Purpose:
Statistical iterative image reconstruction (SIR) algorithms are effective for reconstructing high-quality low-dose cone beam computed tomography (CBCT). The performance of SIR strongly depends on the prior/penalty term. In this work, we develop and evaluate an edge-preserving penalty term in SIR that incorporates high-order neighbors.

Methods:
CBCT projection data of a CatPhan 600 phantom was acquired on a Varian Acuity simulator (Varian Medical Systems, Palo Alto, CA) using two protocols: 80mA/12ms/projeciton for high dose and 10mA/10ms/projection for low dose. Low-dose CBCT images were reconstructed by minimizing an objective function based on the penalized weighted least-squares (PWLS) criterion. Conventionally, the penalty term is used to enforce the smoothness constraint within a local neighborhood (e.g. up to third-order neighbors). In this work, we propose a non-local anisotropic quadratic penalty term that incorporates higher-order neighbors. The relative contribution from different neighbors is controlled by the absolute difference between the selected neighbors. For neighbors associated with larger differences, equivalence between them will be discouraged. Contrast-to-noise ratio (CNR) at different regions of interest (ROIs) is calculated to quantitatively evaluate the proposed high-order neighborhood penalty.

Results:
Noise is substantially reduced in low-dose CBCT reconstructed using the iterative PWLS algorithm, while the edges are well-preserved. The CNRs in selected ROIs in PWLS-reconstructed images are higher than that of the corresponding FDK reconstructed high-dose images. Using the higher-order neighbor penalty, the average CNR of the selected ROIs is 24% higher than the image reconstructed by PWLS using the penalty with the conventional local neighbor.

Conclusions:
A higher-order neighborhood methodology is proposed for the penalty term in PWLS iterative image reconstruction for enhancement of low-dose CBCT image quality. PWLS coupled with higher-order neighbor penalty outperforms the PWLS with conventional local neighbor penalty.

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