Comparative Dosimetric Impact of Dental Prostheses and Metal Artifact Reduction In Head-and-Neck Radiotherapy: Pinnacle Versus Monaco

Hsin-Ho Tai, MSc[1], Hsin-Hon Lin, PhD[2], Yuan-Chun Lai, PhD[1], Chun-Chao Chuang, PhD[3], Yu-Chien Yeh[1] and Chun-I Cheng[1]
[1]Changhua Christian Hospital, Changhua, Taiwan, [3]Chung Shan Medical University, Taichung, Taiwan
[2]Department of Medical Imaging and Radiological Sciences, Chang Gung University, Taoyuan, Taiwan

2026 JULY 19–22 VANCOUVER, BC
JOINT AAPM | COMP MEETING

ABSTRACT

Purpose:
To evaluate the dosimetric impact of Metal Artifact Reduction (MAR) on metal and ceramic dental prostheses using two different treatment planning systems (TPS): Pinnacle (CCC) and Monaco (Monte Carlo).

Methods:
Metal and ceramic prostheses were scanned with and without MAR using an agar phantom (2D evaluation) and a PH-47 anthropomorphic phantom (VMAT). Dose accuracy was assessed against artifact-free reference plans using mean dose deviations, lateral dose profiles, and Gamma analysis (3%/3mm).

Results:
Without MAR, metal dentures caused systematic underestimation (up to -3.8%). MAR application showed algorithm-specific responses: Pinnacle achieved near-zero mean dose error, while Monaco exhibited systematic over-compensation (~+2.3%). In VMAT, metal-induced local deficits reached -10% at dose boundaries. While MAR improved overall accuracy, Monaco demonstrated superior boundary agreement compared to Pinnacle's residual underestimation at the edges.

Conclusions:
Dental prostheses primarily disrupt the dose at profile boundaries. While MAR improves general accuracy, its effectiveness depends on the algorithm: Monaco risks over-correction for metal, while Pinnacle shows boundary limitations. Relying solely on DVH is insufficient; detailed dose profile analysis is essential for clinical safety.

CONTACT

Hsin-Ho, Tai
Changhua Christian Hospital
135 Nanhsiao Street, Changhua, 500 Taiwan
thh0828@gmail.com
+886-975-157-793

INTRODUCTION

Precise dose distribution is essential for tumor control and tissue sparing in head-and-neck radiotherapy. High-Z dental prostheses often cause significant metal artifacts through beam hardening and photon starvation, distorting Hounsfield Units (HU) and leading to TPS dose calculation uncertainties. While Metal Artifact Reduction (MAR) improves image quality, its impact on dosimetric accuracy depends on both material properties and specific TPS algorithms. This study evaluates the systematic dosimetric differences between Collapsed Cone Convolution (CCC) and Monte Carlo algorithms across various materials and MAR conditions to establish clinical reference indicators.

METHODS AND MATERIALS

To evaluate the material properties and clinical impact of dental prostheses, this study utilized two validation models:

- **Phantom Models**: A custom agar phantom was used for basic 2D evaluation, while a PH-47 head-and-neck anthropomorphic phantom simulated clinical VMAT.
- **Materials & Imaging**: Metal and zirconia ceramic dentures were imaged using GE Discovery RT CT, both with and without MAR technology.
- **Dose Calculation**: Plans were calculated using Pinnacle (Collapsed Cone Convolution) and Monaco (Monte Carlo) treatment planning systems.
- **Evaluation Baseline**: Reference dose distributions were established via manual density override on artifact-free CT images.
- **Assessment Metrics**: Accuracy was assessed through mean dose variation, lateral dose profiles, and planar dose verification using OCTAVIUS 2D arrays with Gamma analysis (3%/3mm).

Table 1: Planar dose verification results (Gamma analysis 3%/3mm).
This table evaluates the impact of denture materials and MAR correction on dose agreement across various field sizes using OCTAVIUS 1500 and 1600 2D array detectors.

1600 2D Array	5x5		10x10	
GPR(%)	Pinnacle	MONACO	Pinnacle	MONACO
Water	99.5	95.7	100	100
Tooth	100	98.6	100	100
Metal	89.2	94.3	99.5	97.8
Ceramic	92.9	93.2	99.8	98.4
Metal MAR	96.6	91.8	98.3	97.7
Ceramic MAR	95.7	96.1	99.1	99.2

1500 2D Array	10x10		15x15	
GRP(%)	Pinnacle	MONACO	Pinnacle	MONACO
Water	100	95.4	98.3	94.4
Tooth	100	95.4	97.9	89.1
Metal	100	95.9	95	92.3
Ceramic	99.5	93.6	97.3	92.1
Metal MAR	100	95	98.5	92.1
Ceramic MAR	100	95	96.7	93.7

RESULTS

Table 1 shows that baseline accuracy (water/tooth) exceeded 98.3%. However, metal dentures in 5x5cm2 fields reduced passing rates to 89.2% (Pinnacle) and 94.3% (Monaco) due to artifacts and shadowing effects. Ceramic dentures had a lesser, yet present, impact. MAR correction significantly restored accuracy across all materials—notably improving Pinnacle's metal group to 96.6%—confirming its effectiveness for both high- and low-density dental materials.

Agar Phantom Evaluation: Metal vs. Ceramic Dentures.
Metal Dentures (Fig. 1): Uncorrected metal caused systematic dose underestimation, most pronounced in large fields. MAR implementation effectively corrected Pinnacle (-3.76% to +0.12%) but led to a +2.32% overestimation in Monaco, especially in small-to-medium fields (Fig. 1b), suggesting algorithm-specific "over-compensation."
Ceramic Dentures (Fig. 2): Impact was smaller and more stable, with uncorrected reductions of ~3.6% across all fields. MAR improved Monaco to -0.33%, showing excellent compatibility with Monte Carlo calculations, while Pinnacle improved to -1.28% but retained a residual negative deviation due to CCC algorithm limitations at density interfaces (Fig. 2).

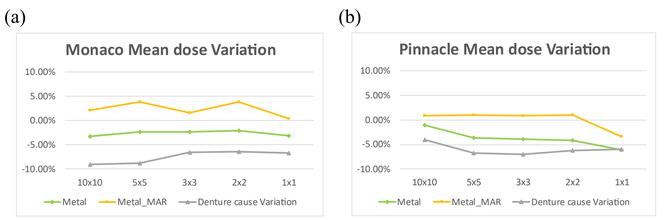


Figure 1: Mean dose variation for metal dentures in an agar phantom across various field sizes.

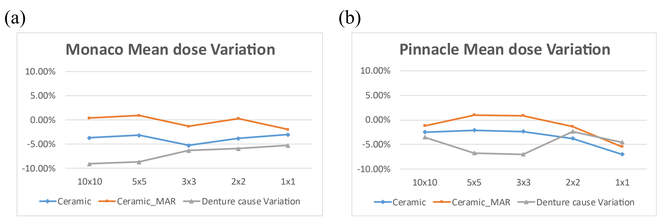


Figure 2: Mean dose variation for ceramic dentures in an agar phantom across various field sizes.

Clinical Evaluation: PH-47 Phantom (VMAT) Metal Dentures (Fig. 3): Without correction, doses were systematically underestimated (Monaco: -1.61%; Pinnacle: -2.57%) with local fluctuations reaching -10%. MAR improved mean deviations to <1%, though significant local residual errors (up to ±10%) persisted. Ceramic Dentures (Fig. 4): Uncorrected underestimation ranged from -1.10% to -2.16%. MAR effectively restored accuracy (deviations <0.3%), with Monaco demonstrating superior profile agreement compared to Pinnacle's slight persistent downward shift.

DISCUSSION

Pinnacle (CCC) and Monaco (Monte Carlo) exhibit significant differences at dose boundaries that DVH metrics fail to capture. MAR often shifts the direction of errors rather than eliminating them entirely. While Monaco shows better clinical boundary agreement, it is prone to over-compensation in 2D evaluations due to HU over-smoothing. Conversely, Pinnacle risks residual boundary underestimation. Relying solely on DVH may overlook critical local dose risks near dental prostheses.

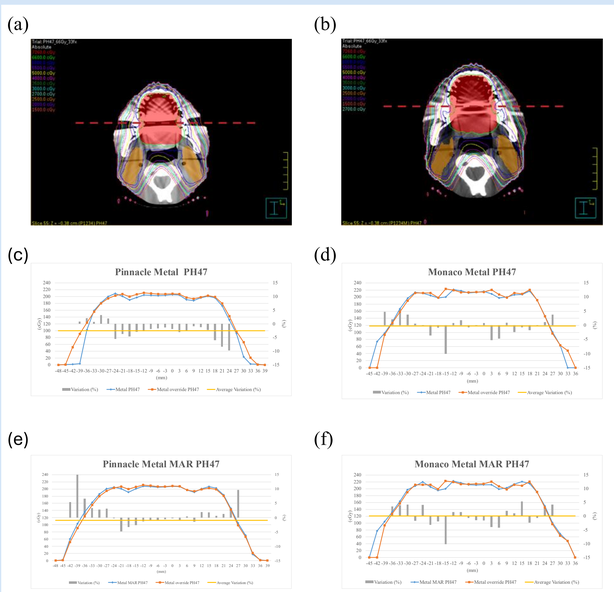


Figure 3: Dose distribution and dose profile comparison of the metal denture in PH47

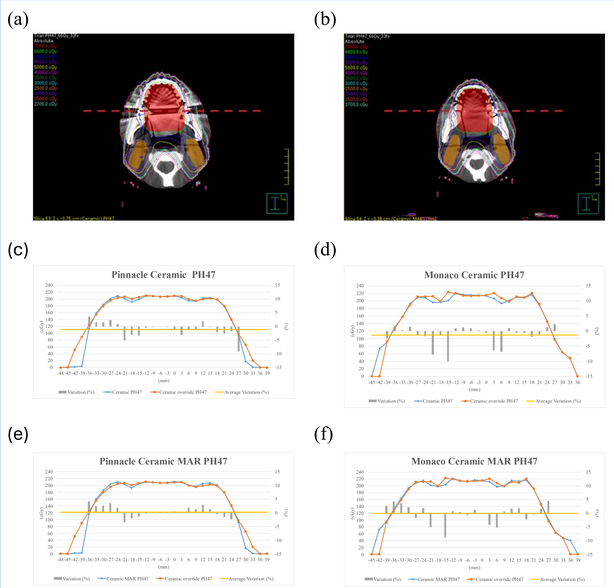


Figure 4: Dose distribution and dose profile comparison of the ceramic denture in PH47

CONCLUSIONS

Dental prostheses cause clinically significant dose perturbations, with risks concentrated at profile boundaries rather than in mean dose changes. Although MAR improves general accuracy, effectiveness is algorithm-dependent: Monaco may over-compensate for metal, while Pinnacle risks boundary underestimation. Clinical plans must incorporate dose profile analysis alongside DVH data to ensure treatment precision.

REFERENCES

1. Hu, Y. H., Seum, W. C. T. H., Hunzeker, A., Muller, O., Foote, R. L., & Mundy, D. W. (2023). The effect of common dental fixtures on treatment planning and delivery for head and neck intensity modulated proton therapy. Journal of Applied Clinical Medical Physics, 24(7). https://doi.org/10.1002/acm2.13973

© Poster Template by Genigraphics® 1.800.790.4001 www.genigraphics.com