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# DAP Measurements in Dental/Maxillofacial Cone Beam CT

E. GINGOLD[1], A. STRATIS[2], and D. MIHAILIDIS[3]
1Thomas Jefferson University, Philadelphia, PA
2KU Leuven/UZ Leuven, Leuven, BE
3University of Pennsylvania, Philadelphia, PA

## INTRODUCTION

Dental and maxillofacial cone-beam CT scanners (dental CBCT) have become extremely common in dental practices. There are a variety of ways to evaluate the radiation output and the radiation dose delivered to patients by these systems. A common dose metric reported by these systems is the Dose-Area Product (DAP) or Kerma-Area Product (KAP). In some countries, DAP/KAP is mandated for use as Dose Reference Levels (DRLs) and Achievable Doses (ADs). Measuring the DAP/KAP to establish and verify DRLs and ADs, and to verify the accuracy of the machine-reported values, should be a part commissioning and routine performance evaluations.

The purpose of this study is to evaluate several methods for measurement and validation of the machine-reported DAP/KAP in dental and maxillofacial cone-beam CT. A "point" (small area) measurement of dose/air kerma is suitable for a uniform beam. When a beam shaping bow-tie filter is present, the non-uniform beam necessitates a dose measurement that is integrated over the full field of view.

## AIM

This poster illustrates several different approaches for measuring DAP/KAP on dental CBCT units in the clinical setting.

## METHODS

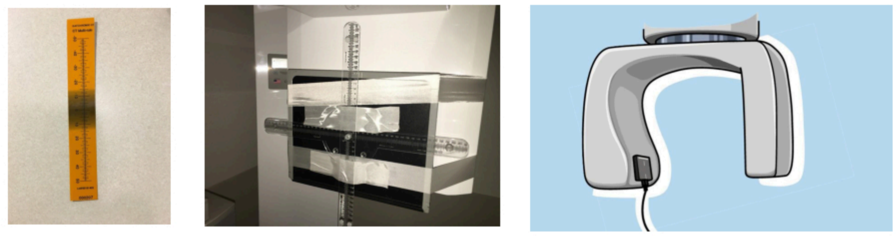
Multiple methods for measuring DAP were evaluated on two CBCT scanners of the same model (i-CAT FLX). Three methods were employed to measure x-ray field dimensions:

- Radiochromic film
- An electronic beam profile device
- Storage phosphor radiography (aka "CR")

Three methods were used to measure the radiation output

- A solid state dosimeter placed at the front center of the image receptor ("point" dose)
- A solid state dosimeter placed at the x-ray tube exit window in the approximate center of the field of view
- A 100 mm long 1 cm diameter cylindrical ionization chamber (standard CT "pencil" chamber) placed at the x-ray tube exit window in both horizontal and vertical orientations

A commercial DAP meter was used to measure DAP directly.



a b c

*Figure 1 Three methods for measuring the CBCT radiation field area. (a) Radiochromic self-developing film (b) CR storage phosphor cassette affixed to image receptor (c) electronic beam edge/width detector*

## METHODS

a b c

*Figure 2 Three methods for measuring the CBCT dose or air kerma. (a) solid-state small-area dosimeter at x-ray window (b) solid-state small-area dosimeter at geometric center of image receptor (c) 100mm long CT ionization chamber positioned vertically and horizontally*

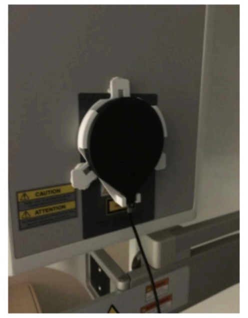


*Figure 3 Commercial DAP/KAP meter (Radcal Inc, Monrovia, CA)*

A 100 mm CT "pencil" ionization chamber was placed at the x-ray tube exit window in both horizontal and vertical orientations. Air kerma measurements were made over a range of beam heights (vertical fields of view, variations in cone angle). DAP was determined from the average of the horizontal and vertical chamber measurements, multiplied by the beam area in the same plane measured using film (Gafchromic XR-CT2) or electronic profiler (Quart Nonius). . Air kerma was also measured at x-ray tube exit window and at the geometric center of the image receptor measured with a small area solid-state dosimeter (Radcal AccuGold AGMS). Beam area in the plane of the image receptor was measured using storage phosphor cassette radiographs (Agfa CR). Nine standard exams (protocols) of the i-CAT FLX were evaluated. All protocols used 120 kV, 5mA and 8.9 seconds scan time. The only difference between these protocols is the FOV and offset position of the scan (some dental CBCT exams are offset from isocenter based on the anatomy of interest).

## RESULTS

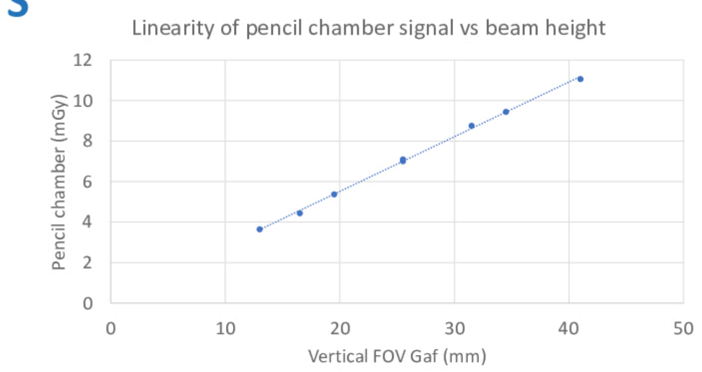



*Fig 4. Vertical orientation 100mm pencil chamber results*

## RESULTS

Fig 4 shows the linearity of chamber air kerma vs beam height measured with Gafchromic film, demonstrating that this technique, which integrates the full width or height of the beam and is thus insensitive to a beam-shaping bowtie filter, is a viable measurement technique. The detector air kerma measured with a small area dosimeter at the geometric center of the image receptor is almost independent of beam area (DAP) except for a slight dependence on field size reflecting increased scatter (Fig 5). An electronic beam profiler was compared to the film for field dimension measurements (example Fig 6). Electronic vs film area measurements averaged 1.5% different, maximum difference 6.9%. DAP measurements using three techniques are shown in comparison with the machine-reported ("Indicated") DAP in Table 1. Measured values are consistent with each other, and are 10-32% below the value programmed into the CBCT machine, based on the protocol and FOV. Figure 7 summarizes the discrepancy between measured and machine-reported DAP, comparing solid-state "point" dosimeter (SS) vs 100 mm long integrating pencil ionization chamber (chamber) at the exit window, and solid-state dosimeter at the image receptor (SS-IR). Nominal 8cm beam width is associated with greater DAP discrepancy than the nominal 16cm beam width. For a given field size, DAP measurements were consistent with each other to within 5 percent.

| | | | 100 mm CT "pencil" ionization chamber at tube exit window | | Solid-state dosimeter at tube exit window | | Solid-state dosimeter at image receptor | |
|---|---|---|---|---|---|---|---|---|
| Exam | FOV (DxH) (cm) | Indicated DAP (mGycm²) | Measured DAP (mGycm²) | Deviation | Measured DAP (mGycm²) | Deviation | Measured DAP (mGycm²) | Deviation |
| Maxilla-small | 8x5 | 168 | 116.2 | -31% | 114.9 | -32% | | |
| Both arches - small | 8x8 | 239 | 184.0 | -23% | 177.6 | -26% | 176.1 | -26% |
| Single arch | 16x4 | 202.8 | 169.6 | -16% | 177.7 | -12% | | |
| Maxilla | 16x6 | 302.9 | 254.2 | -16% | 266.6 | -12% | | |
| Mandible | 16x6 | 291.4 | | | 261.5 | -10% | | |
| Both arches | 16x8 | 388.9 | 332.4 | -15% | 342.0 | -12% | | |
| Arches/TMJ | 16x10 | 501.3 | 410.9 | -18% | 422.5 | -16% | | |
| Arches/TMJ-Large | 16x11 | 543 | 447.2 | -18% | 462.7 | -15% | | |
| 3D Ceph | 16x13 | 623.9 | 527.8 | -15% | 549.9 | -12% | 552.6 | -11% |

*Table 1. Summary of DAP measurements and deviations from machine-reported values*

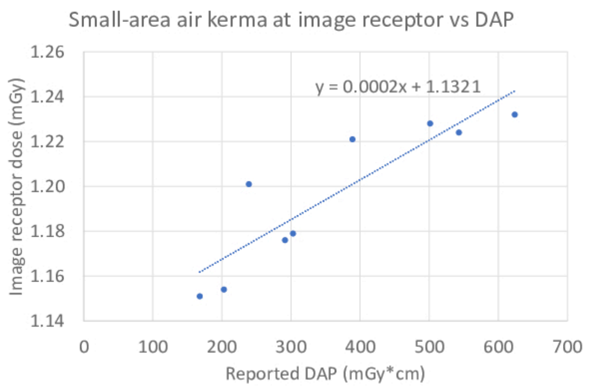



*Figure 5. Image receptor dose vs reported DAP*

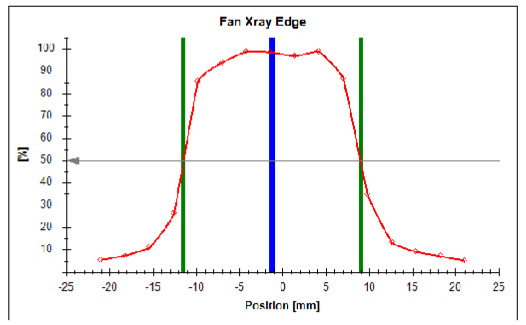



*Fig 6. Example output of electronic beam profiler (Quart Nonius)*

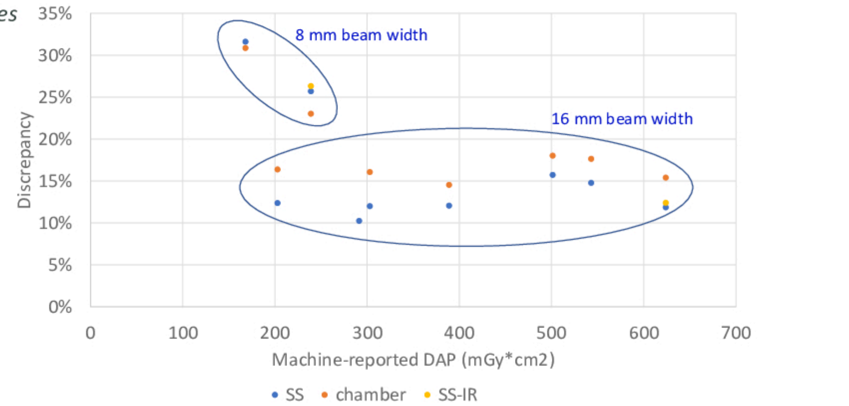



*Fig 7. Discrepancy between reported DAP values and measurements for 3 different techniques*

## CONCLUSIONS

We have demonstrated multiple methods to validate the reported DAP from dental Cone-beam CT systems in the clinic. Storage phosphor cassette, radiochromic film, and electronic beam profiler can measure beam area. A solid-state small area dosimeter and 100 mm CT ionization chamber were used successfully to measure radiation output. A prototype commercial DAP meter was evaluated and preliminary results will be reported in future work. All DAP measurements that were within reasonable measurement error of the system-reported DAP value, within 10-20% except for the smallest beam width where the discrepancy was higher, 22-32%. This larger discrepancy may reflect partial irradiation of the SS and ion chamber detectors for small beam size.

## REFERENCES

"QUALITY CONTROL IN CONE-BEAM COMPUTED TOMOGRAPHY (CBCT) EFOMP-ESTRO-IAEA PROTOCOL" https://www.efomp.org/uploads/2017-06-02-CBCT_EFOMP-ESTRO-IAEA_protocol.pdf.

## CONTACT INFORMATION

eric.gingold@jefferson.edu