Assessment of MR compatibility of selected dental alloys

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Introduction

The increasing number of indications for MRI examination of the head and neck regions is associated with growing amount of patients with metal objects present in the orofacial region, such as dental crowns, fixed bridges, splints and implants, surgical fixtures and clips. This trend also reflects the frequent usage of dental implants in the reconstruction of prosthetic defects in the oral cavity and in modern surgical methods in traumatology (osseosynthesis with micromeshes and microplates). These appliances are made of various metal alloys, differing greatly in their magnetic susceptibility as well as conductivity, which determine their MR impact. For reasons of data quality or safety, the presence of some of these materials may limit the patient's eligibility for an MRI examination, especially of the maxillofacial region (dental MRI, oncological and traumatological diagnoses or genetic malformations) or MRS. The clinical demand for MR-compatible materials will be even emphasized in systems with higher magnetic field. The goal of this work was to provide dentists and dental alloy producers with indications about the MR significant differences between various materials and, ultimately, to help them to prefer more MR-compatible materials.

Materials and Methods

Among the commercial materials tested there were (1) alloys of precious metals (Au, Pt, Ag, Ir, Pd), (2) alloys of non-precious metals (Co-Cr, Ni-Cr), and (3) amalgams (Hg+Ag-Sn-Cu). For their evaluation, cylindrical samples (length 20mm, diameter 4mm) were prepared, placed in a plastic holder in parallel with B_0 = 4.7T and immersed in water. 2D gradient echo images (TE=4.36ms) were taken from 1-mm-thick slices perpendicular to B_0, set to intersect the sample in the middle. The slice selection gradient of 90.5 mT/m (3860 Hz/mm) was sufficient to limit the slice deviation to <1mm, which was confirmed to be negligible by numerical modeling and by imaging of orthogonal slices. The readout distortion (gradient of 20.0 mT/m, or 850 Hz/mm) was taken care of in data evaluation. Unwrapped phase images were used for the construction of B_0 inhomogeneity maps, which were compared with the results of a numerical model based on Fourier-domain calculation [1]. The values of magnetic susceptibility were derived by least-square-error fitting. The electric conductivity was determined by standard electrotechnical measurements of the same cylindrical samples.

Results

None of the 23 tested materials was ferromagnetic, no forces or torques were detected. The table summarizes the composition of the materials (weight %), the conductivities σ and magnetic susceptibilities χ found.

Material	Ag	Au	C	Ce	Co	Cr	Cu	Fe	Hg	Ir	Mn	Mo	Nb	Ni	Pd	Pt	Si	Sn	W	Zn	Ti	σ [S.m/mm²]	χ [10⁻⁶]
Hg+Ag-Sn-Cu 1	69.3						10.9											19.4		0.4		**3.67**	**-30**
Hg+Ag-Sn-Cu 5	42						26.5											31.5				**4.13**	**-30**
Hg+Ag-Sn-Cu 2	69.4						4.6											26				**3.24**	**-28**
Hg+Ag-Sn-Cu 3	50						20.1											29.9				**3.79**	**-26**
Hg+Ag-Cu-Sn	70						15		3									12				**3.41**	**-25**
Hg+Ag-Sn-Cu 4	43						25.4		2									29.6				**3.92**	**-25**
Au-Pt-Ag	2	77.6								<1						18				1.8	<1	**5.37**	**-24**
Au-Pt-Pd		78								<1					6.8	11.5						**5.49**	**-23**
Ag-Sn	89.9																	9.3		<1		**2.55**	**-23**
Ag-Pd	57.5														40			<1		2.1		**4.07**	**-16**
Ag-Pd-Cu-Au	59.9	5					10			<1					22.5			<1		2		**6.23**	**-12**
Ag-Au-Pd-Cu	44.8	20					14.4								20					<1		**4.77**	**-11**
Ni-Cr-Mo 3				0.3		22.6		0.5				9.6	1	65			1					**0.81**	**373**
Ni-Cr-Mo 2			<0.02	0.5		22.5		0.5				9.5	1	65			1					**0.8**	**410**
Ni-Cr-Mo 1						20.5						5		66			1.5					**0.89**	**415**
Co-Cr-Mo-W			<0.02	0.5	61	26		0.5				6					1		5			**1.18**	**800**
Co-Cr-W-Mo					63	24						3	1				1		8			**1.14**	**826**
Co-Cr-Mo-W					61	26		<2			<2	6					<2		5			**1.18**	**920**
Co-Cr-Mo 1			0.3		62.5	29.5					0.6	5.5					1.4					**1.15**	**950**
Ni-Cr-Fe			<0.1			23		9				3		63.2			1.8					**0.84**	**990**
Co-Cr-Mo 2			<0.35		64	28.65					<0.35	5					<0.35					**1.23**	**1100**
Co-Cr-Mo 3			<2		63.5	28.5		<2			<2	5.8					<2					**1.26**	**1370**

Discussion and Conclusion

Materials from the first group (yellow) and amalgams (grey) are slightly diamagnetic (χ= -11x10^{-6} to -30x10^{-6}) and do not influence B_0 homogeneity significantly except in the object's very close vicinity. The highest conductivities were found in the group of precious-metal alloys, while the conductivity of amalgams was marginally lower. Materials of the second group (blue) were found highly paramagnetic (χ=370x10^{-6} to 1370x10^{-6}) and less conductive. As a result, these materials lead to large B_0 inhomogeneities. Large differences exist, however, within this group. Increased RF heating and higher B_1 inhomogeneity and are to be expected with the former two groups of materials.

Acknowledgements

This work has been supported by the Grant Agency of the Ministry of Health of the Czech Republic (IGA MZCR 8110-3/2004) and in part by the Grant Agency of the Czech Republic (GACR 202/02/1493).

References

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