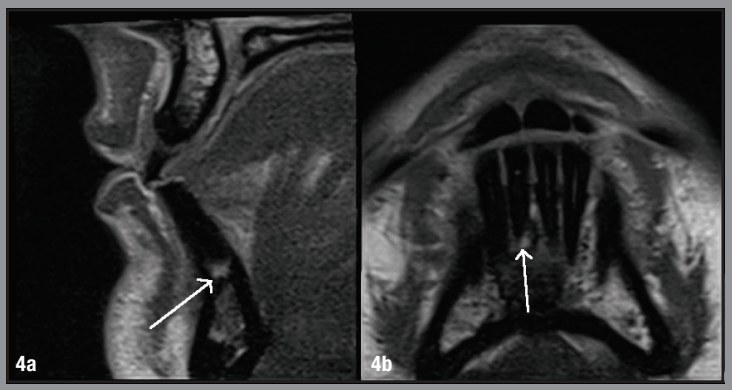
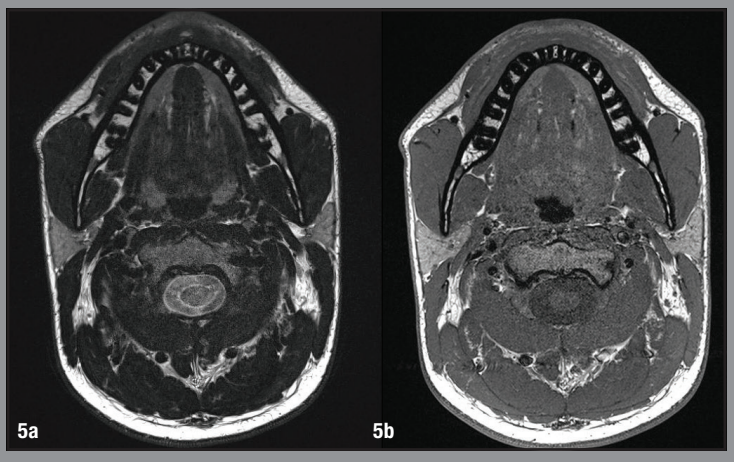


Fig. 2: Course of the inferior alveolar nerve. Sagittal FLAIR sequence illustrating the nerve's pathway in relation to an impacted lower wisdom tooth.

Fig. 3: T1-weighted Turbo Spin Echo (TSE) imaging of the impacted tooth 48, presented in sagittal (left) and axial (right) sections.

Figs. 4a+b: T2-weighted Turbo Spin Echo (TSE) sequence of the mandibular anterior region, clearly depicting a hyperintense zone apical to tooth #41, indicative of an acute inflammatory process.



Figs. 5a+b: Axial sections of a 3.5T MRI, displaying T1-weighted imaging **(a)** and an additional T1-weighted sequence **(b)** for a detailed view of the mandible.

Reducing the field strength decreases structural demands, simplifying installation, conserving resources (including helium and energy) and enabling a more compact design. With a smaller footprint, lighter weight and reduced cooling requirements, the ddMRI system offers greater flexibility in installation sites. It operates using Siemens DryCool energy system, requiring just 0.7 l of liquid helium for magnet cooling over its entire lifespan. In contrast, conventional low-field MRI systems in human medicine consume approximately 200 l of helium, which must be regularly replenished. This drastic reduction in helium usage not only lowers acquisition and maintenance costs but also significantly enhances the system's sustainability.

Achieving truly practice-friendly device dimensions remains a challenge. Currently, the ddMRI system is still designed as a whole-body MRI, requiring substantial space. At present, it occupies 24 m^2—comparable to the size of a spacious waiting room. Furthermore, despite ongoing efforts to reduce its weight, the system still weighs 32 tonnes.

Given the current hardware, software and application requirements, the primary target audience for the ddMRI unit remains universities and dental clinics. According to the companies involved, these institutions have already shown strong interest in the technology. Once the necessary regulatory approvals have been secured, regular distribution will commence, paving the way for wider adoption in academic and clinical research settings.[1]

A major advantage: Radiation-free imaging

The most significant benefit of dental MRI is its ability to generate images without ionising radiation, making it a major advancement in patient safety. Unlike conventional imaging methods such as CBCT and CT, which rely on X-rays that can damage DNA, MRI sequences are produced using a strong magnetic field that aligns protons in the body. As a result, dental MRI eliminates radiation exposure, rendering the principles of as low as reasonably achievable and as low as diagnostically acceptable obsolete. Moreover, without the need to justify radiation exposure, unlimited imaging becomes possible.[2]

This breakthrough is particularly beneficial for dental specialties that rely on frequent imaging, such as paediatric dentistry, orthodontics and restorative dentistry. Children, in particular, stand to gain from radiation-free imaging, ensuring safer diagnostics without long-term risks. Additionally, dental MRI is an ideal solution for patient groups requiring repeated examinations, such as those undergoing tumour follow-up, pregnant women or other individuals in sensitive life stages where radiation exposure poses long-term risks.[3] Beyond these applications, dental implantology stands to gain significantly from this new technology because it opens up new diagnostic possibilities while ensuring maximum patient safety.

Advantages for oral surgery

Besides long-term patient safety and superior visualisation of soft-tissue structures, dental MRI offers several further advantages over conventional imaging modalities used in dental practice, such as CBCT and panoramic radiography.[4–6] One notable capability is the precise localisation of the inferior alveolar nerve within the mandibular canal during third molar surgery. Compared with conventional imaging techniques, dental MRI provides clearer native visualisation, reducing the risk of nerve damage and improving surgical planning.[7] Additionally, MRI surpasses other imaging methods in the early detection of diseases with significant soft-tissue involvement.[8] They offer detailed visualisation of muscles, nerves and ligaments, making them particularly valuable for identifying pathological soft-tissue processes such as tumours at an early stage.[9]

> "The most significant benefit of dental MRI is its ability to generate images without ionising radiation, making it a major advancement in patient safety."

Advantages for dental implantology

In dental implant planning, dental MRI offers a key advantage: the precise localisation of nerves and soft-tissue structures, such as the gingiva, and their anatomical relationship to the planned implant site. This level of detail is crucial for ensuring accurate implant placement and minimising surgical risks.[10,11]

While conventional CT excels in bone visualisation, early studies on implant planning using dental MRI have shown promising results, addressing one of the key limitations of MRI in comparison to CT. Research conducted both *in vitro* and on patients has successfully demonstrated the feasibility of implant planning and guided implantation using CAD/CAM techniques.[12,13] For optimal implant planning in complex intra-oral anatomies, a hybrid approach combining ddMRI and CT should be considered. This integration would allow practitioners to leverage the supe-

rior soft-tissue visualisation of ddMRI while benefiting from the detailed bone representation of CT, ultimately leading to more precise and predictable treatment outcomes.

3D visualisation

For years, the primary advantage of CT and CBCT has been their ability to generate 3D datasets. In CT imaging, a dataset is acquired that can be reconstructed in multiple planes, including sagittal, coronal and transverse views. However, recent advancements in dental MRI technology now also enable high-quality 3D visualisation, bridging the gap between these imaging modalities.[14]

> "This technology has enormous potential."

Additionally, functional MRI has long been used to assess motion-related soft-tissue pathologies, particularly in the diagnosis of temporomandibular disorder. This capability allows for a more comprehensive evaluation of temporomandibular joint function and pathology, offering valuable insights beyond static imaging.[15]

Disadvantages and limitations of dental MRI

One disadvantage of MRI compared with other imaging techniques in dentistry is the duration of the scanning process. CT scans are typically acquired within seconds, whereas each MRI sequence usually takes several minutes. During the scan, the patient must remain still because any movement can significantly reduce image quality owing to motion artefacts. However, recent advancements have led to the development of faster scanning protocols.

The development of MRI-compatible dental implants has helped overcome one of the previous drawbacks of all imaging techniques, the generation by dental implants of significant artefacts in the images.[16] Newer materials and techniques reduce these artefacts and improve the quality of MRI scans in patients with dental implants. Consequently, new scanning protocols also focus on suppressing implant-related artefacts.[17,18]

In general, the visualisation of teeth in MRI still has limitations. However, initial approaches are being explored to enhance dental imaging using AI-assisted techniques.[19]

Another key limitation of MRI in dentistry is its cost and limited availability. Many dental practices, particularly those outside hospital settings, lack access to MRI referrals within a reasonable time frame. However, ongoing research and technological advancements in dental MRI are expected to help reduce costs and improve accessibility in the coming years.

Additionally, dental MRI systems require specific technical modifications compared with MRI scanners used in medical radiology.[20] As previously mentioned, MAGNETOM Free.Max Dental Edition introduces promising solutions to these challenges, paving the way for broader adoption in dental diagnostics and treatment planning.

Preliminary conclusion

No statement encapsulates the promise of dental MRI better than the words of neuroradiologist Dr Monika Probst: "This technology has enormous potential." The future significance of this innovation is underscored by a notable shift within the German Society of Dentistry and Oral Medicine. Its well-known working group on radiology (Arbeitsgemeinschaft Röntgenologie) has been renamed the Arbeitsgemeinschaft für Bildgebung in der Zahn-, Mund- und Kieferheilkunde (working group on imaging in dentistry and oral medicine).[21] This change reflects the evolving landscape of dental imaging, to which MRI and ultrasound—both non-radiological technologies—are becoming integral. As a result, the term "radiology" no longer fully represents the expanding spectrum of imaging techniques, necessitating its replacement. Among these advancements, dental MRI stands out as the most promising, offering unparalleled potential for future developments and groundbreaking applications in dentistry.

Acknowledgement

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Literature

contact

Dr Georg Bach
doc.bach@t-online.de
www.herrmann-bach.de

Markus Bach
markus.bach@unimedizin-mainz.de
www.unimedizin-mainz.de

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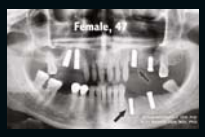

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