

A comparative study of Magnetic Resonance (MR) and Computed Tomography (CT) in the pre-implant evaluation

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Summary

A comparative study of Magnetic Resonance (MR) and Computed Tomography (CT) in the pre-implant evaluation.

Aim. *A successful implant therapy is based on an accurate assessment of the anatomy of the jaws. The aim of our study was to evaluate the reliability of magnetic resonance imaging (MR) compared with computed tomography (CT) for dental implant planning in respect to bone measurements and to observe and analyze the differences.*

Method. *We have studied 30 cases in which scans were performed with CT and MR. The images provided by the MR and CT examinations were delivered to three specialists in oral and maxillofacial radiology to measure the bone height at the specific sites. The measurements obtained by the specialists in MR and CT images were compared using the ANOVA test with a 0.05 significance level.*

Result. *In all 30 cases examined, MR images appeared perfectly comparable to CT images. The differences between the measurements from the MR and CT exams varied from 0.04 to 1.1 mm. There were no statistically significant differences (P=0.9).*

Conclusion. *The MR, when compared with CT, shown to be reliable in respect to bone measurements for dental implant planning. However, further studies are necessary to determine the technical advantages of Resonance at lower fields, compared with those of CT and MR with medium or high magnetic field.*

Key words: Magnetic Resonance Imaging, dental implant, computed tomography, implant planning.

Introduction

A successful implant therapy is based on an accurate evaluation of the patient's anatomy of jaws.

Proper patient selection and careful pre-surgical planning are essential to the success of implant therapy. They are essentially based on the evaluation of the quality and quantity of the bone and on the location of anatomical structures that might be limiting the implant such as the mandibular canal, mental foramen, maxillary sinus, surface of nasal pit and the incisive canal. This evaluation can only be complete if the acquired information interests all three dimensions of space and faithfully reproduces natural dimensions.

Methods used in the past for implant programs only allowed bi-dimensional and inexact analyses. Only more recently, some instruments are able to provide stratigraphic images whose use is limited to individual implant sites, while the cranial radiography in lateral projection represents a partial solution in the study of the anterior portion of the jaw.

The selection, especially in the case of multiple implants, is based on computed tomography (CT) which allows us to have images in section of vital structures and three-dimensional reconstructions.

All these radiographic techniques expose the patient to ionizing radiations that can be harmful to the body; in the case of CT this exposure is significant.

CT analyses are also more prone to artefacts due to metallic dental materials and to those in correspondence with the dense cortical bone (1). DentaScan was introduced to reduce the excessive dose of radiations to the eyes and the thyroid gland. It has a special software to draw out thin layers that are orthogonal to the dental arch, in each point, and similar layers in orthopantomography. (2,3).

Magnetic Resonance images (MR), instead, use the principle of nuclear magnetic resonance to give cross sectional images with a high spatial resolution without the use of ionizing radiations. These evaluations led us to use the MR in the quantitative and qualitative tridimensional evaluation of the alveolar bone crest.

The aim of this study has been to evaluate and compare the results in identifying a correct pre-implant treatment using MR rather than CT DentaScan.

Magnetic resonance (MR)

The acquisition of MR images is based on a set of physical principles completely different from those that characterize radiographic techniques.

A special feature of the MR is the use of electromagnetic fields and radiofrequency waves, which, except for few recognized cases, are not believed to be harmful to the

body (4,5). This relative biological safety is the key element that leads to testing its clinical applications.

All the data employed to create the final image come from the study of hydrogen atoms, particularly suitable for their high concentration in the human body and for the favourable physics of their nuclei (4).

These atomic nuclei, properly stimulated, first absorb and then give out energy that is detected in the form of electrical signals. A computer collects and processes this signal, transforming it through a series of mathematical algorithms in an MR image

The different signal intensity is represented in the MR image by a change in the grayscale: white corresponds to a high signal, grey corresponds to an intermediate signal, and black corresponds to absence of signal. The signal of each frame depends on the sequence used. Sections with a detectable flow, such as blood in the lumen, are usually identified as sections that do not emit any signal, because their nuclei leave the studied body section before these can be spotted (1).

Depending on the parameter which is taken into consideration there will be images weighted in proton density (PD), T1 or T2, which are different and must be interpreted differently.

The MR T1 images show high quality and anatomical resolution, so as to look like actual anatomical drawings: the dense cortical bone looks very dark; the trabecular bone, rich in medullary adipose tissue is very clear; the mucous membrane, the periosteum and the neurovascular structures also appear very clear; the air is black. T2 images have lower spatial resolution but sometimes, due to their high intrinsic contrast, they assume particular value in discriminating normal and pathological structures (6).

The image is determined by the sequence of acquisition which is used. Choosing the type of sequencing is the main way for the operator to optimize the signal received by the system under consideration (7). MR is, like CT, a type of tomography: it allows the formation of representative images only of the structures formed in layers that have been pre-selected, and pre-oriented in space (2,3). It is possible directly scan each plane of interest, without the need for further reconstruction of the image, contrary to what happens with CT DentaScan (8).

MR in implantology

Until recently, MR, mainly used in dentistry in the study of the temporo-mandibular joints (9,10), was believed not to be suitable for applications in the field of implantology. Faithfully reproduced data in all dimensions (necessary for implant diagnosis) seemed threatened by the fact that any alteration of the homogeneity of the applied magnetic field results in a geometric distortion of the image. This alteration occurs in presence of ferromagnetic elements, such as metal dental restorations or radiological markers of the template, but also in tissue-air interface (4).

It was then observed (11) that the artefact to ferromagnetic elements is extremely localized and does not bring a significant problem, since the edentulous implant site is still relatively distant. Furthermore, the difference in magnetic behaviour between tissues and air, responsible for the distortion, affects the implant assessments, since the angle and depth measurements are taken under the mu-

cosa, away from the interface with air.

It was suggested that a partial solution might be to apply a gel between the mucosa and radiological template in order to remove the air and reduce the artefact. However, this does not solve the problem in the upper jaw, where the interface between air and Schneider mucosa remains unchanged. It is also important to note that the geometric distortion is greatly reduced if you employ scanners that use a magnetic field of lower intensity. Gray et al. (5) have obtained favourable results using tomography dedicated to the study of joints that uses fields of a considerably reduced intensity (0.2 Tesla) if compared to the usual (0.5-1.5 Tesla).

Further improvements can be achieved by changing, when appropriate, the protocol of image acquisition and using receiving coils specifically designed for the single application. In implantology when you are faced with complex cases, where there are very few points of reference, the use of a template is recommended. Once routinely radiographic examinations (Fig. 1) and diagnostic wax-up are performed, a modified template can be built, similar to the traditional radiological template, but without metal or gutta-percha landmarks (Fig. 2).

The template for MR (scanning template) consists of a mask of transparent acrylic resin, in which holes of 2 mm in diameter, with a proper slope, are dug through potential implant sites. The holes are filled with a solution of 2 ml of Gd-DTPA (Magnevist, Schering AG, Berlin, Germany) (11) in 1000 ml of saline and then sealed with acrylic resin (Fig. 3). The resin appears as a dark area, with low signal, and produces no artefacts. Magnevist II contains metal ion gadolinium, a paramagnetic substance that, by reducing the T1 of the protons of the water of the solution, increases the signal (12). In T1-weighted ima-



Figure 1 - Panorex.



Figure 2 - Modified template, similar to the traditional radiological template, but without metal or gutta-percha landmarks.



Figure 3 - Holes filled with a solution of 2 ml of Gd-DTPA in 1000 ml of saline and then sealed with acrylic resin.

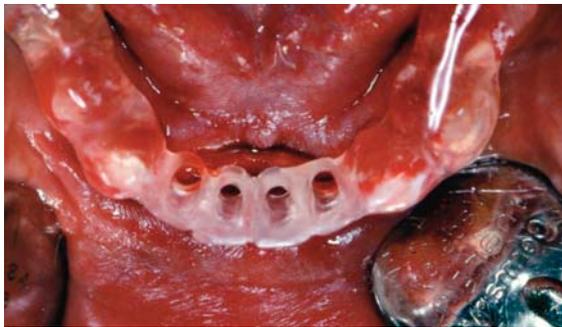


Figure 4 - The scanning template modified into a surgical template.

ges, the markers that are accordingly obtained are clearly visible, and therefore offer clear reference points that allow you to make the measurements necessary to turn the scanning template into a surgical template (Fig. 4). The purpose of this study was to evaluate and compare the ability to conduct a proper pre-implant treatment identified through the use of MR rather than CT DentaScan.

Materials and methods

We selected 30 patients with monoedentulism or partial edentulism requiring the insertion of osseointegrated implants. After the usual routine radiographic examinations, the group underwent both CT DentaScan and MR of the jaws. In more complex cases a diagnostic wax-up was carried out and a template was built: this was first used as a template for CT DentaScan and later modified in the template scan for MR, replacing the metal or gutta-percha landmark with a solution of gadolinium or 0.2% saline. The CT DentaScan was performed for each patient according to standard procedures. The MR of the jaws, for implant evaluation purposes, was performed by acquiring images PD, T2-weighted and T1-weighted. The MR examination was performed using a scanner with 1.5-magnet and a coil head, which is dedicated to the study of the head and the neck.

Spin-echo sequences were used: these require about three minutes for each acquisition with a slice thickness of 3 mm and a space between each layer and the other of 0.3 mm. During the initial MR a (scout) triplanar (axial,

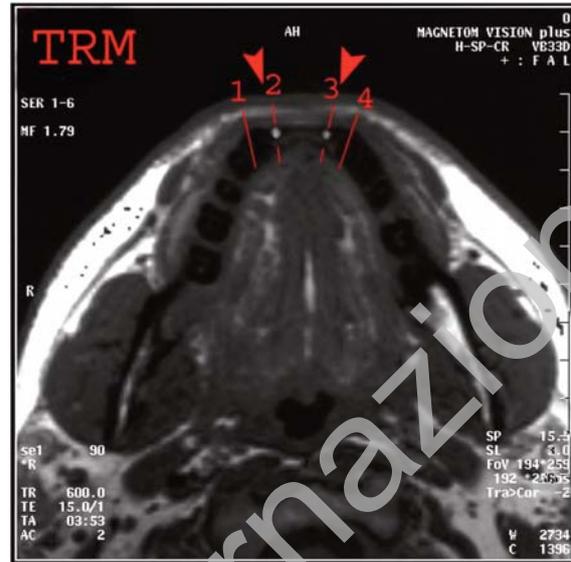


Figure 5 - The marker of the template scan are located through a set of axial images.

coronal and sagittal), low resolution, with a fast gradient-echo sequence test-scan is carried out: this provides the images needed to control the alignment of the patient; the scan time is 6-14 seconds. The sagittal test scan is used to prepare a set of axial images aligned to the mandible or maxilla as needed. The edentulous sites or the marker of the template scan are located through this set of axial images (Fig. 5). On the basis of data from the axial reference image the orientation of the next set of orthoradial pictures is determined.

In the event that a template scan has been used, potential sites are indicated by landmarks labelled with Gd-DTPA, clearly visible on T1-weighted images. The same axial reference image is then used to program the oblique sagittal sections, tangential to the jaw line in the posterior. The orthoradial (Figs. 6-7) images provide excellent cross-sectional information of the depth and, together with the oblique sagittal images obtained by performing cuts parallel to the hypothetical axis of implantation, allow a quantitative three-dimensional assessment.

However, if the oblique sagittal set of images is not properly oriented, the quantity of available bone is over- or underestimated because of the wrong perspective. For this purpose, a cross-evaluation with the set of orthoradial images is useful in order to reduce the risk of error. The images provided by the MRI and CT examinations were delivered to three specialists in Oral and Maxillofacial Radiology to measure the bone height at the specific sites. The measurements obtained by the specialists in MRI and CT images were compared using the ANOVA test with a 0.05 significance level.

The measurements on the available bone can be made by using the centimeter grade scale available on the printed copy. If necessary, a reference grid can be laid over the image for measurement. The numbering of the single cuts must be shown on the axial reference image or set-up and on the Panorex type image, to allow a quick identification of significant cuts. It is advisable that the set-up image with the numbers be printed on film along with the

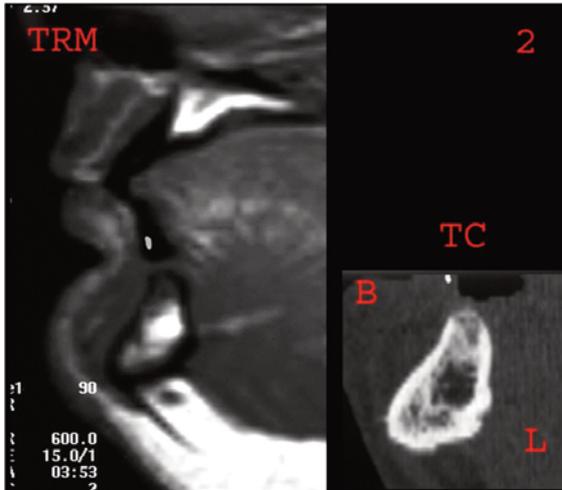


Figure 6 - Orthoradial and sagittal images.

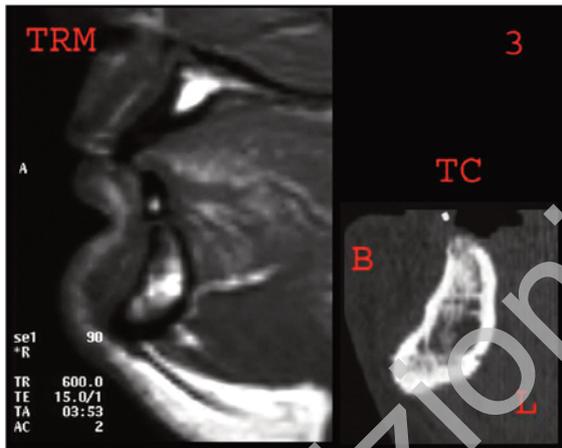


Figure 7 - Orthoradial images parallel to the hypothetical axis of implantation.

images of the cuts, in order to allow the surgeon to orient the images according to a correct plan, and to prevent involuntary reverses to the opposite side of the maxilla.

Results

In all cases, it was possible to plan the placement of osseointegrated implants using both CT DentaScan and MR of the jaws (Fig. 8).

The differences between the measurements from the MR and CT exams varied from 0.04 to 1.1 mm. There were no statistically significant differences ($P=0.9$).

Being able to clearly identify nerves and vessels the safety of those operating systems is substantial, and implants can be safely and securely placed in sites (Fig. 9) where it would otherwise be dangerous if using bi-dimensional radiographic techniques. In the MR images the cortical and medullary bone are easily distinguished, thus allowing us to anchor the apical cortical bone for optimal implant osseointegration.

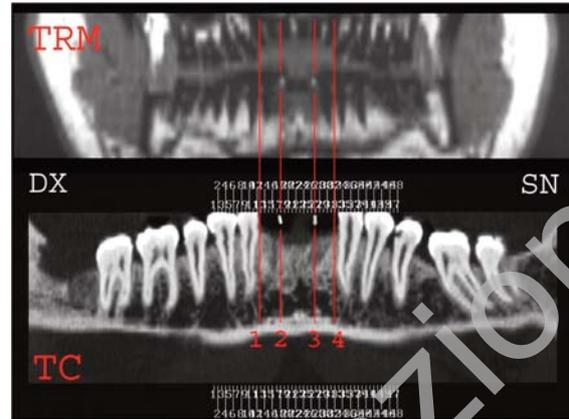


Figure 8 - Differences between the measurements from the MR and CT exams.

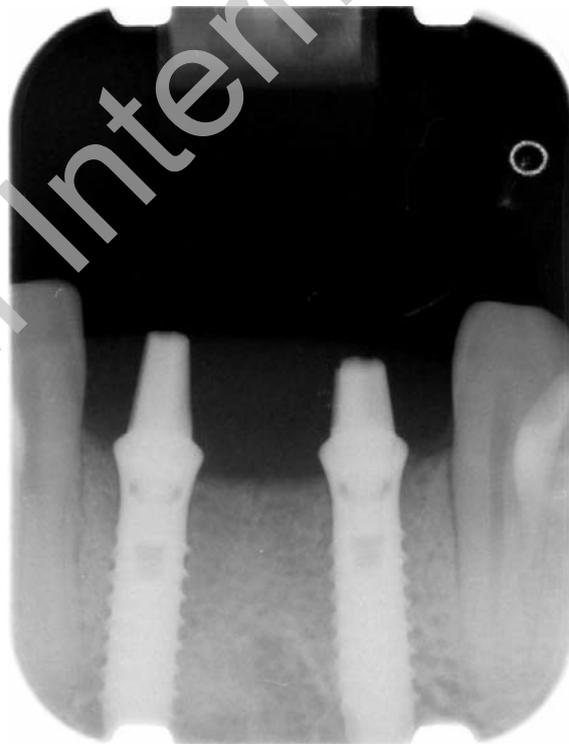


Figure 9 - X-ray control of implant position.

In MR the production of artefacts is minimal and localized. It was found exclusively around ferromagnetic structures like the old small metal dentin pins. This is a good result if compared to CT where there is less image degradation in correspondence with amalgam fillings, but the degradation is potentially important since it occurs near the region of interest, and also there is a difference in magnetic susceptibility between bone and soft tissues and between tissues and air; this also sets changes in the magnetic field which can cause a distortion of the MR image.

The effects at the bone-tissues interface are really negli-

gible, while the image distortion caused at the tissue-air interface may be more important, especially when the depth of the implant placement are measured in the order of 10 mm. However, current errors are substantially minimal, since the two points between which the depth of insertion is measured are not directly at the interface with the air, but are covered by mucosa. The problem of spatial distortion requires further investigation: yet it is important to note that the distortion is highly dependent on imaging protocols that are being used; the spin-echo protocols, used by us in the images, minimize these artefacts. In all 30 cases examined, MR images appeared perfectly comparable to CT images. Moreover, the image of the tissues is so exact to show even the formation of clot in the empty alveolus on the mend.

Discussion and conclusions

Considering the increasing attention towards the absorption of ionizing radiation for diagnostic purposes, it becomes increasingly difficult to subject patient to CT if the pathology is not very significant. (13). In the dental field CT images are usually reconstructed using a software which reduces radiation exposure (14). This procedure, however, can lead to dimensional errors (7). With the exception of few medical counter-effects, MR is a valid alternative to CT: it is biologically safe (does not use ionizing radiation), provides clear images of the implant sites and also allows the use in more complex cases of templates (15).

Although the images are different from those of CT, the surgeon is able to familiarize with the MR images. It may still be argued that similarly to the methodology of CT DentaScan, a considerable amount of information about sites of interest could be acquired using a single three-dimensional sequence gradient-echo with high-resolution, which would allow you to create appropriate images for the reconstruction without the need to acquire additional sets of images with different orientations (16).

We have not pursued this technique for the higher risk of magnetic susceptibility artefacts (17) that you have with the gradient-echo images, and also for the scan time in regard to the two-dimensional spin-echo sequences, with the associated risk of degradation of the image due to movement of the patient.

MR provides high-resolution images of the implant site, which give three-dimensional information on spatial relationships of vital structures, and is not subject to errors inherent in the use of the technique for measuring the depth and the angle of implant placement related to mandibular nerve.

Additional clinical tests, aimed at the comparative evaluation of MRT and CT DentaScan in pre-implant planning procedures, are reasonably required to determine the individual technical advantages of one technique over the other. MR is a method with good definition, unlike CT: it allows complete flexibility in the alignment of the cuts, so the operator can move the acquisition plan as appropriate.

Another recently acquired possibility offered by MR is to use equipment dedicated to the study of small joints with a permanent magnet of 0.2 Tesla. The low field scanner is an open scanner where the patient is lying under the magnet on a table, not isolated by walls. This and the

much lower noise produced by these scanners at low field, due to the reduced vibration forces acting on the coil magnetic field gradient, make this procedure acceptable.

The possibility of using low-field MR with a 0.2 Tesla magnet means costs reduced by half when compared to a 1 Tesla machine; this equipment is widely available, since it is used in the diagnosis of small joints: there is great potential for MR to be accessible to implant surgeons. All relevant structures (18) are well displayed; however, further studies are necessary to determine the technical advantages of resonance at lower fields, compared with those of CT and MR with medium or high magnetic field. It should, however, be noted that currently the high costs of equipment and management, as well as the limited availability of facilities for the realization of this type of diagnostic procedures, represent a significant barrier to widespread use of MR in practice. In all cases examined, MR images appeared perfectly comparable to CT images. Moreover, the image of the tissues is so exact to show even the formation of clot in the empty alveolus on the mend.

In the future the use of open low-intensity magnetic field scanners, could be a solution to reduce costs and extend the application of the technique without exploiting the few scanners available for the study of serious diseases.

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