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Mechanical Evaluation of a Helical Drive System for Rotating Shield Brachytherapy in Prostate Cancer

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RTF is the President of pxAlpha, LLC, which is developing an RSBT delivery system.

INTRODUCTION

Prostate RSBT delivery requires a unique mechanical delivery system that can precisely control helical source motion in order to generate highly conformal dose distributions.

- Delivery mechanisms have been described in multiple theoretical studies but have suffered from many limitations creating barriers to clinical implementation.
- The proposed mechanism for RSBT clinical delivery is a single-source, single-catheter system which uses a catheter angular drive system to automatically control the insertion of a therapeutic catheter into each needle in serial in a helical manner.

PURPOSE

- To mechanically assess the potential clinical viability of a helical delivery system to enable rotating shield brachytherapy for prostate cancer based on the ^{169}Yb isotope.
- Treatment delivery occurs in an automated manner using a single partially shielded source that treats each implanted needle in serial.

METHODS

- Helical source motion is generated by coupling the rotational and translational motion of a threaded rotating catheter which is connected to a nitinol needle containing the partially shielded source at its distal end (Fig 1).
- The catheter is controlled by a gear drive system containing a central gear with an asymmetric inner profile that corresponds to the axial profile of the catheter along its longitudinal axis.
- Rotational motion is generated by redundant high-torque, high-resolution stepper motors with an angular precision of 0.9° per step coupled to the asymmetric central gear.
- The threaded rotating catheter has a pitch of 5 mm to allow for up to 72 angular dwell positions per rotation.

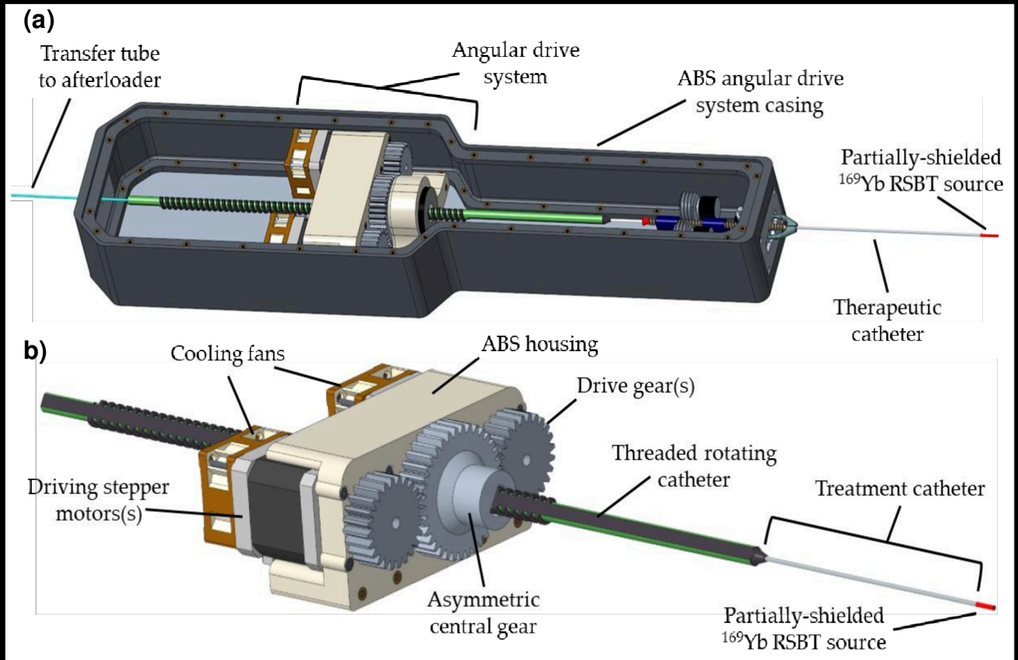

Figure 1 (a) Catheter angular drive system schematics with accessory components removed to highlight functional mechanisms (b) cross-sectional view with distal housing component removed demonstrating gear drive system and interface with threaded rotating catheter

RESULTS

- The prototype system was constructed (Fig 2) using primarily 3D printing and mechanical accuracy measurements of the helical source motion were obtained.
- Mechanical accuracy of the constructed angular drive system prototype (Fig 2) was evaluated in 3-D space using a FARO (Lake Mary, FL) FaroArm®, a coordinate measuring machine accurate to within ±0.016 mm.
- Translational (controlled by rotation) catheter positioning error was 0.18 ± 0.12 mm or less for all three step sizes considered over the 16 cm evaluation length.
- Angular positioning accuracy for 6.25° step sizes was 0.07 ± 0.78° and, for 22.5° step sizes, was 0.05 ± 1.6° (mean ± standard deviation).

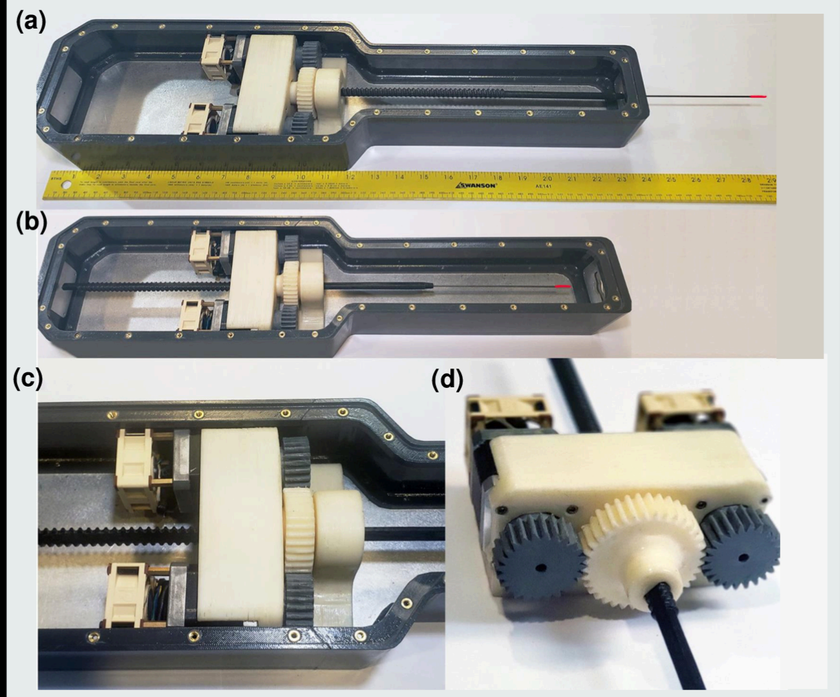

Figure 2 Constructed prototype with therapeutic catheter (a) fully inserted, (b) fully retracted, (c) zoomed view of gear drive system within housing, and (d) cross-sectional view demonstrating asymmetric central gear interface.

CONCLUSIONS

- The prototyped catheter angular drive system was able to control helical motion of the source to within clinically relevant tolerances, demonstrating adequate mechanical accuracy.
- Successful production and evaluation of the prototyped system, which is a core component of a complete future clinical delivery system, provides initial evidence for the feasibility of RSBT clinical implementation for prostate cancer.

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CONFLICT OF INTEREST

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