Advanced Implanted Markers for High Precision IGRT Localization

PolyMark™ Marker

1. Introduction

The use of implanted fiducial markers and daily imaging to improve tumor localization was introduced in the early 1990s. This methodology has now become the standard of care in cases where inter- or intrafraction motion is likely to occur. The high precision localization gained via the use of fiducial markers has allowed for reduced treatment margins, which in turn greatly reduces complication from radiotherapy. Furthermore, the advent of stereotactic body radiation therapy (SBRT) is well accommodated by the improved localization achieved when using implanted markers.

Design engineers are now looking to improve on the current marker offerings by carefully recognizing the unique needs of specific treatment sites and requirements of the varying image guided radiation therapy (IGRT) offerings.

2. PolyMark Marker

The PolyMark is based on the research and development of Mark de Langen (et al) at Erasmus University Hospital in the Netherlands. Recognizing a need for a fiducial marker that would reduce artifact in CT, de Langen set about specifying a new type of implanted marker. Instead of using a metallic material, other non-metallic offerings were explored and polyetheretherketone (PEEK) was decided upon as the main component. A tiny surgical stainless steel wire was placed at the core to create a signal in magnetic resonance images.

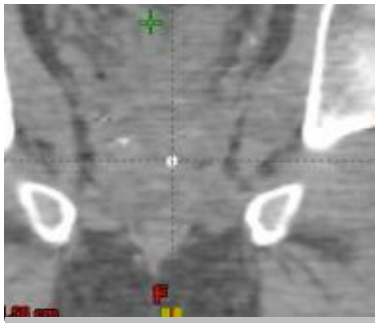

Figure 1

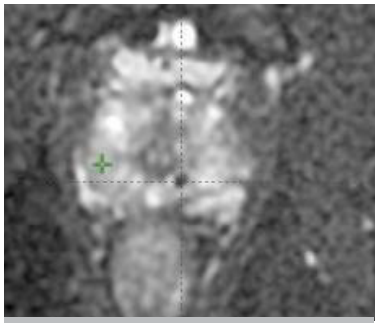

Figure 2

Feature advantages of Polymark markers:

Figure 1 – Virtually artifact free in CT
Figure 2 – Creates a black void in MR
Figure 3 – Clearly visible in all kV based IGRT systems
Figure 4 – Fabricated with a continuous spiral-cut surface to inhibit migration

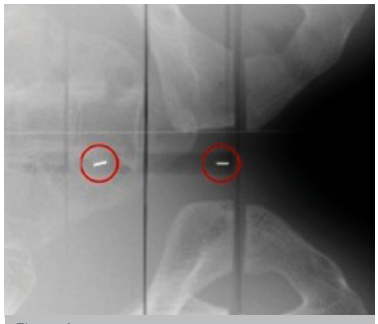

Figure 3

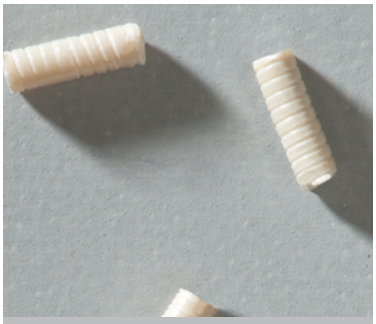

Figure 4

The PolyMark is currently available in two sizes: 1.0 mm in diameter and 3.0 mm in length, and 0.8 mm in diameter and 3.0 mm in length.

3. PolyMark Testing

A comprehensive review of all medical imaging platforms was performed prior to the PolyMark's FDA clearance . These tests include CT, MR, kV CBCT, and kV planer images.

Special consideration is given to MR imaging and interaction with the MRI device as a function of its magnetic field. The PolyMark Marker was tested for MR compatability using four separate tests defined by the American Society for Testing and Materials (ASTM). In all cases a 3-Tesla, Excite, HDx Software 14X.M5, General Electric Healthcare, Milwaukee, WI, active-shielded, horizontal field scanner was used for testing.

Listed below is a complete battery of tests that were performed.

1. ASTM F2052 - Standard Test Method for Measurement of Magnetically Induced Displacement Force on Passive Implants in the Magnetic Resonance Environment

The markers were suspended from a thin, lightweight string (weight, less than 1% of the weight of the device) attached at the 0° indicator position on the protractor. The length of the string was 20cm, which was long enough so the device could be suspended from the test fixture and hang freely in space. Motion of the string with each device was not constrained by the support structure of the protractor.

Results:
Mixed Media Marker: PEEK Polymer and steel

	Deflection Angle (degrees)
Measurement #1	1
Measurement #2	1
Measurement #3	1

Deflection Angle (degrees, m ± SD)
1 ± 0

Regarding this test, the ASTM standard reads, “If the implant deflects less than 45°, then the magnetically induced deflection force is less than the force on the implant due to gravity (its weight). For this condition, it is assumed that any risk imposed by the application of the magnetically induced force is no greater than any risk imposed by normal daily activity in the Earth’s gravitational field.” PolyMark passed this test easily.

2. ASTM-F2213 - Standard Test Method for Measurement of Magnetically Induced Torque on Passive Implants in the Magnetic Resonance Environment

The marker was placed on the test apparatus in an orientation 45° relative to the static magnetic field of the 3-Tesla MR system. The use of 45° increments is deemed appropriate for a qualitative assessment of torque for an implant or device. The marker was directly observed for possible movement with respect to alignment or rotation relative to the static magnetic field of the 3-Tesla MR system. The investigator viewed the inside of the MR system bore during the test procedure, thus facilitating the observation process. The marker was then moved 45° relative to its previous position and again observed for alignment or rotation. This process was repeated to encompass a full 360° rotation of positions for each device in the 3-Tesla MR system. The entire procedure was conducted three times and a mean value was calculated for each device with it orientated along its long axis and short axes.

Results:
Torque

Long Axis	Short Axis
0	0
0	0
0	0

Torque (m ± SD)

Long Axis	Short Axis
0 ± 0	0 ± 0

3. ASTM F2182 - Standard Test Method for Measurement of Radio Frequency Induced Heating Near Passive Implants During Magnetic Resonance Imaging.

This report pertains to the MRI-related heating test conducted at 3-Tesla on the PolyMark Marker. MRI-related heating was assessed for this device using a plastic phantom that was filled with a semi-solid, gelled-saline that was prepared to simulate human tissue. The ASTM head/torso phantom has a configuration and dimensions to approximate the human head and torso. Fluoroptic thermometry probes were attached to the marker and temperature changes measured and described.

Results:
Mixed Media Marker: Polymer/Stainless Steel

Thermometry Probe	Highest Temperature Change (°C)
Probe #1	+1.6 °C
Probe #2	+1.5 °C
Probe #3	+1.5 °C
Probe #4	+0.7 °C
Background Probe (without implant/device)	+1.5 °C
Background Reference Probe (without implant/device)	+0.7 °C

4. ASTM - F2119 - Standard Test Method for Evaluation of MR Image Artifacts from Passive Implants.

MR imaging artifacts were assessed for the marker in association with the use of a 3-Tesla MR system. This test was accomplished by performing MR imaging of the marker inside a gadolinium-doped, saline filled plastic phantom. MR imaging was conducted with the marker placed inside of the phantom. The marker was attached to a plastic frame to facilitate positioning and MR imaging within this phantom and the artifact results were recorded and are describe below.

Results:
Mixed Media Marker: Polymer/Stainless Steel

Signal Void Size	43-mm^2	20-mm^2	90-mm^2	64-mm^2

Mixed Media Marker: Gold/Titanium

Signal Void Size	73-mm^2	8-mm^2	168-mm^2	49-mm^2
Static Magnetic Field (T)	3	3	3	3
Pulse Sequence	T1-SE	T1-SE	GRE	GRE
TR (msec.)	500	500	100	100
TE (msec.)	20	20	15	15
Flip Angle	N/A	N/A	30°	30°
Bandwidth	16 kHz	16 kHz	16 kHz	16 kHz
Field of View	24 cm	24 cm	24 cm	24 cm

Matrix Size	256 x 256	256 x 256	256 x 256	256 x 256
Section Thickness	10 mm	10 mm	10 mm	10 mm
Imaging Plane	Parallel (long axis)	Perpendicular (short axis)	Parallel (long axis)	Perpendicular (short axis)

(T1-SE, T1-weighted spin echo; GRT, gradient echo; N/A, not applicable)

The marker had acceptable readings for all four tests and was deemed MRI compatible.

The marker was then placed in a tissue equivalent phantom and all of the aforementioned imaging studies were performed. The PolyMark was found to lie within acceptable ranges for all tests performed and is clearly visible in each of the imaging platforms.

4. Biocompatibility Testing

The PolyMark has been submitted for a full battery of biocompatibility testing. In all cases the tests yielded acceptable results and the full reports are kept in the technical file.

Test	CAT.
LAL Pyrogen Testing Polymer	Biocompatibility
Cytotoxicity Testing (MEM) Polymer	Biocompatibility

5. Sterilization Testing

EO sterilization is used for the implanted fiducials. In all cases the tests yielded acceptable results and the full reports are kept in the technical file.

Residual EO Polymer	Sterilization
Bioburden Polymer	Sterilization
B / F Test PEEK	Sterilization

6. PolyMark Clinical Application

The PolyMark can be used in any soft tissue that requires a marker for future medical procedure. The intended use is as follows:

- This marker will serve as a surrogate locator in situations where the location of specific anatomy, normal or diseased, needs to be marked for future procedures.
- The marker is placed either in advance or during a treatment procedure.
- The marker can be visualized using medical imaging devices and provide a reference from which the treatment can be guided.

Figure 5

7. Specifications

The PolyMark Marker is currently available in two configurations:

0.8 mm in diameter and 3.0 mm in length in a sterile (4) pack.

- Typically used with an existing delivery system such as an endoscope.

1 mm in diameter and 3.0 mm in length, preloaded into an 18 GA by 20 cm long (seeding) needle.

- Sterilized in a Tyvek pouch and ready for clinical use (Figure 5).

8. IGRT Systems

The PolyMark has been imaged across many IGRT platforms and is suitable for use in any kV-based system. Limited by its lower density, the marker is not suitable for use with MV based IGRT solutions. While it was trackable with the CyberKnife at a low transmission factor, as tissue equivalent material was added it became untrackable and is therefore not considered validated for use with the typical imaging system on the current CyberKnife.

9. Conclusion

The PolyMark provides clear, artifact free images for planning and accurate fusion of MR and CT datasets. It shows up as a clear white point for IGRT using kV based systems. Its unique spiral cut surface guards against migration once implanted. The marker is cleared for use in all soft tissue applications making it the optimal solution for high precision radiotherapy.

All markers have received clearance for marketing by the FDA and are CE marked for sale in the European Union.

All markers in this report are available from CIVCO Radiotherapy, (www.CivcoRT.com) or 800.842.8688.