Title: Scatterless Cone-beam CT - A Parametric Modeling and Metal 3D Printing Approach

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Structured Abstract:

Introduction: Cone-beam computerized tomography (CBCT) differs from traditional single slice CT by using a multi-dimensional paradigm for data acquisition. Unfortunately, this approach allows Compton scatter to affect multiple rows of the detector's array and therefore multiplies its detrimental effects in image quality by orders of magnitude. The increased scatter fraction cannot be fully corrected during image post-processing; and therefore scatter related image artifacts, increased noise, and errors in quantitative imaging remain a challenge in current clinical CBCT systems. The objective of this study is to take advantage of additive manufacturing technology (i.e. 3D printing) to design and manufacture two prototypes of anti-scatter grids (ASGs) with the potential to improve the performance of quantitative CBCT imaging systems.

Methods: Two parametric modeling node trees were designed using open-source software (Blender 2.78) to generate both rectangular and hexagonal highly focused anti-scatter grids. The interface allowed users to modify ASGs characteristics using seven numerical values (i.e. cell width, septal thickness, grid height, focal spot etc.) Additionally, this parametric approach avoided computational intensive calculations and optimized the object's geometry. One rectangular non-focused ASG was fabricated using chrome-cobalt and selective laser melting (AM400, Renishaw plc). This rectangular non-focused ASG served as a preliminary prototype; and had a diameter of 40 mm, a height of 10 mm, a grid ratio of 10:1, a septal thickness of 0.1 mm; and a transmission efficiency of 83%. To increase efficiency, a second hexagonal focused ASG was fabricated using the same technology but using stainless steel (AM125, Renishaw plc). The hexagonal grid, which was designed to fit a preclinical micro-CT scanner, had a diameter of 74 mm, a height of 15 mm, a grid ratio of 10:1, and a transmission efficiency of 86.19%.

Results: Parametric modeling software produced two optimized STL files, rectangular and hexagonal, which were compatible with a commercially available 3D printing interface (Renishaw, QuantAM). Both prototypes' septal thickness was confirmed using a measuring microscope (Olympus STM6). Septal thickness averaged (100.6 μm, rectangular; and 102.4 μm, hexagonal). There were no significant differences between the x and y-axis and mechanical stability was maintained. Finally, radiographic transmission efficiency was greater than 80%.

Discussion: Selective laser melting coupled with parametric modeling is capable of producing highly efficient ASGs, which are capable of effective scatter rejection in CBCT. High transmission efficiencies are a result of both very thin septa and no additional filler material to maintain geometrical stability. This approach might lead to nearly complete scatter rejection. Future goals include the use of denser materials such as tungsten.