Metal Artifact in CBCT and the Impact on Dental Implant Planning

A. ISMAIL, N.L. FORD

University of British Columbia, Vancouver, Canada

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INTRODUCTION

Cone beam computed tomography (CBCT) imaging is commonly used for pre-surgical treatment planning for dental implant placement. Current practices and guidelines indicate that a CBCT should be evaluated for every implant (Tyndall 2012). Meanwhile, image quality is known to be affected by several factors, including metal artifacts which produce image deterioration via bright streaks radiating from the metallic object to loss of gray values in its vicinity. These metal artifacts are common in the oral cavity in the presence of metal restorations (amalgam fillings) and crowns.

AIM

The aims for this study are to:

1) Establish the variation from "truth" of CBCT images with no restorations to estimate the accuracy of our CBCT machine (CS9300, Carestream, Atlanta USA) under common settings.
2) Determine the impact of progressively increasing metal artifacts via amalgam restorations and stainless steel crowns (SSCs) on linear measurement accuracy. Variables to be evaluated include:
   1) Field of View (FOV) size
   2) Manual and semi-automated measurements in 3 software packages: CS9300, DTX studio (Nobel Biocare, Zurich Switzerland), and MicroView (Parallax Innoations, Ilderton Canada).

METHOD

Holes were drilled into porcine mandibles at known distances from the alveolar crest on the buccal and lingual surfaces and filled with gutta percha, a radiopaque marker commonly used in dentistry (as seen in Figure 1).

Baseline CBCT images were taken, followed by images with progressively increasing amalgam restorations and SSCs (up to a total of 8 restorations per jaw). The single site FOV (5x5 cm) was taken using the average adult protocol (84 kVp, 5 mA, 12 s, 0.2 mm voxel spacing). Images were acquired on both sides of the mandible, as this FOV only covers a couple of adjacent teeth. The full arch FOV was also taken using the average adult protocol (90 kVp 4 mA, 6.2 s, 0.18 mm voxel spacing) and covered the full width of the mandible in a single exposure.

Measurement between the buccal and lingual gutta percha points on the mandible was performed using a digital caliper to establish "truth" and compared to the same measurements taken digitally on the CBCT images (Figure 2). Measurements were compared under conditions with no restorations and with increasing numbers of restorations.

RESULTS

Figure 1: Full mucoperiosteal flap raised between the first and second premolar; placement of 3 mm gutta percha points at 3, 6, and 9 mm from the alveolar crest. Measurements between the buccal and lingual points at 3 mm is known as GP-1, at 6 mm is GP-2, and at 9 mm is GP-3.

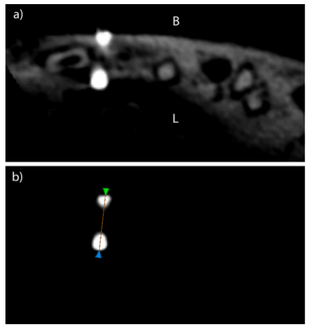

Figure 2: CBCT images from MicroView displaying gutta percha points at 3 mm from the alveolar crest at (a) commonly viewed settings; the buccal surface of the mandible is marked as, B, and the lingual surface is marked as L. The same image (b) after using the window and level function to eliminate grey values below a threshold in order to display the gutta percha points only and using the measurement tool to measure the distance.

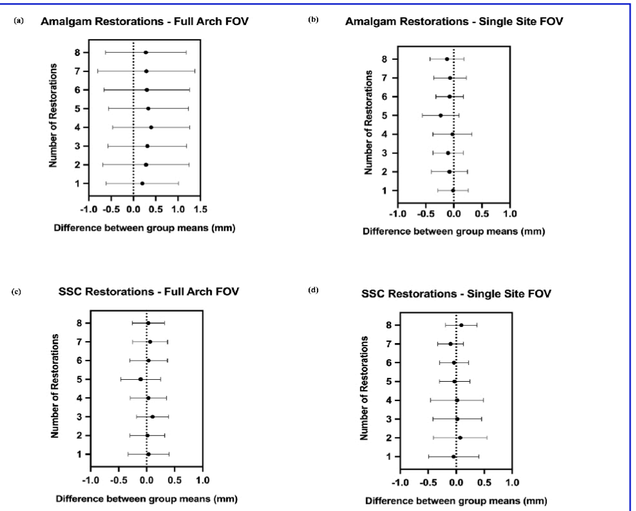

Figure 3: The difference between group means with increased number of restorations compared to the baseline images (no restorations), in mm, with 95% confidence intervals.

Comparison between "truth" (digital caliper) and baseline CBCT with no metal artifact demonstrated differences ranging from 0–1.7 mm, as shown in Table 1. This range of variation appears to be consistent even with increasing metal artifact, with no clear detectable pattern of change. When compared to baseline measurements, scans with amalgam and stainless-steel restorations showed a maximum difference of 0.54 ± 0.64 mm and 0.62 ± 0.64 mm respectively. The change in measurements was not found to be significantly different with increasing metal restorations, as shown in Figure 3.

To enable comparison of deviation from the baseline (no metal restorations), as more metal artifact was introduced, the measurements were subtracted from the baseline numbers to get the difference. These differences for the large FOV are shown in Tables 2 and 3 as the averages ± the standard deviation.

	Jaw AA			Jaw BA			Jaw CA			Jaw A			Jaw B			Jaw C		
Gutta percha points	Caliper	CBCT	Diff	Caliper	CBCT	Diff	Caliper	CBCT	Diff	Caliper	CBCT	Diff	Caliper	CBCT	Diff	Caliper	CBCT	Diff
Left																		
GP-1 (mm)	5.0	5.6	0.6	5.2	5.1	-0.1	3.8	4.7	0.9	6.1	5.4	-0.7	6.1	6.9	0.8	4.1	5.8	1.7
GP-2 (mm)	7.5	7.3	-0.2	6.2	7.1	0.9	5.2	6.2	1.0	6.9	7.6	0.7	8.0	8.1	0.1	6.2	7.8	1.6
GP-3 (mm)	11.0	11.3	0.3	9.3	9.3	0.0	7.0	7.7	0.7	9.0	9.6	0.6	9.6	9.8	0.2	9.0	9.6	0.6
Right																		
GP-1 (mm)	5.2	5.8	0.6	4.4	4.3	-0.1	4.1	4.1	0.0	5.5	6.2	0.7	6.8	6.4	-0.4	5.4	4.7	-0.7
GP-2 (mm)	7.0	7.6	0.6	6.2	4.9	-1.3	5.8	6.6	0.8	7.3	6.7	-0.6	8.2	8.1	-0.2	7.5	7.2	-0.3
GP-3 (mm)	10.6	10.7	0.1	8.5	7.5	-1.0	6.9	7.5	0.6	8.5	9.0	0.5	9.1	9.8	0.7	9.3	10.0	0.7

Table 1. Caliper and baseline CBCT measurements for the full arch FOV, in mm, prior to any restorations being added.

Table 2: Amalgam full arch FOV (10x5 cm) group. The difference in mm, between distances measured on CBCT images with increasing restorations, and distances measured on baseline CBCT images with no restorations. Each difference shown is an average of three measurements (GP-1, GP-2, GP-3), and displayed as average ± standard deviation.

	Average		
# of Amg	MicroView	DTX	Carestream
Left : 1	0.41 ± 0.40	0.36 ± 0.46	0.11 ± 0.15
Left : 2	0.28 ± 0.29	0.29 ± 0.41	0.19 ± 0.27
Left : 3	0.30 ± 0.20	0.31 ± 0.43	0.20 ± 0.18
Left : 4	0.37 ± 0.37	0.36 ± 0.45	0.22 ± 0.28
Right : 5	0.32 ± 0.35	0.38 ± 0.52	0.17 ± 0.27
Right: 6	0.36 ± 0.40	0.36 ± 0.48	0.36 ± 0.44
Right: 7	0.54 ± 0.64	0.32 ± 0.42	0.23 ± 0.35
Right: 8	0.36 ± 0.26	0.32 ± 0.43	0.32 ± 0.34

Table 3: Amalgam full arch FOV (10x5 cm) group. The difference in mm, between distances measured on CBCT images, and distances measured on the mandible with the digital caliper. Each difference shown is an average of three measurements (GP-1, GP-2, GP-3), and displayed as average ± standard deviation.

	Average			
# of Amg	Semi-Automated MicroView	Manual MicroView	Manual DTX	Manual CS9300
None	0.64 ± 0.76	0.53 ± 0.49	1.05 ± 0.61	1.03 ± 0.57
Left : 1	0.56 ± 0.69	0.69 ± 0.73	1.09 ± 0.71	1.02 ± 0.61
Left : 2	0.85 ± 0.88	0.49 ± 0.45	1.13 ± 0.72	1.04 ± 0.61
Left : 3	0.60 ± 0.71	0.49 ± 0.43	1.07 ± 0.72	1.07 ± 0.65
Left : 4	0.61 ± 0.64	0.43 ± 0.45	1.01 ± 0.71	0.98 ± 0.66
Right : 5	0.78 ± 0.90	0.51 ± 0.52	1.11 ± 0.82	1.03 ± 0.53
Right: 6	0.83 ± 0.97	0.54 ± 0.49	1.13 ± 0.64	1.17 ± 0.60
Right: 7	0.92 ± 1.18	0.67 ± 0.81	1.07 ± 0.66	1.11 ± 0.68
Right: 8	0.89 ± 1.10	0.47 ± 0.41	1.10 ± 0.72	1.18 ± 0.67

CONCLUSIONS

This study reports no significant difference in measurements made on an in vitro experimental porcine model with up to eight (8) metal restorations bilaterally.

There may be a difference of up to 1.7 mm between measured anatomical points and CBCT imaging under commonly used settings.

While this result may be clinically important, it does not appear to be affected by increasing metal artifact due to amalgam restorations or stainless-steel crowns.

When measurements were repeated using three different software packages, there was a significant difference between semi-automated and manual measurements on MicroView compared to manual measurements on the other two software packages. This significant result was found only in the full arch amalgam group. MicroView offers increased flexibility in the manipulation of the image, including improved zoom functionality which made identifying the analogous points easier. Improved software functionality, including automated measurements may improve treatment planning for implants.

The findings of this study support current clinical practices accounting for a safety margin of up to 2 mm with any CBCT image, and not limiting CBCT scans for patients with multiple metal restorations.

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CONTACT INFORMATION

Dr. Nancy L. Ford: nlford@dentistry.ubc.ca