

Interactions between Leone orthodontic and implantology devices and medical imaging techniques

Leone Quality System decided to compile this document considering the numerous demands received in the past years, about dental implants' and devices for fixed orthodontic appliances' possible negative effects on patient or images during the exams of Magnetic Resonance Imaging (MRI) or Computed Tomography (CT), including in this last category the Cone Beam Computed Tomography (CBCT). The literature review and the experts' advice allow us to state that, for what concerns the investigation technique involving ionizing radiations (TC and CBCT), both the metallic orthodontic devices and the metallic dental implants do not induce adverse effects on the patient and the chance of artifacts is nowadays reduced by regulating the parameter's settings during the image acquisition and thanks to the post processing software. As regards the MRI, a distinction should be made between the dental implants and the orthodontic device. The firsts, hardly, cause pulling or heating sensation for the patient and the eventual artifacts are usually attributable to the implant-prosthetic device's presence. The metallic fixed orthodontic devices, instead, that can or might acquire magnetic properties, might be dangerous for the patient or can create artifacts on images.

Magnetic Resonance Imaging (MRI), or Magnetic Resonance Tomography (MRT), is a image generation technique, used primarily for diagnostic purposes in the medical field, and based on the physical principle of nuclear magnetic resonance. It is a representation of an anatomical district, derived from the interaction between the atoms with a constant magnetic field and a rotating magnetic field orthogonal to the first.

The atoms' magnetic moment tends to align with the constant magnetic field and to rotate for the rotating magnetic field. The frequency of the rotating magnetic field is chosen in order to create a resonance condition. Once the rotating magnetic field is removed, the atoms return to their initial equilibrium state. The longitudinal and transversal variation of atoms' magnetic moment is recorded by the receiver coil and used to develop the image (In Figure 1, apparatus for MRI).

The MRI is not generally dangerous for the patient, except for the cases in which the magnetic field interacts with metallic materials present in the patient's body.



Figure 1: Apparatus for MRI

Instead, the patient is exposed to ionizing radiation (X-Rays) when undergoes to a Computed Tomography (CT). The CT result is the representation of the attenuation coefficient of the X-Rays in the anatomical district. It is known also as Computed Axial Tomography (CAT), but the axial attribution is not appropriate, it is more correct to define it Spiral CT, or helical CT. The Spiral CT allows to record data referred to an entire volume in one step, thanks to the combination of the slip ring technology and the smooth movement of the patient's bed through the gantry. Further application of the Computed Tomography is the Cone Beam Computed Tomography (CBCT), also referred to as C-arm CT, cone beam volume CT, or flat panel CT. It is a medical imaging technique based on radiology imaging technology that uses an X-ray source that makes one complete rotation of 360° degrees around the object to be examined, emitting a conical- or pyramid-shaped beam (cone beam). The advantage of this technique is that the total radiation doses used are generally lower than other CT exams. CBCT has become increasingly important in treatment planning and diagnosis in implant dentistry.

The inconvenience of these techniques is the use of ionizing radiations, hazardous for the patient.

For what concerns the medical imaging techniques based on the ionizing radiation (Computed Tomography, Cone Beam Computed Tomography), all the orthodontic and implantology devices do not show side effects on the patient and the eventual artifacts are usually attributable to the device presence (Figure 2).



Figure 1: CBCT image, example of artifacts generated by the metal brackets. In particular, the lighter lines in a radial pattern around the metallic devices, are due to the phenomenon of scattering of X-rays.

While, the effect of the orthodontic and implantology devices should be carefully monitored during MRI.

The Leone devices that can affect the MRI could be grouped into two categories:

1. Devices for implantology: dental implant, mono-implant for overdenture, healing caps, cover cap (polymer and medical grade barium), abutments and other prosthetic components.
2. Fixed orthodontic devices: metal brackets, bands, tubes, wires, archwires and springs, ligatures and preformed ties, expansion screws, silver solders, implants for orthodontic anchorage, radio-opaque medical grade barium and polyurethane separators.

The implantology devices, reported at point 1, are made of non-magnetic Grade 5 Titanium, which chemical composition is in accordance with ISO 5832-3. The polymeric cover cap presents 40% of barium sulfate which is a diamagnetic material¹. Some peculiar prosthetic components are made of gold non-magnetic alloy. Normally, these articles do not produce side effects on the MRI. However, according to the type of machine, the magnetic field magnitude, the anatomical district investigated, the induced magnetism due to standard practices in dental clinic (use of other metallic tools and devices for the application or the presence of other metallic device in the mouth), some artifacts may be generated on MRI scans. Generally, these artifacts do not lead to clinical misinterpretation of the images, since are usually attributable to the implant's presence; and do not cause pulling or heating sensation for the patient.

The orthodontic devices, reported at point 2, are made up of non-magnetic stainless steels type AISI 316, AISI 301, AISI 302, AISI 303, AISI 304, while some orthodontic brackets are made up of semi-austenitic steel type AISI 630 with intrinsic ferromagnetic features. Springs, wires and archwires can be realized also in non magnetic noble alloy of Nickel-Titanium, Chromium-Cobalt or Titanium-Molybdenum. Radio-opaque

¹ Diamagnetic materials create an induced magnetic field in a direction opposite to an externally applied magnetic field, and are repelled by the applied magnetic field. Therefore, the barium sulphate it is a characteristic contrast agent in the CT exam, while it is not commonly used as a contrast medium in the examination of MRI even if it is rarely used to enhance the performance of the exam in the gastrointestinal tract.

separators in modules have a content of around 10% of diamagnetic medical grade barium. Consequently, it is necessary to know the exact identification of the articles in the patient's mouth (through Leone identification code and lot number) in order to define the initial magnetic features. However, the austenitic stainless steel shows a not stable non magnetic phase that turns into a martensitic magnetic phase if plastically deformed, e.g. bending. The stainless steel seems to inevitably turn in a ferromagnetic state also after welding process. Besides, all the metallic alloy and parts with initial non-magnetic features may undergo a partial induced magnetism, which may be caused by the application, the assembling and the joint use with accessories and instruments, used during the shaping of the custom-made orthodontic appliance, or the presence of other metal parts in the mouth of the patient (Figure 3).

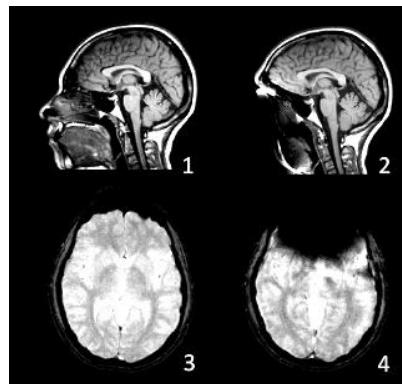


Figure 2: Distortion caused by stainless steel brackets detected by the 2 MRI sequences:

- 1, plastic trays, sagittal T1-weighted image;
- 2, stainless steel brackets, sagittal T1-weighted image;
- 3, plastic trays, axial GRE;
- 4, stainless steel brackets, axial GRE. [Elison, 2009]

Since Leone orthodontic articles are always used to manufacture custom-made orthodontic appliances by skilled personnel through not controlled manufacturing process using sometimes also products from different manufacturers, it is impossible to foresee all the cases.

Please notice that Leone orthodontic articles and fixed custom-made orthodontic appliances (assembled with those devices) have not been evaluated for safety and compatibility in the MRI environment. They have not been tested for heating, migration, or image artefact in the MRI environment. The safety of the orthodontic articles and fixed custom-made appliances in the MRI environment is unknown. Scanning a patient who has these devices may result in patient injury or create artifacts on images.

In conclusion, we suggest to the patient to report in advance to the health personnel responsible for MRI (Magnetic Resonance Image) the presence in the mouth of any type of device and dental material, based on the information received from the dental care provider, who will also take into account the considerations outlined in this document.

References

- Abbaszadeh K, Heffez LB, Mafee MF. Effect of interference of metallic objects on interpretation of T1-weighted magnetic resonance images in the maxillofacial region. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2000;89:759–765.
- Arash Poorsattar-Bejeh Mira,b,* and Manouchehr Rahmati-Kamelc, Should the orthodontic brackets always be removed prior to magnetic resonance imaging (MRI)?, *J Oral Biol Craniofac Res.* 2016 May-Aug; 6(2): 142–152.
- Aurélien Beau, Denis Bossard and Sarah Gebeile-Chauty, Magnetic resonance imaging artefacts and fixed orthodontic attachments, *European Journal of Orthodontics*, 2015, 105–110.
- Blankenstein F1, Truong BT, Thomas A, Thieme N, Zachriat C., Predictability of magnetic susceptibility artifacts from metallic orthodontic appliances in magnetic resonance imaging. *J Orofac Orthop.* 2015 Jan;76(1):14-29.
- Blankenstein FH1, Truong B, Thomas A, Schröder RJ, Naumann M., Signal loss in magnetic resonance imaging caused by intraoral anchored dental magnetic materials, *Rofo.* 2006 Aug;178(8):787-93. [Article in German].
- Costa A., Appenzeller S., Yasuda C., Pereira F., Zanardi V., Cendes F. Artifacts in brain magnetic resonance imaging due to metallic dental objects. *Med Oral Patol Oral Cir Bucal* 14(6):E278-82 (2009).
- Destine D., Mizutani H., Igarashi Y. Metallic Artifacts in MRI Caused by Dental Alloys and Magnetic Keeper. *J Jpn Prosthodont Soc* 52 : 205-210, 2008.
- Eggers G., Rieker M., Kress B., Fiebach J., Dickhaus H., Hassfeld S. Artefacts in magnetic resonance imaging caused by dental material. *MAGMA* (2005) 18: 103–111.
- Elison JM1, Leggitt VL, Thomson M, Oyoyo U, Wycliffe ND, Influence of common orthodontic appliances on the diagnostic quality of cranial magnetic resonance images. *Am J Orthod Dentofacial Orthop.* 2009 Jan;135(1):8.
- Gegauff A., Laurell K., Thavendrarajah A., et al. A potential MRI hazard: forces on dental magnet keepers. *J Oral Rehabil* 1990; 17:403-410.
- Go K., Kamman R., Mooyaart E. Interaction of metallic neurosurgical implants with magnetic resonance imaging at 1.5 Tesla as a cause of image distortion and of hazardous movement of the implant. *Clinical Neurology and Neurosurgery*, Volume 91, Issue 2, 1989, Pages 109-115.
- Haacke E. M., Brown R. W., Thompson M. L., Venkatesan R. *Magnetic Resonance Imaging: Physical Principles and Sequence Design*. John Wiley, 1999.
- Hornak J. P. *The Basics of MRI. Interactive Learning Software* 2008. Edizione italiana a cura di: Larobina M. e Alfano B. - CNR - Istituto di Biostrutture e Bioimmagini, Napoli, III Edizione - Ottobre 2010.
- Jin LY1, Lin J., Influence of dental metallic materials on MR imaging, *Zhejiang Da Xue Xue Bao Yi Xue Ban.* 2009 May;38(3):328-32. [Article in Chinese].
- Lissac M., Metrop D., Brugigrad, et al. Dental materials and magnetic resonance imaging. *Invest Radiol* 1991;26:40-45.
- Lomurno G., Lucarini L., Isaza Penco S., Regi L. Gaudiano S. Bracket ortodontici in corso di risonanza magnetica nucleare. *Mondo Ortodontico* 2003; 6: 445-452.
- Mattson J, Simon M. *The Pioneers of NMR and Magnetic Resonance in Medicine: The Story of MRI*. Jericho & New York: Bar-Ilan University Press, 1996.
- New P., Rosen B., Brady T., Buonanno F., Kisler J. Burt C., Hinshaw W., Newhouse J., Pohost G., Taveras J. Potenzial Hazards and Artifacts of Ferromagnetic and Nonferromagnetic Surgical and Dental Materials and Devices in Nuclear Magnetic Resonance Imaging. *Radiology* 1983; 147: 139-148.
- Nicolini C., Rigo A. *Biofisica e Tecnologie Biomediche*. Zanichelli, 1994.
- Patel A., Bhavra G. S., O'Neill J. R. S. MRI scanning and orthodontics. *Journal of Orthodontics*, Vol. 33, 2006, 246–249.
- Roth C. *MR Safety, OutSource Inc*, 1996.

- Sadowsky P., Bernreuter W., Lakshminarayanan A., Kennedy P. Orthodontic Appliances and Magnetic Resonance Imaging of the Brain and Temporomandibular Joint. *The Angle Orthodontist*, January 1988; 9-20.
- Sanders MA1, Hoyberg C, Chu CB, Leggitt VL, Kim JS., Common orthodontic appliances cause artifacts that degrade the diagnostic quality of CBCT images, *J Calif Dent Assoc.* 2007 Dec;35(12):850-7.
- Shafiei F., Honda E., Takahashi H., Sasaki T. Artifacts from dental casting alloys in magnetic resonance imaging. *J Dent Res* 82 (8), 2003. Pp 602-606.
- Shellock F., Crues J. High-Field-Strength MR Imaging and Metal Biomedical Implants: An Ex Vivo Evaluation of Deflection Forces. *American Journal of Roentgenology* 1988; 151: 389-392.
- Shellock F., Curtis J. MR Imaging and Biomedical Implants, Materials, and Devices: An Updated Review. *Radiology* 1991; 180: 541-550.
- Starčuk Z., Bartušek K., Hubálková H., Bachorec T., Starčuková J., Krupa P. Evaluation of MRI artifacts caused by metallic dental implants and classification of the dental materials in use. *Measurement Science Review*, Volume 6, Section 2, No. 2, 2006.
- Suh J., Jeong E., Shin K., Cho J., Na J., Kim D. Han C. Minimizing artifacts caused by metallic implants at MR imaging: experimental and clinical studies. *American Journal of Roentgenology* 1998; 171: 1207-1213.
- U.S. Food And Drug Administration. Guidance for Industry and FDA Staff. Establishing Safety and Compatibility of Passive Implants in the Magnetic Resonance (MR) Environment. August 21, 2008.
- Valli G., Coppini G. *Bioimmagini*. Patron Editore, Bologna, 2005.
- Wolbarst A. B. *Physics of Radiology*. Prentice Hall, 1993.
- Borsa, Gulmanelli, Scannicchio. *Fisica biomedica*, Pavese, 1983.
- Hinshaw D. B. Jr., Holshouser B., Engstrom H., Tjan A., Christiansen E. Catelli W. Dental material artefacts on MR images. *Radiology* 1988; 166: 777-779.
- www.wikipedia.it, October 2016.
- Zahra Dalili Kajan, Jalil Khademi, Ahmad Alizadeh, Yasamin Babaei Hemmaty, and Zahra Atrkar Roushan, A comparative study of metal artifacts from common metal orthodontic brackets in magnetic resonance imaging, *Imaging Sci Dent.* 2015 Sep; 45(3): 159–168.
- Erika Ozawa, Ei-ichi Honda, Kulthida Nunthayanon Parakonthun, Hiroko Ohmori, Kazuo Shimazaki, Tohru Kurabayashi and Takashi Ono, Influence of orthodontic appliance-derived artifacts on 3-T MRI movies, Ozawa et al. *Progress in Orthodontics* (2018) 19:7.
- Maria Francesca Sfondrini, Lorenzo Preda, Fabrizio Calliada, Lorenzo Carbone, Luca Lungarotti, Luisa Bernardinelli, Paola Gandini and Andrea Scribante, Magnetic Resonance Imaging and Its Effects on Metallic Brackets and Wires: Does It Alter the Temperature and Bonding Efficacy of Orthodontic Devices?, *Materials* 2019, 12, 3971.
- Ingrid Różyło-Kalinowska, Beata Walawska, Agnieszka Predko-Engel, Elżbieta Jurkiewicz, Andrzej Urbanik, MAGNETIC RESONANCE IMAGING IN ORTHODONTIC PATIENTS Guidelines of the Polish Orthodontic Society (PTO), the Polish Medical Radiological Society (PLTR), and the Polish Dental Association (PTS), *J Stoma* 2019; 72, 1: 1–3.
- Adrienn Dobai, Fanni Dembrovszky, Tamás Vízkelety, Péter Barsi, Fanni Juhász and Csaba Dobó-Nagy, MRI compatibility of orthodontic brackets and wires: systematic review article, Dobai et al. *BMC Oral Health* (2022) 22:298.