MR-visible Surgical Meshes: Optimization and Phantom Studies

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Introduction: Pelvic organ prolapse (POP) is a common disease in elderly women [1]. One way of treating POP can be with classical surgery or with help of partially absorbable alloplastic material, so called meshes. Yet besides visible negative side effects, such as mesh erosions, other to be mentioned post-operative complications can occur after mesh implantation (e.g. complex pain syndromes). Often, another surgery is the only option for diagnosing the complication origin and in consequence being able to treat correctly. As a possible method for better diagnosing the MRI could be used to qualify misplacement or deformation of the implanted mesh; however, current meshes are not visible in MR and CT images. In this work MR measurements are presented to develop and optimize an MR visible implantable mesh for POP repair. Magnetic particle concentrations were determined based on relaxometric evaluation, and thread material with magnetic particles was tested for its MR visibility.

Materials & Methods: Two different iron-oxide materials (*FeOOH* and Fe_3O_4) were used to create MR visible meshes. Initially, measurements of the relaxation times T1, T2, and T2* were performed for different concentrations of these materials in both gel and palm oil. In particular, R2 values were measured for *FeOOH* dissolved in concentrations from 0% to 1%, and for Fe_3O_4 between 0% and 0.1% (Fig 2). Based on the measurements, SERASIS® (Serrag Wiessner, Naila, Germany) implants were woven of polypropylene threads with embedded ferromagnetic pigments (Fig 1, Table 1). For MR imaging, the thread material was placed in a water bath. Images of the setup were acquired at a 1.5T MR system (Tim Symphony, Siemens Healthcare, Erlangen, Germany) with 3 standard imaging sequences (Table 2).

Results & Discussion: Figure 2 shows that R2 of the solution depends linearly on the concentration of the pigments indicating that an increasing pigment concentration in the threads improves the visibility of the mesh. Figures 3a-c show the visibility of sample 3 in MR images taken with standard imaging sequences. Sample 1, 2 and 4 are only visible in the FLASH image (Fig 3a), though with reduced contrast. Since the pigments are embedded in the polypropylene threads, a direct comparison with the solution data is not possible. Higher pigment concentrations than those found in the R2 measurements need to be used to make the mesh MR-visible. A concentration of 0.2% Fe_3O_4 is a good compromise between the signal decay in the proximity of the threads and a clear visibility of the mesh.

Conclusion: MR-visible mesh implants can be manufactured, when ferromagnetic particles are added to the mesh material in an adequate concentration. Surgical meshes with an 0.2% Fe_3O_4 concentration could simplify follow-up examinations, which might help avoiding additional surgical interventions.

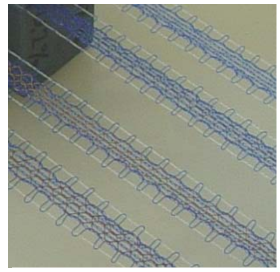

Figure 1: *Photograph of the mesh materials (from bottom left to top right) sample 1 to 4.*

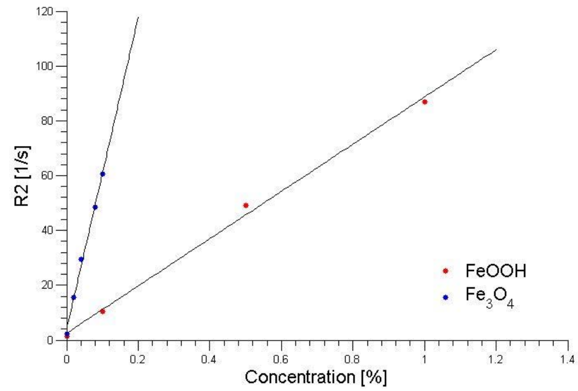

Figure 2: *Plot of measured R2 values of Fe_3O_4 and FeOOH dissolved in gelatin*

	Pigment yellow 42 (FeOOH)		Pigment black 11 (Fe_3O_4)	
Sample	1	2	3	4
Concentr.	5.0 %	2.5%	0.2%	0.02 %

Table 1: *Concentration of pigments in different samples*

	TR [ms]	TE [ms]	BW [Hz/px]
FLASH 3D	15	6	179
Turbo Spin Echo	4000	110	260
TrueFISP	3.8	1.79	751

Table 2: *Imaging sequences and parameter used to test the MR-visibility of the mesh implants*

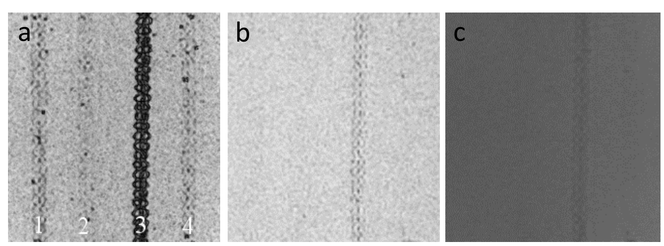

Figure 3: *Minimum intensity projection (mIP) from (a) 3D FLASH and (b) Turbo Spin Echo image. (c) TrueFISP single slice image*

References: [1] Brocker KA, Alt CD, et al. Eur J Obstet Gynecol Reprod Biol. 2011 Jul;157(1):107-12

The first and the second author have contributed equally to this work.