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ORIGINAL ARTICLE

Digital volume tomography in the assessment of mandibular invasion in patients with squamous cell carcinoma of the oral cavity – A prospective study

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1. Introduction

Cancers in the upper part of aero digestive tract comprises 5% of all the malignancies, most common among them is the squamous cell carcinoma (Acton et al., 2000). The incidence and prevalence of oral squamous cell carcinoma (OSCC) in Indian subcontinent is relatively high because of prevalent habits like chewing tobacco, betel quid and areca-nut which increases the risk of developing OSCC (Feller and Lemmer, 2012). Tumor adjacent to the mandible can invade bone, either by direct extension (Huntley et al., 1996) or by the perineural infiltration (Carter and Pittam, 1980). There are no clear guidance to state the amount of bone resection required beyond the tumor, and in majority of the cases soft tissue extension of the tumor determines the amount of resection (Brown et al., 1994). The decision to maintain the continuity of the mandible demands thorough understanding of the anatomy as well as proper assessment of tumor extension (Huntley et al., 1996).

Preoperatively it is difficult to assess the degree of mandibular bone involvement, because there is no single imaging tool available to evaluate the extent of bone invasion 100% accurately (Singh, 2008). Different modalities including clinical examination, plain radiographs, conventional computed tomography (dentascan), magnetic resonance imaging (MRI) and nuclear medicine studies have been studied (Ziegler et al., 2002). Conventional radiographs in the form of orthopantomograph (OPG) provides a decent survey of the mandible, but bone mineral loss should be 30–50% before any change is seen (Huntley et al., 1996; Van Cann et al., 2008) Radionuclide bone scintigraphy utilizing radio-active labeled phosphate compounds along with OPG improves diagnosis in the preoperative evaluation. But this high sensitivity is escorted with very low specificity. Periodontal diseases, infections, infarctions and soft tissue involvement in and around the mandible will show a false positive result (Huntley et al., 1996). MRI is less useful in evaluating the cervical bone involvement due to the absence of signal from cortical bone because of less number of mobile hydrogen ions (Huntley et al., 1996; Boeddinghaus and Whyte, 2008). Digital volume

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tomography (DVT) is a recent imaging technology. DVT is capable of higher special resolution than dentascan (Genden et al., 2005).

So the purpose of this study is to evaluate the diagnostic accuracy of DVT in contrast with OPG, dentascan and histological study in assessing the invasion of mandible of patients with OSCC, clinically adjacent or fixed to the mandible.

2. Materials and methods

This is a prospective study involving 21 biopsy proven cases of OSCC of mandibular alveolar ridge, gingivobuccal sulcus, and floor of the mouth (Fig. 1) treated in Sri Dharmasthala Manjunatheshwara Craniofacial Unit, Dharwad, India, between the period of November 2012 and September 2014.

2.1. A plain radiographic examination using an OPG was done to study bony involvement. Presence of invasion and depth of invasion as shown by OPG was measured. Following this they were subjected to dentascan and DVT examination.

2.2. Dentascan imaging
Siemens's somatome emotion duo CT scanner was used for all cases. Images were captured in three planes axial, sagittal, coronal with slice thickness between 3 and 5 mm. Mandible and adnexa were subjected to 1 mm slices. These images were post processed with dental software package dentascan (software package from Siemens Ltd.). A curve was selected from an axial image on the crest of the ridge of mandible regardless of tumour location.1 mm slices were post processed with dentascan software. Reformatted panaromic and parasagittal images were obtained. A particular site from the core of the tumour was chosen and depth of invasion of the tumour at that particular site was assessed using the cross reference points as delineated by the software. A millimeter scale allows for accurate measurements.

2.3. DVT imaging
Kodak 9000c 3d scan extra oral imaging system scanner was used for all cases (Fig. 2). Images were captured in three planes axial, sagittal, coronal (Fig. 3) with slice thickness between 76 μm and 2 mm. Minimum slice thickness is 76 μm and Field of view is 50 * 37 mm. Constant scanning parameters were 85 kV and 28 mA. Reformatting permitted the panoramic and cross sectional views to be scanned. DVT scans were assessed for the bone invasion based on the amount of cortical bone erosion adjacent to the soft tissue tumor mass. Investigators knew the clinical location of the tumour but were not aware of the dentascan and OPG findings. As a part of treatment plan, patients underwent surgery involving marginal mandibulectomy or segmental resections of mandible (Fig. 1a). Immediately post resection specimens were stripped off from the periosteum to assess the involvement of carcinoma in mandible. (Figs. 1b, 1c).

2.4. Histopathological examination was done to assess the bone invasion and depth of invasion (Fig. 4). All four values were computed and statistically analysis was done using Kappa analysis to check the sensitivity and specificity, positive predictive value (PPV) and negative predictive value (NPV), correlation in depth scores of OPG, dentascan, DVT, Direct inspection and histopathological examination. Accuracy of dentascan and DVT in assessing the presence of invasion and depth of mandibular invasion was determined.

3. Results

Our study group consisted of 21 patients, among them 19 were males and 2 were female. All the patients were biopsy proven cases of OSCC. The lesions were either fixed or clinically adjacent to the mandible with no obvious bone involvement on plain radiographs though invasion was suspicious. There were 20 cases involving gingivo buccal sulcus and one case involving the floor of mouth (Table 1). Among 21 cases, one case was T2N1M0, one case was T2N2M0, and nine cases were T3N1M0, three cases were T3N2M0, three cases were T4N1M0 and four cases were T4N2M0 (Table 2).

3.1. Comparison of OPG and histopathological findings

When OPG and histopathology findings were compared we found that OPG had sensitivity of 36.36% and specificity of 100%. The PPV and NPV was found to be 100% & 58.82%. There was an agreement of 66.67% when OPG and histopathology were compared. Kappa agreement of 0.35 (not > 1) was noted. These results show that chances of false negative were higher with OPG.

3.2. Comparison of dentascan and histopathological findings

When dentascan and histopathological findings were compared the sensitivity was 100% and specificity of 90%. The PPV and NPV was 91.67% and 100%. There was an agreement of 95.24% and the Kappa

Fig. 1 Patient with carcinoma of buccal mucosa.

Fig. 1a Wide excision of tumour and neck dissection marking.

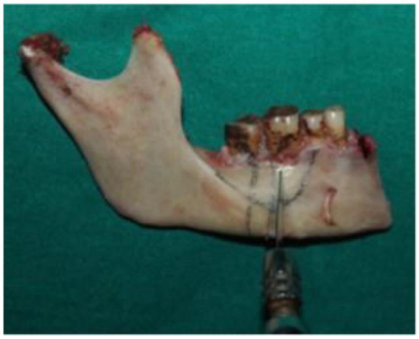

Fig. 1b 4 mm bone slice cut using electric saw.

Fig. 1c Resected primary tumour, hemimandible, neck dissection specimen.

Fig. 2 DVT scanner.

agreement of 0.91 (not > 1) was noted. These result suggests that dentascan has considerable diagnostic ability in determining mandibular invasion.

3.3. Comparison of DVT and histopathological findings

DVT and histopathological findings were compared and statistics showed that sensitivity, specificity, PPV, NPV was 100% each. An agreement of 100%, Kappa agreement of 1 (not > 1) was noted (Tables 3 and 4). These data states that DVT has maximum diagnostic ability in determining mandibular invasion.

3.4. Comparison of OPG and dentascan

When OPG and dentascan were compared, sensitivity of 33.33%, specificity of 100% was noted. The PPV of 100% and NPV of 52.94% was seen. An agreement of 61.90% with Kappa agreement of 0.30 (not > −1 to 1) was noted. This states that identification of true positives is less with OPG when compared to dentascan.

3.5. Comparison of OPG and DVT

On comparison of OPG and DVT, the sensitivity was 36.36%and specificity was 100%. The PPV and NPV was 100% and 58.82%. The agreement when OPG and dentascan were compared was 66.67%, Kappa agreement was 0.35 (not > −1 to 1). This states that identification of true positives is less with OPG when compared to DVT.

3.6. Comparison of DVT and dentascan

On comparison of DVT and dentascan the Sensitivity was100% and specificity was 90%. The PPV and NPV was found to be 91.67% and 100%. There was an agreement of 95.24%. The Kappa agreement of 0.90 (not > 1) was noted. This states that there is statistically significant correlation between DVT and dentascan in the assessment of mandibular invasion.

3.7. Depth scores

Correlation between depth scores of OPG and histopathology was significant statistically with r-value of 0.55 (r being −1 to +1); DVT and histopathology were most significant statistically with r-value of 0.97 (r being −1 to +1); dentascan and histopathology were statistically highly significant with r-value of 0.96 (r being −1 to +1). Among the three modalities OPG, dentascan and DVT, DVT and dentascan have the maximum correlation and is the most accurate method in determining the depth of invasion in mandibular invasion cases of OSCC. Correlation between depth scores of OPG and DVT were statistically significant with r-value of 0.0.60 (r being −1 to +1); OPG and dentascan was statistically significant with r-value of 0.48 (r being −1 to +1); dentascan and DVT was statistically highly significant with r-value of 0.95 (r being −1 to +1) (Table 5). Among the three modalities, DVT and dentascan have the maximum correlation in determination of depth scores and the ability to determine depth of invasion.

4. Discussion

The OSCC of the mandible can either be adjacent or fixed to it. Lesions present upon gingiva of mandible are usually fixed to it. Two specific histological patterns of invasion by OSCC into mandible are seen, one is infiltrative and the other is erosive. As the amount of bone invasion increases there is a progression from erosive to infiltrative pattern. The erosive pattern is usually associated with shallow mandibular invasion so marginal resection is suitable in such cases (Genden et al., 2005). Hence segmental resection is not needed in all the patients with OSCC, even in tumors which are close to the mandible. Significant reconstructive challenges may be faced when segmental resection of the mandible is done. Along with this there can be cosmetic problem and also mastication and deglutition may be affected depending on the amount and location of bone resection. Whereas Marginal mandibulectomy, has less morbidity, and it can give adequate tumor margins if tumor has not breached the cortical bone. Hence preoperative assess-

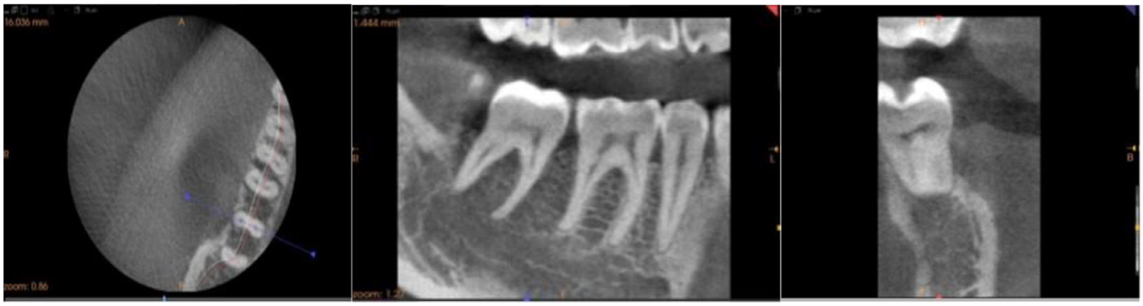

Fig. 3 DVT axial view, sagittal view, and coronal view showing erosion of cortex, loss of trabecular pattern and cortical thinning.

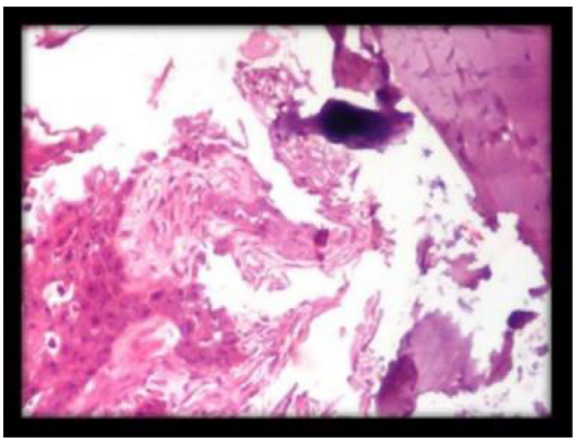

Fig. 4 Histopathological invasion assessment.

Table 1 Diagnosis wise distribution of patients.

Diagnosis	No of patients	% of patients
Ca GBS	20	95.23
Ca FOM	1	4.77
Total	21	100

ment of bone invasion is very crucial in planning the treatment (Brockenbrough et al., 2003). There is an association between the preoperative radiographic findings and histopathologic findings of the excised tumor specimen. In 63.2% of cases with erosive bone defects, amount of bone involved did not exceed the extent of the radiographically detected bone defects (Genden et al., 2005).

In our study, we assessed the tumor invasion in mandible by OPG, dentascan, and DVT and kept the histopathological assessment of tumor invasion as a gold standard. A sample of 21 biopsy proven cases of OSCC, in which lesions were clinically adjacent or fixed to the mandible without clear-cut bone involvement on plain radiographs though invasion was suspicious were chosen. In our study we found that OPG had a sensitivity of 36.36%, specificity of 100%, PPV of 100%, and NPV of 58.82%. Therefore chances of false negatives were higher with OPG. A similar study conducted on 23 biopsy proven cases of OSCC patients, compared the OPG and histopathological findings. They found that OPG had a sensitivity of 55% and specificity of 92%. The PPV and NPV was 85.7% and 68.8% (Hendrikx et al., 2010). There have been other studies which have found similar sensitivity and specificity (Acton et al., 2000; Van Cann et al., 2008; Genden et al., 2008; Momin et al., 2009). Our findings using OPG is in accordance to values quoted in literature.

When dentascan and histopathological findings were compared, we found a sensitivity of 100%, specificity of 90%, and PPV of 91.67% and NPV of 100%. So the dentascan has considerable diagnostic ability in determining the presence of mandibular invasion. A similar study conducted to evaluate the diagnostic efficacy of dentascan with histopathological findings in 36 biopsy proven cases of OSCC. They found that dentascan had sensitivity of 95%, specificity of 79%. The PPV and NPV was 87% and 92% (Brockenbrough et al., 2003). In a series of studies, the evaluation of bone invasion in OSCC by dentascan revealed high specificity and low sensitivity (Van Cann et al., 2008; Genden et al., 2005; Brockenbrough et al., 2003). There were many studies conducted which has stated that dentascan has better diagnostic accuracy (Acton et al., 2000; Brockenbrough et al., 2003; Dreiseidler et al., 2011). The findings in our study with dentascan were better than those mentioned in the literature.

On comparison of DVT and histopathological findings, the sensitivity and specificity was 100% with PPV and NPV of 100% each. Therefore DVT has maximum diagnostic ability in determining mandibular invasion. A similar research was conducted to check the diagnostic accuracy of DVT in comparison with the histopathological findings in 23 patients with OSCC. DVT had sensitivity of 91%, specificity of 100% with PPV of 100% and NPV of 92% (Hendrikx et al., 2010). There have been other recent studies which have shown similar kind of results in the literature (Momin et al., 2009; Dreiseidler et al., 2011).

Table 2 TNM classification.

Staging	T2NIM0 (III)	T2N2M0 (IV)	T3N1M0 (III)	T3N2M0 (IV)	T4N1M0 (IV)	T4N2M0 (IV)
No. of cases	1	1	9	3	3	4

Table 3 Agreement between DVT presentation and histopathology procedures.

DVT presentation	Histopathology			
	Positive	Negative	Total	%
Positive	11	0	11	52.38
Negative	0	10	10	47.62
Total	11	10	21	
%	52.38	47.62		

Agreement	Expected agreement	Kappa	Std. Err.	Z-value	P-value
100.00%	50.11%	1.0000	0.2182	4.5800	0.00001*

* $p < 0.05$.

Table 4 Sensitivity and specificity of DVT over histopathology.

Sensitivity	a/a + b	100.00
Specificity	d/c + d	100.00
Positive predictive value	a/a + c	100.00
Negative predictive value	d/(b + d)	100.00
Disease prevalence	(a + b)/(a + b + c + d)	0.52

Table 5 Correlation between OPG, DVT presentation and Dentascan with histopathology in relation to the depth scores.

Other methods	Correlation between histopathology with		
	r-value	t-value	p-value
OPG	0.5555	2.9119	0.0089*
DVT presentation	0.9762	19.6083	0.00001*
Dentascan	0.9637	15.7238	0.00001*

* $p < 0.05$.

In our study, with regards to depth score assessment, dentascan and DVT had the maximum correlation with r-value of 0.9637 and 0.9762 (r not > 1) respectively, r value was statistically significant with p-0.00001 ($p < 0.05$).

In Head and neck surgery, DVT and dentascan are valuable tool in detecting the extent of mandibular invasion. DVT and dentascan, not only detects the bone invasion but also helps in mapping the lesion very accurately. Hence these two modalities help in preoperative planning with regard to the extent of resection and reconstruction. This can even help in better counselling of the patient (Yanagisawa et al., 1993). Dentascan is not free from artifacts, particularly that due to motion. Some patients may have amalgam fillings in their teeth. Since the fillings are above the jaw bone artifact casted by amalgam would be minimal and does not affect the quality of images. Similarly root canal procedures and fixed partial denture work have minimal effect on image quality (Au-Yeung et al., 2001). With the knowledge of limitations and pitfalls of dentascan, it can be used as valuable tool to evaluate mandibular invasion (Brockenbrough et al., 2003).

DVT has lead over dentascan. The major advantage is that the patient can be in upright position when compared to supine position in dentascan. DVT also offers more precise information, because there is no collapsing of soft tissues dorsally. Less radiation is involved using DVT when compared to dentascan. DVT has the potential to prevent unnecessary resection of the mandibular. This leads to less segmental defects and consequent less composite free flap reconstructions, thus reducing patient's morbidity.

5. Conclusion

In our study, we found that dentascan and DVT both have better sensitivity and specificity when compared to OPG for the assessment of invasion and depth of invasion. DVT can accurately visualize bone invasion in the mandible at a lower cost when compared to dentascan and also it requires lesser radiation level. We conclude by stating that DVT can be a valuable tool detecting the mandibular bone invasion as well as in providing the necessary extent of resection required to give tumor free margins. The value of DVT in recording the extent of invasion is still to be evaluated. Due to smaller sample size in this study, further research with larger sample size is required to standardize our conclusion.

Conflict of interest

The authors declare that there is no conflict of interest.

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