Radio-opacity of Bioresorbable X-ray Markers in the Cervical Spine

Bron, J L; Hoogendoorn, R J; Ruffieux, K; Wuisman, P I; Smit, T H

Introduction
In the past years, spinal cages composed of bioresorbable materials, especially polylactides, have been introduced in clinical practice. Advantages of the new generation cages include that they are temporary, have a lower modus of elasticity and are radiolucent. Biodegradable cages lack interference with Computer Tomography or Magnetic Resonance Imaging, offering advantages for accurate assessment of the fusion segment. However, the radiolucency of the cage may compromise the conventional radiological positioning and follow up after surgery. In order to determine the exact intra- and postoperative position of the cage, tantalum marker balls are currently embedded in the bioresorbable cages. Tantalum markers however, remain within the fused bone after the cage itself has been desorbed, and have the risk of migration or become the focus of an disseminated infection. These possible risks could be prevented by using bioresorbable X-ray markers. The aim of this study was to investigate the radio-opacity of degradable markers, composed of different concentrations Barium Sulfate (BaSO₄) dissolved in polylactide, which could be embedded in bioresorbable cages.

Materials and Methods
POM sample-discs containing a 1.0 and 1.5 mm marker of BaSO₄ dissolved in polylactide, were fabricated in four concentrations (w/w 30, 50, 65 and 75 %). (Fig. 1) From each concentration 3 different sample discs were prepared. Blanc discs and discs containing 0.5 mm titanium wire samples were used as control.

![Figure 1: picture (l) and schematic presentation of sample plate (r)](image)

Initially, an overview plain radiograph was obtained from all samples. Thereafter, the intervertebral disc between the 5th and 6th cervical vertebral body of a goat cadaver was incised anteriorly. After evacuation of the intervertebral disc the samples were placed randomly in the disc space and anteroposterior plain radiograph were taken (Fig. 2). An aluminium wedge of stepwise increasing thickness, 5 - 50 mm, in 5.0 mm increments, was used as a standard for radiopacity measurements and was included in every radiograph. All radiographs were taken using a single bundle set at 33 mAs, 40 kV, 0.6 s. Average intensity values (range 0-255) were measured on the digital x-ray images by randomly selecting 3 positions on every marker and on every step of the aluminium standard. The values of the standard were fitted to a curve, representing the relation between intensity and aluminium thickness. Using this curve, the radio-opacity of the markers (expressed in mm aluminium) was calculated.

![Figure 2: X-ray of cervical spine with a sample plate implanted](image)

Results
Analysis of the wedge radiographs resulted in a logarithmic relationship between aluminium thickness and intensity. The R²-value of the aluminium standard curve was 0.99, which indicates a high correlation between aluminium thickness and intensity. All samples could be accurately identified on plain radiographs as the position of the plates (Fig 2). The radio-opacity of the samples significantly increased with increasing BaSO₄ concentrations (Fig. 3). On the overview radiograph, these differences were statistically significant (p<0.05). On spine X-rays however, the absolute opacity values and the variation between the values were higher due to over-projection of soft tissues. From each concentration BaSO₄, the opacity of the sample with 1.5 mm thickness exceeded the 1.0 mm sample, but this was not significant. The BaSO₄ samples were significantly more opaque than the titanium wire sample, for concentrations > 50 % BaSO₄ (p<0.05).

![Figure 3: Mean opacities of 4 concentrations BaSO₄ and Titanium](image)

Discussion
All markers showed excellent visibility on plain radiographs, allowing accurate position determination of the samples plates in the cervical spines. For maximal visualization, markers should ideally contain 100 % BaSO₄. When the concentration BaSO₄ exceeds 65%, however, marker preparation becomes more difficult. Comparison of current biodegradable markers to titanium wires, which are frequently used in vivo, reveals a higher radio-opacity of all markers. Except from 30% BaSO₄, these differences were statistically significant. However, the diameter of the titanium wires that were used currently was 0.5 mm against 1.0 and 1.5 mm diameter of the BaSO₄ samples. The aluminium step wedge is still the only accepted way to evaluate the radio-opacity of barium sulfate on radiographs and is therefore used in the current study. We found a logarithmic curve to describe the relationship between the aluminium step wedge and the intensity on plain radiographs. This is in contrast to other investigators who found a linear relationship. The reason for this may be the fact that we used a higher thickness of the step wedge (0 – 50 mm) compared to the former investigators (0 – 10 mm).

In conclusion, the current study proves biodegradable BaSO₄ markers to provide a suitable substitute for current generation non-resorbable markers in addition to cervical spinal fusion procedures.

References