MR-IMAGING OF RESINS AND COMPOSITES AS BIOCOMPATIBLE MATERIALS FOR MEDICAL APPLICATIONS

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Introduction/Purpose

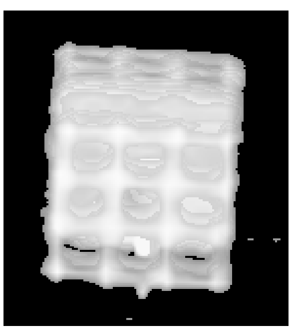
Resins and high-dense polymers are used in an increasing number of medical applications as implant material for instance in hip cups, pacemakers, cervical and lumbar spine implants as well as in joints replacing the function of the cartilage layer. Composites consisting of methacrylate and ceramic compounds are used for dental care due to their superiority in hardness over simple polymers. Imaging methods based on MR are known for their advantages in the visualization of soft tissue in the human body but standard 2DFT imaging is not capable of collecting signal from the very fast decaying magnetization in such type of materials due to the very short T2 [1]. Therefore only the contours of the solid implant material might be visualized, leaving inner structure including possible manufacturing errors or mechanical degradation due to mechanical stress undetected. We investigated, whether it is possible to visualize resins and composites by special pure phase encoding MR-methods (Single Point Imaging: SPI) and detect also inhomogeneities in the material due to incomplete polymerization and mechanical stress. We also investigated which resolution might be obtained with 3 dimensional SPI using specifically designed phantoms based on resins.

Materials and methods

The small sized, 3-dimensional hollow-cave-type resolution phantoms (half period a/2 = 800 µm) were manufactured using stereolithography (SLA) based on the laser induced surface polymerization of a liquid photosensitive monomer. The composites mainly consisting of a methacrylate (BIS-GMA) and barium-aluminum-fluoride with silicon-dioxide as filler are used for conservative dentistry in routine application. For simulation of incomplete hardening we illuminated the small thin composite disks ($12x12x2mm^3$) via an absorption mask, which consisted of several small finger type openings of about 1 mm lateral size, using intense blue light from a clinically applied light source. High resolution T2*-weighted SPI is achieved on a 3T-MR-scanner using a powerful gradient-system (G=200 mT/m) and a sensitive small sized 1H-free birdcage resonator.

Results

A maximum intensity type projection of the 3D-SPI data set is shown in fig. 1. The openings and bars are visualized, indicating the high resolution obtained (r < 800 µm). In composites incomplete solidification below the fingers of the mask is observed in hyperintense areas of the T2*-weighted SPI-image (see fig. 2 nr. 1). Mechanical stress via a point-type load from the backside in the center of the sample is reflected in a brighter circular-type zone (see fig. 2 nr. 2).



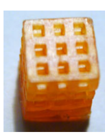


***Fig. 1a** Photo of the 3D-resolution phantom. The cube manufactured via SLA (epoxy) exhibits small 800 µm wide periodically arranged bars and openings.*

***Fig. 1b.** Maximum intensity projection image of the 3D-SPI-data (TD = 80 µs, VS: 344 x 344 x 406 μm^3)*

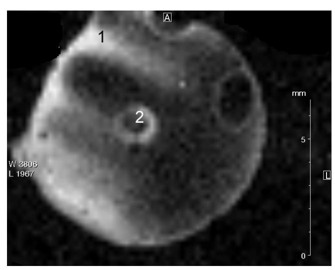


***Fig. 2** T2*-weighted SPI-imag of an irradiated composite paste disk (TD: 240 µs, VS: 292x 292x625 μm^3). Hyperintense areas indicate incomplete solidification (1). Destruction of parts of the polymer matrix from a mechanical load is also observed (2).*

Conclusion

The visualization of semisolid areas in composites and epoxy materials is possible by short detection-time MR-methods. The solidification process may be quantified via T2*. Structures of a/2 = 800 µm might be detected in incompletely polymerized epoxy materials. The final resolution is actually depending on the individual T2* of the biocompatible material, the sensitivity of the MR-detector and gradient-strength available.

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References

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