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Technical Note

The fixity of prostate seed implants: The impact of the strand surface on its ability to migrate inside oil and gel medium

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ABSTRACT

PURPOSE: Radioactive seed implants are widely used to treat cancer patients, most commonly those with prostate cancer. However, the seeds have a tendency to migrate after placement in patients, a phenomenon that can result in unfavorable outcomes. The ability of the seed strand to migrate was investigated by examining the impact of the strand surface on the velocity of its movement inside oil and gel media.

METHODS AND MATERIALS: We investigated the motion of smooth surface strands and strands with different grooved helical profiles after they were placed in oil and gel media. Three patterns of grooved helices were studied (60, 140, and 300 rotations per meter). The movement of the strands through a tube filled with the medium was recorded by the motion sensor, and the drag forces on the individual strands were calculated and compared for the oil and gel media.

RESULTS: The strands with 60, 140, and 300 rotations/meter grooved helical surfaces demonstrated less mobility in both oil and gel than the strands with a smooth surface. The strand with the highest number of helical grooves per meter recorded the largest drag force and moved more slowly in both media.

CONCLUSIONS: The differential in the motion of the smooth strand and the strands with grooved surfaces can be attributed to the increased surface area of the grooved strands. This finding is significant since it will impact, theoretically, the design, and thus the migration of seed implants that are used to treat cancer patients, particularly those with prostate cancer. © 2015 American Brachytherapy Society. Published by Elsevier Inc. All rights reserved.

Keywords: Strands; Grooved helical surface; Drag forces; Radioactive seed; Migration

Introduction

Radioactive seed implants have been commonly used to treat cancer patients, and the most common type of cancer being treated with seed implants is prostate cancer. It is estimated that in 2010, a total of 217,730 men were diagnosed with prostate cancer [1]. Treatment options for early-stage prostate cancer include surgery, radioactive seed implant, and external radiation. Seed implant has become a more widely used treatment option because of its excellent cure rate, its convenience, and fewer side effects [2−13].

When implanting cancer patients with radioactive seed implants, loose seeds or strands with usually 2 to >5 seeds are connected in a bio-absorbable sleeve that is implanted subsequently in patients under ultrasound and fluoroscopy guidance. The accurate placement of the seeds is crucial for achieving the ultimate goal of cure without complications. However, these seeds and strands have a tendency to migrate (large dislocations) and shift (small dislocations) from their intended positions [14, 15]. It should be mentioned that seed migration or shifting can also be caused by prostate edema after implantation [16]. These migrations and shifts can result in adverse outcomes, both in terms of cancer cure as well as treatment complications. When a few seeds or strands of seeds shift away from the target area, cold spots are created (areas within the intended

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target receiving less than the intended therapeutic dose). Similarly, when these seeds/strands shift toward normal surrounding organs, such as the rectum and bladder, a higher than intended radiation dose is given to these organs, a situation that can result in severe treatment complications (bleeding, perforation, and fistula formation).

Although post-implant dosimetric analyses of prostate brachytherapy are commonly reported, the long-term persistence, or fixity, of seeds implanted in the prostate gland and periprostatic region remains unclear and under-reported, with only a few reports regarding the loss or migration of the seeds in the implanted region. In a recent report, at least one seed was lost in 31.5% of patients with a migration rate of 1.02%; 9.3% of patients had at least one seed located in the lung. The fraction of patients experiencing no seed loss decreased from 40% at 28 days to 20% at 180 days for I-125 and from 24% to 7% for Pd-103 over the same time interval [17]. Physicians at the Cookridge Hospital in the United Kingdom studied whether seed embolization to the lungs can be minimized with the use of stranded seeds alone for brachytherapy. Two hundred thirty-eight patients with early prostate cancer were treated between December 2001 and December 2002 with prostate brachytherapy implementing the stranded seed technique alone. During the prostate seed implant all patients had fluoroscopy and immediately following had radiographs of the pelvis. At an average of 55 days, a sample of 100 patients had a chest radiographs done. After review it was revealed that in all 238 cases the number of seeds found in the preceding radiograph matched the number of seeds implanted and concluded that with use of stranded seeds (RAPIDStrand™, Oncura Ltd, Buckinghamshire, England) for prostate brachytherapy, there was no evidence that seeds migrated to the lung [18]. Fagundes *et al.* also evaluated the difference between stranded and loose procedures of brachytherapy and their outcomes. Four hundred seventy-three patients were treated with brachytherapy between September 1998 and December 2003. With the use of MICK applicator™ (Mick Radio-Nuclear Instruments, Inc., Mount Vernon, New York, USA), 337 (71%) procedures placed seeds freely in the cancerous region. The stranded or RAPIDStrand™ was introduced in April 2002 and implanted for 136 (29%) patients. The dosimetric analysis of the data collected showed that the stranded approach resulted in greater V_{100} values (92.5%) than for free seeds (89.3%). This study concluded that the RAPIDStrand™ technique demonstrates an advantage over the standard free-seed method [19].

To demonstrate the impact of loose seeds and strands migration or dosimetry, Moerland *et al.* compared intraoperative (Day 0) dosimetry with postoperative dosimetry 4 weeks after the implant in patients treated in the period 2005−2007. Patients with stranded or loose seed implants had on average adequate D(90) values of 161 ± 30 Gy. Post-implant D(90) values were 22 ± 27 Gy lower compared with intraoperative planning. Decline of dose coverage between intraoperative planning and post-implant dosimetry was significantly larger for the stranded seed implants [20]. This situation is attributable to the fact that multiple seeds are embedded in the smooth strands and any shift of the strand from the intended site will bring about a decline in dose coverage to the target area.

Given the observations above, it is reasonable to conclude that minimizing or eliminating displacement of seeds/strands from their intended locations putatively will improve cancer cure rates and decrease treatment complications. In this study, we investigated the impact of different surface structures of strands on their ability to migrate by measuring the velocity of their movement in various media and comparing smooth-surfaced strands to strands having various helix-patterned grooved surfaces.

Methods and materials

Four types of L-lactide bio-absorbable strands (Zeus Industrial Products, Inc. Orangeburg, South Carolina, USA) were tested; one possessed a smooth surface and the other three had grooved profiles (Fig. 1). The grooved strands consisted of one with 60 rotations per meter and a second with 140 rotations per meter; the third strand demonstrated 300 rotations per meter. The diameter of their inner walls was 58 μm and their outer wall diameter was 100 μm. The depth of the grooves for the different strands is the same, but there are different helical groove rotations per unit length for the different strands.

The transient velocities of the different strands in two different media were determined: vegetable oil and JELL-O™ (Kraft Foods Global, Inc., Glenview, Illinois, USA). For experiments on the smooth strands in the oil, as illustrated in Fig. 2, vegetable oil was poured into a 1-m long vertical transparent tube having a diameter of 35 mm. A string was threaded through the smooth strand. A small weight was tied firmly to one end of the string, and the threaded strand was positioned until it made contact with the attached weight. The attached weight helped to keep the strand submerged in the oil and also ensured that the strand remained vertical. The strand together with its attached weight was lowered into the tube of oil at room temperature (23 °C) and to a depth of approximately 5 cm from the bottom.

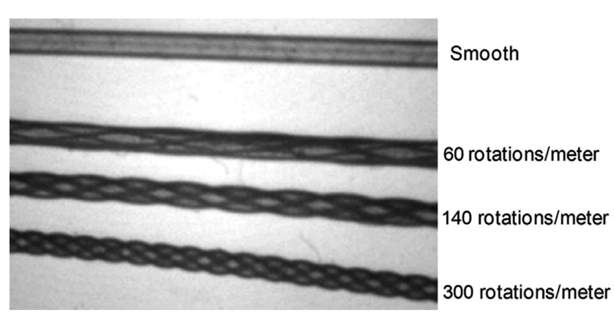

Fig. 1. Photos of four different L-lactide bio-absorbable strands.

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