Is There a Clinical Benefit with a Smooth Compensator Design Compared to a Plunged Compensator Design for Passive Scattered Protons?

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Purpose/Objectives

The purpose of this study was to investigate the potential dosimetric and milling time benefits of smooth compensators.

Learning Objectives:

1) Understand the purpose of a compensator in passive scattered protons
2) Outline the uncertainties with plunged-depth compensators
3) Investigate the potential benefits of using smooth compensators

Introduction

Proton therapy has the ability to deposit the maximum dose per beam in the target at a defined depth with its Bragg Peak. This gives protons the ability to preserve healthy tissues distal to the target. The distal dose conformity is aided by a wax or acrylic compensator for passively scattered proton therapy.2-3

The most common manufacturing design for compensators is a “plunged” technique. The plunged technique mills the compensator through a series of points, one-by-one to a specific depth with a drill bit of a specified diameter, usually 2.5mm, and taper angle, usually 2.3 degrees. A high resolution design is optimal, but the thickness of the drill bit degrades the degree of resolution of the compensator design and resultant dose distribution on the distal end of the target. In addition, this technique can be very time consuming because the compensator design is very complicated and involves hundreds of plunge points. Clinical effectiveness and patient start times can be affected by the time requirements of the plunge technique.

Alternatively, a “smooth” compensator design is available in the TPS. The plunged-depth points must be converted into a three dimensional wireframe surface so that the smooth compensator design is needed for this technique. The smooth compensator design marginalizes steep depth gradients, reduces the dose distal dose resolution issues related to the drill bit size, and eliminates drill bit tapering issues in the TPS algorithm.

Methods and Materials

Five patients from five different clinical sites, prostate, lung, liver, brain, and CSI, were selected for this study. The patients were randomly selected within each site in order to give the study a broad analysis and distribution of various anatomical sites.

Four smooth compensator plans were designed and compared to the original plunged depth plan. The “Smooth Base” plan is a copy of the original plunged depth plan with the same parameters, but the compensator milling design was changed to smooth. The three additional smooth compensator plans were Double Smear (DS), PTV +1cm, and Manual Edits (ME). The DS plan had double the calculated smear value with all other parameters unchanged. The PTV +1cm plan added an additional 1cm to the PTV which was used for the compensator design only. The ME plan was individually assessed and the treatment planner made manual adjustments to the compensator to increase the dose to the areas of the CTV lacking coverage. The plans made sure to have the minimum amount of PTV coverage as the original plunged depth plan in order for the plans to be comparable.

Discussion/Conclusion

Utilization of smooth compensators for passively scattered proton therapy are dosimetrically equal or better than the plunged technique depending on the technique used. Overall, the ME achieves the best dosimetric results but the PTV +1cm technique is a suitable alternative for the brain, lung and liver sites. In conclusion, smooth compensators have a clinical benefit over plunged-depth compensators, achieving similar or better coverage as well as reduced dose to most critical structures. More importantly smooth compensators significantly reduce the manufacturing time by an average of 43.5%, which will improve operational efficiencies. Future studies are needed to verify the robustness and best practices for quality assurance of smooth compensators.

Results

Dosimetric Results:

In comparison to the plunged-depth plan, the ME plans had similar or better results for all five sites. (Table 1) On average for all five sites, the ME plans performed better than the other smooth compensator techniques.

<table>
<thead>
<tr>
<th>Site</th>
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<th>MEDIAN Dose Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
<td>-0.3%</td>
<td>-0.3%</td>
</tr>
<tr>
<td>Lung</td>
<td>0.1%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Liver</td>
<td>-0.7%</td>
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</tr>
<tr>
<td>Prostate</td>
<td>0.0%</td>
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</tr>
<tr>
<td>CSI</td>
<td>0.1%</td>
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Table 1: Dosimetric Results for five smooth compensator plans, one from each treatment site evaluated.

Table 2: The following table displays the dosimetric results for each plan relative to the plunged depth plan. The values for the smooth compensator plans are the absolute differences from the plunge depth result. The point value and priority of each criterion is listed out of a total 150 points.

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Results (continued)

Manufacturing Time

The manufacturing process for smooth compensators reduces the overall time by an average of 43.5%, with a range of 31.4% to 64.2% per field. The average absolute time savings was 20.8 minutes per fields with a range of 10 min. to 39.5 min.

Table 3: Milling and QA results for five smooth compensator plans, one from each treatment site evaluated.

Discussion/Conclusion

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References