Clinical Paper
Head and Neck Oncology

Performance of cone beam computed tomography in comparison to conventional imaging techniques for the detection of bone invasion in oral cancer

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Abstract. Detecting bone invasion in oral cancer is crucial for therapy planning and the prognosis. The present study evaluated cone beam computed tomography (CBCT) for detecting bone invasion in comparison to standard imaging techniques. A total of 197 patients with diagnoses of oral cancer underwent CBCT as part of preoperative staging between January 2007 and April 2013. The sensitivity, specificity, and accuracy of CBCT were compared with panoramic radiography (PR), multi-slice computed tomography (CT) or magnetic resonance imaging (MRI), and bone scintigraphy (BS) using McNemar's test. Histopathology and clinical follow-up served as references for the presence of bone invasion. CBCT and BS (84.8% and 89.3%, respectively), as well as CBCT and CT/MRI (83.2%), showed comparable accuracy ($P = 0.188$ and $P = 0.771$). CBCT was significantly superior to PR, which was reconstructed based on a CBCT dataset (74.1%, $P = 0.002$). In detecting bone invasion, CBCT was significantly more accurate than PR and was comparable to BS and CT/MRI. However, each method has certain advantages, and the best combination of imaging methods must be evaluated in prospective clinic trials.

In addition to the detection of lymph node and distant metastases, the precise determination of the extent of the local tumour in oral cancer is crucial for therapy planning and prognostic stratification.[1] Bone invasion is present in 12–56% of all oral cancer patients.[2] Although the prognostic value of bone infiltration is still controversial, it is highly relevant for the planning of adequate therapy.[1,3] The suspicion of tumour invasion into the adjacent bone results in radical surgery with wide resection and even

Table 1. Published studies including CBCT for the assessment of bone invasion in oral cancer.

	Patient cohort, *n*	Imaging methods	Sensitivity	Specificity	Accuracy
Hakim et al.,[7] 2014	48[a]	CBCT	93%	62%	77%
		CT	63%	81%	72%
		SPECT	96%	48%	72%
Dreiseidler et al.,[13] 2011	77	CBCT	92%	96.5%	93.1%
		CT	80%	100%	89.4%
		SPECT	91%	40%	71.6%
Hendrikx et al.,[12] 2010	23	PR	54.4%	91.7%	73.9%
		CBCT	90.9%	100%	95.7%
		MRI	81.8%	66.7%	73.9%
Momin et al.,[4] 2009	50	PR	73%[b]/56%[c]	60%	–
		CBCT	89%[b]/99%[c]	60%	–
Closmann and Schmidt,[11] 2007	3	Case description			

CBCT, cone beam computed tomography; CT, computed tomography; SPECT, single photon emission computed tomography; PR, panoramic radiography; MRI, magnetic resonance imaging.

[a] Only the patients who underwent all imaging methods are considered.
[b] Cortical invasion.
[c] Bone marrow infiltration.

microvascular reconstructive surgery, which can significantly reduce the quality of life and increase morbidity and mortality.[4,5]

Standard preoperative staging consists of clinical examination and non-invasive imaging, including computed tomography (CT) or magnetic resonance imaging (MRI), to detect loco-regional metastasis and to determine the extent of the primary tumour and infiltration into adjacent structures.[6] Previous studies have reported high specificity and low sensitivity for CT and MRI in detecting bone invasion.[5] Bone scintigraphy (BS), which visualizes the bone metabolism of the whole body, is a highly sensitive imaging method.[7,31] However, given the low prevalence of distant bone metastases in only 2–4% of patients with oral cancer, whole-body imaging seems less appropriate in this regard.[8] Van Cann et al. reported an accuracy of 85% with no false-negative results using CT or MRI in combination with BS for detecting bone invasion.[5] No single imaging modality is considered sufficiently accurate to replace the others.[4,5]

Over the last few years, cone beam computed tomography (CBCT) has become a routine clinical practice in the three-dimensional (3D) examination of the oromaxillofacial region and in preoperative planning.[9] With this technique, both panoramic radiography (PR) and volumetric datasets, similar to multi-slice CT, can be reconstructed, providing multiplanar and 3D images of the viscerocranium. Compared to conventional CT, CBCT has a lower radiation dose, a higher spatial resolution, and similar or even fewer metal-induced artefacts. However, CBCT is not suitable for assessing soft tissue structures.[9,10] In our department, CBCT was established in 2007 for diagnostic imaging in prosthetic surgery, implantology, and traumatology in the oromaxillofacial region.

Until now, the role of CBCT in the preoperative assessment of bone invasion in oral cancer has been evaluated only in a few studies with small numbers of patients (Table 1). Comparisons of technologies for non-invasive diagnostic imaging (PR, CT, MRI, and BS) have differed among the published studies.[4,7,11–13] Also, the reported data for CBCT have shown broad variation, with specificity values of 62–100% and accuracy values of 77–96%.

In this retrospective study, we reviewed a cohort of 197 patients with confirmed diagnoses of oral cancer. To our knowledge, this is the largest cohort that has been used to compare CBCT to other imaging technologies (PR, CT, MRI, and BS) in predicting bone invasion.

Materials and methods

Study design

Between January 2007 and April 2013, 352 patients were referred to our department with a suspected diagnosis of oral cancer (Fig. 1). According to our routine staging protocol and current guidelines, a CT or MRI was performed in all of the patients for the assessment of cervical lymph nodes and the extent of the local tumour.[5,14] A total of 197 of these 352 patients underwent additional BS and CBCT and were therefore included in the study. Medical history, tumour localization, and recent interventions in the oral cavity, e.g., tooth extraction or probe sampling, were documented and accounted for in image interpretation. The imaging findings were validated by histopathology after either a rim or segmental bone resection or a clinical follow-up of at least 6 months (Fig. 1).

The present study was approved by the local ethics committee; no specific informed consent was provided by the patients due to the retrospective nature of the study.

Panoramic radiography and cone beam computed tomography

CBCT was performed using a Galileos CBCT unit (Sirona Dental Systems Inc., Bensheim, Hessen, Germany). The X-ray generator and the detector are mounted across from each other on a U-arm. Both devices rotate around the seated patient. The position of the patient's head was predetermined with a chin rest and a dental splint. A light localizer tagged the midsagittal plane, and contact was made with the forehead rest in the standardized positioning procedure.

The CBCT features a field of view (FOV) of 15 cm, resulting in a reconstructed 3D volume of $15 \text{ cm} \times 15 \text{ cm} \times 15 \text{ cm}$. The volume consists, in the standard mode, of $512 \times 512 \times 512$ isotropic voxels, with a resolution of 0.3 mm. The scan time is 14 s. The effective dose of this device is 43–175 µSv (85 kV/5–7 mA). Secondary reconstructions display PR-like views (panoramic) and cross-sectional views. The data were saved in DICOM data file format. A more extensive (technical) description of the system can be found in the literature.[15]

Under standardized conditions (tinted room, EIZO RadiForce GS320 diagnostic monitor), two experienced maxillofacial surgeons evaluated the images in consensus using Sidexis XG software, version 2.56 (Sirona Dental Systems Inc.). The