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Radiographic aids in oral and maxillofacial surgery – Recent Advances

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Abstract

The current scenario of radiological imaging of the maxillofacial region is a far cry from its humble beginnings. Rapid strides have been made over the years, with Radiology having made an immense impact on the practice of maxillofacial surgery. These advances in imaging, play a vital role not only in the diagnosis of maxillofacial disease conditions but also in the planning and implementation of appropriate and timely treatment. Since Radiology has a crucial role to play in the practice of maxillofacial surgery it is essential that an OMFS should have basic understanding of the core concepts of different imaging techniques, their similarities and differences and should also be able to comprehend how imaging helps both diagnosing the clinical condition of a patient as well as management of the same. In this review article we have reviewed the current advances in the field of radiology and its uses in the field of diagnosis.

Key words: Recent advances, PET CT, SPECT, DEXA, Narrow Band Imaging.

Introduction

The last decade has witnessed a significant change in the field of technology. The evolving technology aids the field of oral and maxillofacial surgery from diagnosis, treatment planning, to the surgical procedure itself.

The success rate of any surgical procedure depends upon pre-operative imaging. We have witnessed a huge leap from intraoral periapical radiographs to laser surface scanning in terms of imaging. The conventional radiographs used to show images in 2-dimensional plane while the recent techniques provide images in the 3-dimensional plane which enables us to see the area of interest upto its finest detail.

Computed tomography (CT) scan

Sir Godfrey Hounsfield discovered the CT scan in 1967, and the first scan was performed in Wimbledon, England in 1971, but it was not publicised for another year. The scan can also be contrast enhanced in order to visualize the soft tissue.

CT scan is used to identify bone fracture along with the presence of bleed in extradural, subdural, intraventricular, subarachnoid and intracerebral compartment. It also plays a vital role in the detection of cerebral blood flow volume and the location of oedema. Its biggest advantage is that with all the resuscitation equipment the scan can be performed without any difficulties and it has a shorter scanning period of approximately 5 minutes. The only problem in the CT scan is that the small extra cerebral lesion in the posterior cranial fossa cannot be detected[1]. Stengel D et al conducted a study to find out the accuracy of the CT scan in patients with major blunt trauma and find out that the sensitivity of pan CT scan was nearly about 84.6% in the head and neck region[2].

Contrast enhanced computed tomography is generally used to detect the carcinoma of the head and neck region. Its sensitivity in the case of primary tumor is about 68% and 63 % in case of recurrent carcinoma. Its specificity in the case of primary tumor is about 69% and 80 % in case of the recurrent carcinoma[3-4].

In CT angiography a special dye is injected in the blood vessel to detect aneurysm, atherosclerosis, blood clot and arteriovenous malformation.

Magnetic resonance imaging (MRI)

Magnetic resonance imaging is based on the behaviour of the positively charged nuclear particles. MRI is non-invasive and the radiation dose is less as it uses non-ionizing radiation. It is used as a diagnostic tool in soft tissue neoplasia, TMJ evaluation, malignant involvement of the lymph nodes, perineural invasion, and soft tissue swelling. But MRI cannot be used to detect the bone related diseases and it has a long scanning time. The sensitivity and specificity of MRI is dependent on the level of malignancy. If the malignancy level is greater than 10mm the MRI has a sensitivity of the 81.5% and specificity of 55.2% if the malignancy level is greater than 15mm then MRI has a sensitivity of the 78.6% and specificity of the 78.8%[5].

MRI spectroscopy is the recent advancement in this imaging system which is used to evaluate the presence of a specific metabolite. MRI spectroscopy differentiates the non-malignant tissue from the malignant ones and also detects the post radiation changes. But its disadvantages are its cost and longer scan time. The longer scan time is generally due to the large number of images and the complexity of reconstruction.

Diffusion weighted imaging (DWI) came into reality in the year 1990. The diffusion weighted imaging is the work of Stejskal, Tanner and Le Bihan[6]. Our body mostly consists of water. This technique uses the random

Brownian movement of water molecule within the voxel tissue. The DWI demonstrates the heterogenicity in terms of apparent diffusion coefficient (ADC) within the solid tumors. Hyper cellular tumor and pathological lymph node shows low apparent diffusion coefficient while oedema, inflammatory and necrotic process shows high apparent diffusion coefficient. DWI is used to detect acute brain is chaemia, white matter disease, haematoma and paediatric brain development and aging. The diffusion weighted imaging plays an immense role in the diagnosis of head and neck pathology[7].

According to Wang et al there is significant reduction in the apparent diffusion coefficient value in neoplasm with the benign salivary gland tumor and cyst of the head and neck region having an ADC value of 1.22×10^{-3} mm^2/s. The ADC value of necrosis helps in differentiating lymphadenitis from the metastasis. The ADC value for lymphadenitis is nearly about 0.89 ± 0.21 but in case of the malignancy it is nearly about 1.46 ± 0.46. It has a predictive value of 86%, a sensitivity of 84% and specificity of 91%[8-9].

^{23}Na in MRI oncology

^{23}Na shows quadrupolar nucleus which is also used for the detection of cancer. It is found that the sodium concentration of the malignant neoplasm is increased by 60% in comparison to the normal glandular tissue[10].

Single photon emitted computed tomiography (SPECT)

SPECT produces images in the same manner as CT and MRI but with thin slices through a particular organ. It is used to detect cardiac perfusion, and brain, liver and bone malignancy. Thalium 201 SPECT shows a sensitivity of 95% in detecting squamous cell carcinoma[11].

Positron emission tomography computed tomography (PET CT)

In PET CT the metabolic or biochemical activity of the body is corelated with the anatomic imaging by CT scan. In this imaging modality intravenous bolus of 18 fluorodeoxyglucose is given 1 to 2 hours before then CT scan is performed at 2 to 3 mm slices and hypermetabolic regions are detected and colour coded. It is useful in diagnosing the distant metastasis, osteomyelitis of the jaw, metastatic masses of unknown origin and acute inflammatory lesions. 18 F-FDG PET CT shows a sensitivity of 87–90 % and a specificity of 80–93 %[12].

Ultrasound

Ultrasound uses the sound waves which is converted to the image form. For the head and neck region 7 to 12 MHz is used for diagnosis. Shorter the wavelength, better the resolution of the image. In comparison to the other modalities ultrasound is non-invasive, rapid, inexpensive, widely available and there is no harmful radiation produced. It is used to diagnose inflammation, salivary gland pathology, arteriovenous malformation, lymph node status and neoplasm[13]. The staging system with the ultrasound shows accuracy of nearly about 90%[14]. Now-a-days ultrasound guided biopsy is also performed as a diagnostic procedure.

Bone scan

Active bone formation in the body can be evaluated by bone scintigraphy method. The radioisotope used is Tc-99methylene diphosphate. Its uptake depends upon the osteoblastic and osteoclastic activity. Osteoblastic activity shows increased uptake of the radioisotope while the osteoclastic activity shows decreased uptake of the radioisotope. The hot spot area appears black as there is accumulation of the radionuclide due to increased bone growth. Cold spot area appears lighter or white because of the decreased metabolic activity. The bone scan has 3 phases i.e., perfusion phase, blood pooling phase and bony phase. It is used for the detection of malignancy, is chaemia, necrosis, hemangioma and radiation therapy[15].

Dentascan (DS)

Dentascan is another modification of the CT scan software programme in which maxilla and mandible can be visualized in all three planes[16]. The Dentascan was initially developed in the mid-1980 but it gained popularity recently. It provides a better evaluation of the osseous maxilla and mandible which is found to be useful in cases of rehabilitation with dental implants[17-19]. Dentascan is also used to evaluate the invasion of carcinoma in the bone. Brocken Brough JM conducted a study to determine the diagnostic accuracy of the Dentascan and found that it shows a sensitivity of 95%, specificity of 79%, positive predictive value of 87% and negative predictive value of 92%. Although it shows highest evidence of diagnosis the problem with it is its cost which is nearly about 1650 dollars[20].

Dual-energy x-ray absorptiometry (DEXA)

DEXA scan is generally used to evaluate the bone mineral density. According to WHO "T" score is the score which is determined to evaluate the mean standard deviation from the reference population and patient's average bone mineral density[21-22].

- Greater than or equal to -1.0: normal
- Less than -1.0 to greater than -2.5: osteopenia
- Less than or equal to -2.5: osteoporosis
- Less than or equal to -2.5 plus fragility fracture: severe osteoporosis

The advantage of DEXA scan is that it is fast, reliable and needs little exposure[23]. Jackson W used the DEXA scan and studied the change in total body composition of a patient with head and neck cancer undergoing chemotherapy and found that there is substantial loss of muscle and fat body mass seen in the patients undergoing concurrent chemoradiotherapy[24].

Narrow band imaging system (NBI)

The recent advancement in the field of cancer detection is the narrow band imaging. If the tumour is less than or equal to 1 centimetre in size, it is very difficult to detect[25]. This technique is based on the principle that it alters the spectral characteristics of illuminating light by limiting the bandwidth of an optical filter in the light source[26]. The NBI contains red, green and blue (RGB) wavelength in sequential video endoscope. The optical filter present in the NBI system allows narrow band light to pass a wavelength of 415nm which only passes superficially through the mucosa and enhances its vasculature. Then a longer wavelength of 515nm is used which reveals the submucosal vessel as it passes the deeper tissue[27]. Blue light has less scattering and penetration in comparison to the red light so the blue light enhances the image resolution[28]. The peak absorption spectrum of the hemoglobin corresponds to the blue light which also enhances the visualization of the submucosal vessel. A monochromatic charge coupled device (CCD) enhances the reflection, and an image processor builds a composite pseudo color image that is presented on a high-definition video screen[27]. Thus, the lesion which is initially not detected through the white light emitted by the endoscope is now visible in the blue light filter of the narrow band imaging based on the neo angiogenesis and increased vascularity of tumor. Integrating this optical technology with magnifying endoscopy (NBI-ME), which allows the endoscopist to zoom in on the mucosa by merely pressing a specialised button, increases the diagnostic usefulness of this optical technology. The advantage of the NBI is that it is not a cumbersome procedure, easy to perform and can also detect the lesion less than equal to

1 centimetre in dimension[29]. NBI is also used to detect the primary tumor[30]. Hayashi et al. studied 46 patients with cervical lymph node metastases due to SCC. In none of the patients could a standard clinical examination or white light naso endo scopy detect a lesion. All of them were then subjected to NBI with magnifying endoscopy, which revealed 26 worrisome lesions. All of them were subjected to a biopsy, and 16 of them were determined to have SCC[31]. Zhou H et al conducted a metanalysis where he included 25 studies with 6187 lesion and found the sensitivity, specificity, positive predictive value, negative predictive value and odds ratio of 88.5%, 95.6%, 12.33, 0.11 and 121.26 respectively in cases of narrow band imaging[32].

Fluorescent lifetime imaging microscopy (FILM)

Fluorescent Lifetime Imaging Microscopy (FILM) is a potential imaging modality that extracts various suggestive factors from autofluorescence signals, such as intensity, lifetime, and wavelength, to distinguish malignant from healthy tissue[33-34]. This method is mostly used for the intraoperative procedure[35].

When development of the oral cancer occurs, there is change in the stratified squamous epithelium, lamina propria and connective tissue due to morphological, biochemical and functional alterations[36]. During the development of precancerous and cancerous lesion there is reduction in the nicotinamide adenine dinucleotide (NADH) and flavin adenine dinucleotide (FAD)[37-38]. The fluorescent intensity of the NADH to FAD is called as the optical redox ratio[39]. A decrease in the optical redox ratio is frequently blamed for increasing cellular metabolic activity, which is a hallmark of neoplastic cell transformation[40]. As a consequence, evaluating NADH, FAD, and collagen autofluorescence for optical biomarkers of oral epithelial cancer could be useful. Duran-Sierra E conducted a study to differentiate the oral epithelial dysplasia, SCC and normal healthy cell and concluded that the auto fluorescent lifetime imaging microscopy provides is a better method to differentiate dysplasia, neoplasia and normal healthy cell[36].

Cone beam computed tomography (CBCT)

In the last 10-year CT scan is replaced by CBCT for a particular region of bone. Detailed reconstruction is found in CBCT as compared to CT scan because of its small voxel size, good spatial resolution and detailed reconstruction of the image[41]. CBCT is used to diagnose chronic sinusitis, implant placement sites, maxillofacial pathology, orthodontic and 3 dimensional cephalometry, post operative aesthetic evaluation in the orthognathic patients, determination of the canal in the tooth, osteomyelitis and salivary gland pathologies. The advantage of CBCT scan is that it provides 3-dimensional data setup, has potential for generating 2-dimensional image like lateral cephalogram, high resolution, easy handling, less disturbance from the metal artefacts, compatible with the digital imaging and communication in medicine and also has low radiation dose. The disadvantage of the CBCT is that low contrast range, limited detector size cause limited field of view, limited soft tissue information and increased noise due to the scatter radiation and along with loss of resolution[42].

Temporomandibular joint arthroscopy

Dr. Ohnishi was the first to perform the TMJ arthroscopy in the year 1974 but he reported in the Japanese literature in the year 1975[43]. It is a technique used for the visualization of the internal joint structures directly and to perform surgical procedures under visual control with the guidance of the arthroscope. It can be used for the diagnostic and therapeutic purposes. The advantages of the TMJ arthroscopy are that no significant incision, reduced incidence of facial nerve injury and the ability of diagnostic along with therapeutic abilities but it requires a steep learning curve to perform.

Conclusion

This paper demonstrates how developments in technology have enabled diagnostic imaging procedures to provide deeper insight into physiological structure and function for medicinal applications. We must also look at the evidence before implementing new radiological procedures, taking into account the influence on clinical results, health economics, and radiation protection concerns.

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