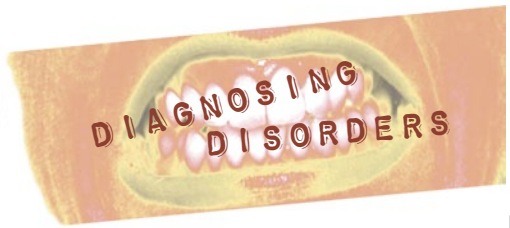

Diagnostic Imaging for Chronic Orofacial Pain, Maxillofacial Osseous and Soft Tissue Pathology and Temporomandibular Disorders

Werner Shintaku, DDS, MS; Reyes Enciso, PhD; Jack Broussard, DDS; and Glenn T. Clark, DDS, MS

ABSTRACT

Since dentists can be faced by unusual cases during their professional life, this article reviews the common orofacial disorders that are of concern to a dentist trying to diagnose the source of pain or dysfunction symptoms, providing an overview of the essential knowledge and usage of nowadays available advanced diagnostic imaging modalities. In addition to symptom-driven diagnostic dilemmas, where such imaging is utilized, occasionally there are asymptomatic anomalies discovered by routine clinical care and/or on dental or panoramic images that need more discussion. The correct selection criteria of an image exam should be based on the individual characteristics of the patient, and the type of imaging technique should be selected depending on the specific clinical problem, the kind of tissue to be visualized, the information obtained from the imaging modality, radiation exposure, and the cost of the examination. The usage of more specialized imaging modalities such as magnetic resonance imaging, computed tomography, ultrasound, as well as single photon computed tomography, positron electron tomography, and their hybrid machines, SPECT/CT and PET/CT, are discussed.

When faced with a patient who has a new onset sustained or episodic orofacial pain, orodental pain, or headache that is not easily explained by local dental or periodontal disease, the dentist must make two determinations. First, he or she must




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decide if the pain is due to a life-threatening cause and if so, make immediate referral to the proper specialist or emergency room. If a life-threatening cause for the symptoms (e.g., pain or headache) is not likely and urgent action is not indicated, the standard of practice suggests that a dentist perform a thorough medical history and a good examination of the intraoral and extraoral structures which often include appropriate radiologic imaging methods (see Sections I.a-b). This examination and the imaging are taken to make sure local maxillofacial osseous or soft-tissue pathology is not overlooked. Sometimes, neuroimaging is required and this assessment can be ordered by the dentist or by a specialist referral for additional diagnosis and possible treatment (see Sections I.c-d).

I.a. Diagnostic Radiologic Imaging Choices

The minimum set of images needed when ruling out maxillofacial pathology in a patient with jaw or facial pain of unknown origin would be to take a panoramic radiographic. Of course, the value of the panoramic film as a routine screening tool for asymptomatic young adults is not of proven value.[1] However, panoramic films increase their value when diagnostically complex cases are under consideration. In recent years, the panoramic screening films are rapidly being replaced by cone-beam computerized tomographic, CBCT, assessment of the jaw and face as a first-line diagnostic test when assessing pain of unknown origin.[2] CBCT is a technology that uses a cone-shaped X-ray beam that goes around the object acquiring volumetric data in one rotation. This allows a shorter scanning time and lesser radiation exposure compared with conventional CT scans.[3,4] The advantages of the CBCT technology are based on the patient's comfort, that information is rapidly acquired, that data can be manipulated and seen in a versatile manner, and that it has the option of magnification, simultaneous multiplanar display, density measurements, the possibility for linear, angular and area measurements and 3-D display of the image if needed.[5] Examples of how CBCT is used for osseous imaging are presented later in this article. When more accurate imaging of the nonosseous orofacial or brain tissues are needed, this is typically achieved with magnetic resonance imaging, MRI.[6] Finally, there are also several other imaging modalities including ultrasound and radionucleotide bone scans when specialized questions are being asked. These methods will be discussed in Sections II.c and III.a-b.

One frequent problem dentists face is how to deal with a patient who has an atypical toothache.

I.b. Imaging for Chronic Orodental Pain

One frequent problem dentists face is how to deal with a patient who has an atypical toothache. This is a persistent toothache *without* definitive evidence of dental-pulpal disease such as periapical radiolucency and/or a thermal or electrical pulp test that shows complete nonresponsiveness (an indicator of nonvitality) of the tooth to stimulation. Note that atypical toothaches may have a hyper-responsiveness to stimulation, but would not test as being "nonvital." There are three main causes of these symptoms including (1) irreversible pulpitis; (2) pain due to a spontaneously active branch of the trigeminal nerve that has become sensitized and the pulpal tissues are not irreversibly altered; and (3) pain due to an incomplete crack or fracture of the tooth. It is quite difficult to distinguish between these three problems. In practice, most dentists believe that a pulpal origin of the pain can be definitively proven or disproven by performing what has been termed a diagnostic root canal or diagnostic extraction. If the root canal or extraction abruptly stops the pain, then the pulpal tissues were indeed the source of the pain. However, if these procedures do not stop the pain, the possibility of neuropathic changes in the nerve supplying the area is elevated. Since no one would elect to have an irreversible procedure as the first choice of diagnosis, discussion of alternative methods for diagnosis beyond pulp testing and periapical imaging is needed. These methods include CT imaging and microscopic diagnosis of tooth cracks.

One recent study assessed the value of direct visual examination of 46 chronically painful teeth in 32 patients after removal of all restorations was performed on the teeth in question to better examine them for evidence of incomplete fracture.[7] They found evidence of incomplete tooth fracture in all examined teeth and in produced pain relief in 29 of the 32 patients, 90 percent, who had endodontics or full-crown restorations. Unfortunately, extensive data on the prevalence of how often endodontic/extraction treatments completely resolve a persistent orodental pain without evidence of nonvitality and no periapical lucency is not available. Clinical experience at

the University of Southern California Orofacial Pain Center suggests that the likelihood of full resolution of tooth pain with endodontics treatment in a tooth with persistent symptoms (>1 year) may not be as high as this prior study suggests. Additional data on this method of diagnosis (direct visualization using an operating microscope) and more long-term studies with careful pain assessment at follow-up is needed. In the meantime, this method should be considered before a diagnostic root canal or diagnostic extraction is performed.

On the horizon is the possibility that incomplete tooth fractures might be detected using either digital dental radiographic images or using conventional CT or CBCT images but this has not yet been proven. One study used 201 extracted teeth (100 fractured and 101 nonfractured) in which they created vertical or oblique root fractures and then imaged these roots with a digital dental imaging system.[8] The radiologists viewing the images had to decide if the image showed evidence of root fracture or not. The resulting data showed a sensitivity for this determination which ranged between 79 percent and 81 percent. The specificity was found to be 86.1 percent and magnification did not help. While these data are interesting, the level of sensitivity and specificity needs to be established for an in vivo situation and for incomplete tooth fractures or cracks, not complete root fractures. With regard to CT as a tooth crack detection method, there is one recent study that reported on the value of a specialized conventional CT device in Germany that was used to visualize vertical root fractures.[9] These authors examined five extracted teeth that had prior root canal fillings yet had chronic pain symptoms and were suspected to have vertical fractures because of the presence of isolated periodontal pockets >/= 8 mm but standard dental radiographs were not able to visualize the fracture. All teeth were carefully extracted and then submitted to imaging using a CT technique.

Figure 1a. Periapical image of a horizontal root fracture of tooth No. 9 *(courtesy of Dr. Jose Maria Malfaz, University of Southern California).*

Figure 1b. CBCT images (sagittal view) of the same tooth seen in Figure 1a. In both views, the fracture line is evident *(courtesy of Dr. Malfaz).*

In all cases the authors claimed that they could easily detect the vertical root fractures or crack lines, but no actual blind testing was done. For this reason, whether or not conventional CT or the new CBCT devices can routinely detect incomplete vertical tooth cracks and fractures has not been proven yet. Of course CBCT can be used to detect more substantial tooth complete fracture cases (those where the teeth components have some physical separation). The figures below show a tooth that has a complete horizontal fracture examined with both a periapical film and a CBCT film (**Figures 1a-c**). No study has yet been performed using CBCT imaging to find its sensitivity and specificity for detecting incomplete vertical fractures in vivo. In such a research project, the gold standard would have to be teeth either examined with a microscope during endodontics treatment or after careful extraction to see if the CBCT prediction was correct (**Figures 1a-b**).

I.c. Neuroimaging for Dangerous Intracranial Pathology

Diagnosis of intracranial pathology typically involves MRI-based neuroimaging, however, the likelihood of a new onset orofacial/headache pain without positive neurologic findings resulting in a positive imaging study for intracranial or other pathology is less than 0.7 percent.[10] This figure comes from a study where 306 patients with normal neurologic findings but with chronic or recurrent headaches were imaged with MRI. They found that 169 (55.2 percent) had no MRI evident abnormality, 135 (44.1 percent) had minor unrelated MRI abnormalities evident and 2 (0.7 percent) had clinically important intracranial abnormalities that were probably related to the chronic or recurrent headache. This rate is consistent with prior literature reports on positive findings when imaging headache patients with negative neurologic examination.[11]

Of course, telling a patient he or she does not need imaging does not necessarily convince them since they may worry about being in the group who does have a positive finding. On this very point, one recent study examined

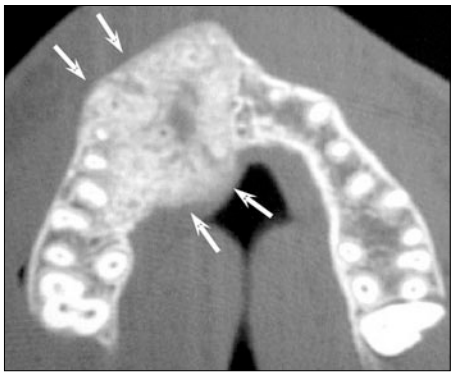

Figure 2a. CT image (axial view) of a fibrous dysplasia showing a unilateral, ill-defined and radiolucent-radiopaque lesion *(courtesy of Dr. Roman Carlos, Centro de Medicina Oral de Guatemala).*

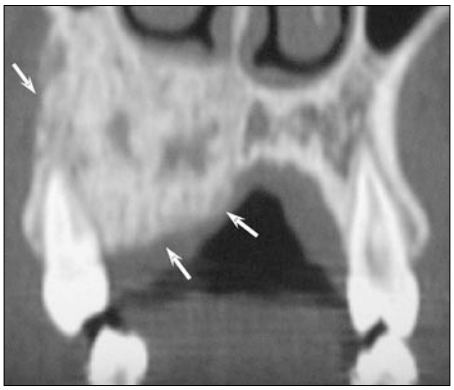

Figure 2b. CT image (frontal view) of the same fibrous dysplasia seen in Figure 2a *(courtesy of Dr. Carlos).*

Figure 2c. Clinical aspect of the same fibrous dysplasia seen in Figure 2a. Note the expansive pattern of the lesion *(courtesy of Dr. Carlos).*

Figure 2d. Clinical aspect of the same fibrous dysplasia seen in Figure 2a. Note the modification in normal occlusion *(courtesy of Dr. Carlos).*

if ordering neuroimaging in patients with chronic daily headache reassured them or increased their anxiety.[12] They measured this by tracking the number of doctor visits and overall costs of health care for a one-year period after imaging. Prior to imaging the subjects in this study were rated on their level of depression and anxiety using the Hospital Anxiety and Depression Scale, HADS.[13] The study was performed at a specialty referral-based headache clinic in South London and included 150 patients who had a negative neurologic examination and had a diagnosis of chronic daily headache. They were randomly assigned to either have a MRI brain scan or not. One year after imaging, the case noted 137 of the 150 enrolled patients were examined and it was determined that the more anxious patients (those with a high HADS score) who had been offered a MRI brain scan said they were less worried about a serious cause for their chronic headaches and they had significantly less health care costs than the group with high anxiety (HADS score >11) who did not have a MRI scan. Based on these findings it seems prudent to suggest that in "negative neurological examination" patients, a MRI scan is not usually required as the odds of intracranial pathology is very low although anxious chronic pain patients may need the reassurance a negative MRI scan provides.

I.d. Neuroimaging and Trigeminal Neuralgia

Neuroimaging is routinely performed for patients who have a clinically confirmed diagnosis of trigeminal neuralgia and who do not fit the following profile: over the age of 60 with unilateral brief severe light-touch triggered divisional pain of the trigeminal nerve and no other neurologic findings. It is also routinely performed for those patients who are medication intolerant and/or wish to consider surgical treatment options. One article examined 51 patients using a MRI-based trigeminal nerve imaging protocol and found that 17 (33 percent) of the patients had nonvascular abnormalities while 27 (53 percent) had vascular contacts or compressions of the trigeminal nerve.[14]

While the 33 percent figure these authors report for nonvascular nerve pathology is much higher than other studies on trigeminal neuralgia, which usually report a prevalence of <15 percent for tumors or multiple sclerosis, the trend they identify is important.[15] Specifically, they found that in younger patients, the rate of tumor or multiple sclerosis was much higher than in those over the age of 60. In addition, these authors reported that if the trigeminal neuralgia involved more than one branch of the trigeminal nerve, one-third of those imaged had tumors. Recently, the question of how often does an MRI detect neurovascular compression abnormalities at the trigeminal root entry zone in patients with persistent idiopathic facial pain, PIFP, sometimes described as atypical

trigeminal neuralgia or atypical facial pain, has been addressed. The study involved examination of 12 patients with unilateral PIFP and compared the neurovascular image finding on the symptomatic side to the asymptomatic side. They found no statistically significant difference between the two sides and reported MRI detection of neurovascular compression had 58 percent sensitivity and 33 percent specificity when they used the presence of symptoms as the gold standard. Obviously this raises the issue of false-positive MRI findings as a problem.

II. Assessing Maxillofacial Osseous Pathology

While pain is illusive and the source of the pain is not always visible, osseous pathology is certainly visible and imaging is critical to any assessment. There are a variety of asymptomatic and sometimes symptomatic osseous lesions of the jaws and temporomandibular joints that require advanced radiologic-based imaging to better document the disorder/pathology, and even to determine proper treatment. Examples of these conditions include any large cyst or expansive lesion of the jaw. The same holds for suspected osteomyelitis or asymptomatic osteonecrosis of the jaws and osteoarthritis of the temporomandibular joint.

When dealing with growing lesions of the bony structures and soft tissue such as might occur with tumors, fibrous dysplasia of the jaws and even normal bony tissues that are potentially undergoing hyperplasia, this may require radionucleotide-based imaging methods. For example, sometimes it is critical to know if the abnormal temporomandibular joint image is a reactive proliferative osseous healing in response to a trauma or a progressively growing neoplastic process such as an osteochondroma (**Figures 2a-d**).

Figure 3a. Radiographic aspect of a periapical lesion showing a typical well-defined round image *(courtesy of Dr. Ali Vaziry, University of Southern California).*

Figure 3b. CBCT views of mandibular incisor periapical lesion from the same patient pictured in Figure 3a *(courtesy of Dr. Vaziry).*

Figure 4a.

Figure 4b.

Figures 4a (sagittal view) and 4b (coronal view). CBCT exam of an arthritic TMJ. Note the lack of normal contour, decreased intra-articular space and increased radiographic density *(courtesy of USC Orofacial Pain and Oral Medicine Center).*

II.a. Radiologic Imaging for Maxillofacial Osseous Pathology

When attempting to detect osseous lesions (radiopaque or radiolucent) in the maxillomandibular tissues, the dentist needs to know what is the correct radiograph to best image the lesion. For example, standard pulpal-pathology-related periapical lesions are best imaged with standard periapical view dental radiographs (**Figure 3a**). However, as a periapical film represents a bidimensional view of a tridimensional structure, there are some instances when this projection does not correctly capture the area of concern because of tooth malposition or abnormal anatomy of the patient, or a superimposed structure (e.g., maxillary sinus). In other instances, the patient cannot open their mouth adequately, they are uncooperative, or have a strong gag reflex preventing usual and customary imaging approaches.

In these cases, it may be necessary to consider either sedating the patient or ordering a panoramic film, a conventional CT or CBCT scan. The two last ones provide multiple planar views from different directions, which is sometimes required before action is taken (**Figure 3b**). The accuracy of conventional CT

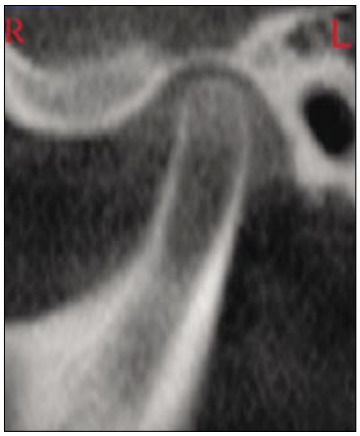

Figure 5a.

Figure 5b.

Figures 5a (sagittal view) and 5b (coronal view). CBCT of a more normal TMJ showing a better contour and intra-articular space *(courtesy of USC Orofacial Pain and Oral Medicine Center).*

Figure 6a.

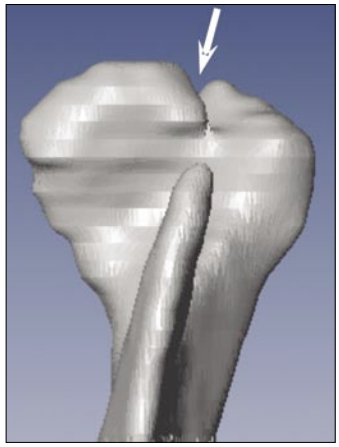

Figure 6b.

Figures 6a and 6b. CBCT image of fractured condyle and 3-D image of same condyle *(courtesy of USC Orofacial Pain and Oral Medicine Center, School of Dentistry).*

films versus standard dental films at detecting periapical lesions was actually evaluated in one study.[16] The authors examined 50 patients (80 roots) with a persistent apical lesion that was referred for apical surgery in the molar or premolar region using both a CT scan and one periapical radiograph. The apical lesion was confirmed (gold standard) at surgery. The results showed that of the 78 lesions diagnosed during surgery, all were visible (100 percent) with the CT scan while the conventional periapical films detected only 61 (78 percent) of these lesions. Obviously, larger lesions of the mandible or lesions below or above the apices of the teeth cannot be imaged with standard dental periapical films, and CT is a preferred method in these situations. For diagnosis of routine periapical lesions in cooperative patients, CT imaging is a far more expensive method and provides far more radiation to the patient than a periapical film. On the positive side, conventional CT and CBCT have the advantage of increased accuracy and they can find the exact relative location of the lesion to the sinus or mandibular canal and therefore should be considered when indicated (**Figures 3a-b**).

II.b. Panoramic Versus CBCT Imaging for TMJ Pathology

Even with a careful clinical examination, some TMJ cases are hard to diagnose accurately.[17-21] For example, patient cases of osteoarthritis that also have severe movement limitations or do not yet present with crepitation on movement. In either case, the most telling clinical sign of osseous TMJ changes, crepitation on motion, is not present. A widely used technique, the panoramic projection can provide information about the condyles, rami, and body, as well as the surrounding structures, including the neck, TMJ, zygomatic arches, maxillary sinus and nasal cavities. It serves as a screening projection to identify possible disorders that may be related to TMJ symptoms making possible the identification of gross osseous changes in the condyle such as asymmetries, extensive osseous erosions, osteophytes, or displaced fractures and neoplasia.

To better visualize the TMJ on a panoramic projection, it should be taken with a partly open mouth and even then the condyle shape is distorted.[22] One recent study examined the prevalence of panoramic TMJ changes in a serologically positive juvenile population (n=97) known to have juvenile idiopathic arthritis (JIA).[23] They found 45 percent of this population had clear TMJ involvement. JIA has a variety of arthritic subtypes, but those children with a polyarticular course, irrespective of their disease onset, had a higher TMJ involvement compared to the oligioarticular group (55 percent

vs. 31 percent). Positive clinical examination findings of pain and dysfunction in the lower jaw exhibited a good specificity but a low sensitivity for radiographically proven TMJ involvement in this population. Moreover, the study revealed that a positive panoramic type radiographic finding of TMJ involvement in JIA patients can occur without having clinical signs.

If a positive finding is seen on a panoramic projection often additional views (usually with CBCT) can be obtained later.[24] A disadvantage of the CBCT is cost, and higher radiation exposure compared to panoramic films, although both of the cost and the radiation exposure are much lower with CBCT than conventional CT.[25] For the TMJ, the CBCT gives spectacular 2-D images, however at present, the 3-D reconstructed views from CBCT images are not quite as smooth as seen in medical computed tomography and, sometimes, artifacts can be misunderstood as degenerative changes (**Figures 4a-b, 5a-b, 6a and 7a-b**). When imaging the TMJ, the most common findings are osteoarthrotic changes but occasionally, a neoplastic change is evident. For example, osteochondroma is a benign tumor arising from the condyle and it is slow growing but can cause progressive deformities of the jaw (**Figures 7a-c**).[26] When a proliferative alteration of the condyle is evident on a film, the differential diagnosis would be a reactive condylar hyperplasia, osteoma, chondroma, osteoblastoma, and osteochondroma. In these cases, patients usually complain of pain, facial asymmetry, and sometimes malocclusion.[27] When active growth is suspected, repeat CBCT imaging is one way of assessing whether the growth is active, and another is a bone scan using a radionucleotide-based image described later (**Figures 4a-b, 5a-b, 6a-b, and 7a-b**).

Figure 7a. CBCT of an osteochondroma in the left TMJ (axial view). Note the irregular condylar bulbous or globular expansion *(courtesy of USC Redmond Imaging Center).*

Figure 7b. CBCT image (frontal view) of the same osteochondroma of Figure 7a.

II.c. Radionucleotide-based Imaging vs. MRI for Osseous Disease and Growth Activity

When an unusual osseous disease is seen on a panoramic, CT, or CBCT, additional imaging with MRI has been used to better understand the soft-tissue changes and visualize the disease in question. For example, osteonecrosis of the maxillofacial structures is rapidly becoming a substantial concern in diagnosis with the increased use of bisphosphonates and more recently, some of the anti-retroviral drugs. One study has recently examined the value of MRI at detecting osteonecrosis of the TMJ with painful internal derangements.[28] T1-(proton density) and T2-weighted MR images were correlated with the histological observations from the marrow of the mandibular condyles showing 78 percent sensitive and 84 percent specificity. This yielded a positive predictive value of only 54 percent due to a high number of false-positive MRI diagnoses and thus, this method has limited value as a diagnostic test. Another study examined the relationship of bone marrow edema pattern and the MRI findings in the mandibular condyles of patients who had a diagnosis of TMJ pain and dysfunction, and who also showed a positive MRI-based finding of condylar bone marrow edema.[29] This study involved repeat MRI images (17 months later) taken after relief of joint pain following arthrocentesis and other nonsurgical treatments (behavior modification, manipulation of the joint and nonsteroidal anti-inflammatory drugs, followed by a stabilization-type splint). The authors report that four of the 14 joints (28.6 percent) showed a normal bone marrow signal, whereas 10 joints (71.4 percent) showed a persistent bone marrow edema pattern.

This finding raises the issue of whether a MRI finding of bone marrow edema is clinically significant. Another interesting feature of MR images is their ability to identify calcification and ossification in tissues that do not normally ossify (e.g., muscles).[30] This rare condition known as myositis ossificans and related to fibrodysplasia ossificans progressive syndrome has an unknown pathogenesis but can be related to an autosomal dominant mutation and trauma. Fibrodysplasia ossificans progressive is certainly a possibility in

Figure 8a. CT of osteomyelitis with a characteristic onion-skin appearance in the posterior body of the mandible *(courtesy of Dr. Michael Pharoah, University of Toronto).*

Figure 8b. Panoramic projection of an osteomyelitis in the mandible *(courtesy of Dr. Parish Sedghizadeh, University of Southern California).*

those patient cases that never open fully after a jaw muscle trauma or injury has occurred. Prolonged jaw trismus can and does turn into a permanent contracture when an inadvertent intramuscular injection of anesthetic containing epinephrine has caused a severe myositis, and even though the patient has had plenty of time for this injury to resolve, they still cannot open wide.

For maxillofacial diseases where an active growth is suspected (e.g., neoplasia) bone scans are increasingly used for diagnosis. Bone scans use a radionucleotide and show areas with increased uptake providing additional information helpful in confirming whether a suspicious lesion is growing or not. In the case of osteochondroma, or even fibrous dysplasia, it is helpful in confirming the diagnosis without a biopsy.[31] There are two recent radionucleotide imaging methods that have a potential value in dental osseous disease detection, including single proton emission computed tomography bone scans, SPECT, and positron emission tomography, PET. Both involve the injection of radionucleotide isotopes and a bone scan to detect the site of its chemical uptake. These methods cannot distinguish between benign or neoplastic growth as this will require a biopsy. One problem with bone scans is that they also show increase nucleotide uptake in sites of active inflammation, which causes false-positives results.

SPECT and PET offer the advantage over traditional planar bone scanning in that they can use CT technology to provide detailed anatomical and 3-D images. In the past, because of the lack of anatomical information, it was not possible to reliably delineate a tumor within the oral cavity due to superimposition. For example, one study compared and contrasted SPECT with standard planar film bone scans in determining growth patterns in the mandibular condyle and reported that while both methods were acceptable in accuracy, the SPECT method was easier to perform with better reproducibility than the standard planar technique.[32] SPECT bone scanning has recently been used for confirmation of the diagnosis of fibrous dysplasia.[33]

One study compared standard radiographs with radionucleotide bone scans of 42 histopathologically proven fibrous dysplasia cases and found that while the fibrous dysplasia patients showed a nonspecific increased 99m-Tc MDP uptake, its appearance was different than bone metastases and other bone diseases. The authors suggested that combining radionuclide bone scanning with standard radiographs provides the best results. Another more controversial study has actually looked at the potential of SPECT bone scans to the diagnosis of idiopathic jaw pain.[34] The study included 20 patients with a diagnosis of chronic idiopathic jaw pain and compared them to 20 age-matched and gender-matched normal controls. Nineteen of 20 patients with jaw pain showed increased signal uptake, and 15 of them showed uptake in the area of the pain. However, 12 out of the 20 controls also showed uptake and the uptake site in these subjects was correlated with previously detected jaw pathoses that had long since healed. Overall, this method showed an unimpressive sensitivity and specificity for detecting painful sites of 0.79 and 0.68, respectively.

One clear drawback of SPECT for diagnosis of atypical pain is that there are a high number of false-positives

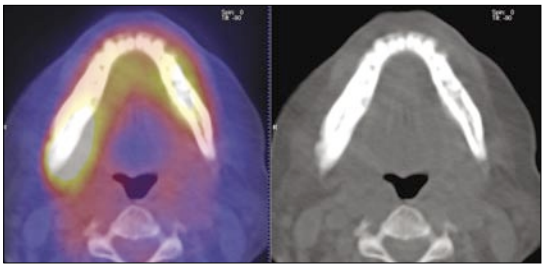

Figure 9a. PET/SPECT of a 54-year-old female with a history of breast cancer with metastases to bone and lung, and multiple chemotherapies. PET/CT images demonstrated intense hypermetabolic activity in the right mandible greater than the contralateral side. These findings are consistent with Zometa-associated biopsy-proven osteonecrosis *(courtesy of Dr. Peter Conti, PET Imaging Science Center, USC University Hospital).*

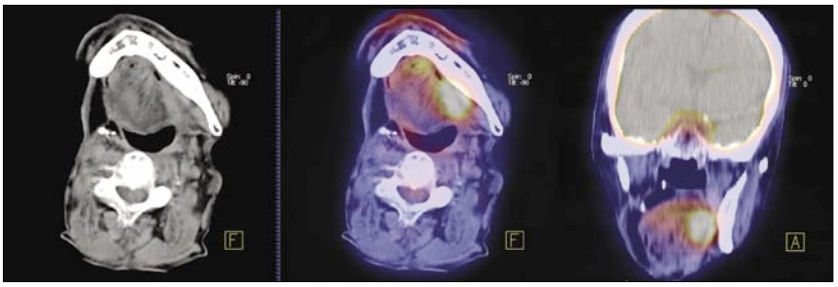

Figure 9b. PET/SPECT of a 53-year-old male with a right tonsillar fossa squamous cell carcinoma. PET/CT images show a focal increased activity internal to the midline of the mandible suspicious for a second focus of malignancy *(courtesy of Dr. Conti).*

which clearly limits its application as a diagnostic test. On the issue of using SPECT for the determination of condyle growth, a recent paper described the case of a 14-year-old girl suffering from condylar hyperplasia and enlargement of ipsilateral jaw body.[35] They described how the SPECT bone scan was used to plan when to perform surgical intervention (i.e., condylectomy) in the management of this case. More importantly, there is a third report on a series of cases were the authors found that the SPECT was able to separate "active growth" from "growth cessation" of the condyle.[36] Finally, PET-based bone scans use 18 fluorodeoxyglucose, FDG, a glucose-based tracer that has become a routine diagnostic tool for staging and restaging patients with pathologies in the oral cavity and lymph nodes, as well as to identify distant metastases. In a systematic review of diagnostic techniques available for excluding or confirming chronic osteomyelitis, FDG-PET imaging demonstrated to be the most sensitive technique, with a sensitivity of 96 percent compared with 82 percent for bone scintigraphy, and 84 percent for MRI.[37] New PET-CT fusion machines are available, allowing both examinations to be performed without having to move the patient. A study evaluating its use for the identification of tumor and metastases found an accuracy rate of 98.4 percent for 18F-FDG PET when compared to CT (87.1 percent) and MRI (99.2 percent); a sensitivity for the identification of nodal metastases of 74.7 percent (52.6 percent for CT/MRI), and a specificity of 93.0 percent (94.5 percent for CT/MRI).[38] Although PET is less sensitive in detecting small tumors (less than 1.0 cm) and tumors of low metabolism, it is showing a good potential to provide information that conventional exams cannot, and with technological advances it may allow improved patient care in the near future (**Figures 8a-b, and 9a-b**).

III. Imaging for Maxillofacial Soft-tissue Disease

Today, the most accessible and commonly used technique when one wants to evaluate the articular soft tissues (i.e., disk) of the TM joint is the MRI. MRI is also indicated for assessment of the salivary and lymph glands in the maxillofacial and submandibular/cervical region (See Section III.a). Another example where MRI is important is when there is a suspected disk displacement without reduction, DDWR, case with limited opening motion. The limitation of motion in these cases could just as easily be due to trismus, so imaging can help confirm one's clinical suspicions (see Section III.b).

III.a. Imaging for Salivary and Lymphatic Glands

Salivary pathologies of concern include sialoadenitis, sialolithiasis and glandular, and extraglandular tumors. Chronic inflammatory disorders of these glands such as sarcoidosis and Sjögrens syndrome also need exploring with imaging before aspiration, cytologic biopsy, and traditional biopsy procedures are undertaken. With the rise of CT and MRI for imaging salivary gland tissues, the need to infuse a radiopaque dye into the gland to image them declined. In the last 15 years, multiple authors have described the value of MRI for diagnosis of salivary pathology. For example, one study on 162 patients with clinically suspected diseases of the major salivary glands

Figure 10. MRI of a TMJ with the displaced articular disk *(courtesy of USC Orofacial Pain and Oral Medicine Center, School of Dentistry)*.

compared ultrasound (sonography), sialography and CT-based-sialography.[39] As the gold standard, they compared the image-based diagnosis with histologically (70 percent), cytologically (26 percent) and clinically proven diagnoses in the remaining subjects. The study reported that sialoadenitis was diagnosed via sonography and sialography with a sensitivity of 58 percent and 54 percent, respectively. Salivary gland tumors were correctly diagnosed by sonography and CT-sialography in 76 percent of the cases, and by sialography in 83 percent of cases. In a second comparative study, the salivary glands of 80 patients with clinically suspected diagnoses of sialoadenitis and/or sialolithiasis were examined using both MRI and digital subtraction sialography.[40]

The gold standard was based on clinical follow-up and biopsy or surgery. The authors reported that digital subtraction sialography provided greater detail than MRI, and the sensitivity and specificity to diagnose chronic sialoadenitis was 70 percent and 98 percent with MRI and 96 percent and 100 percent with digital subtraction sialography. In addition, MRI enabled diagnosis of sialolithiasis with a sensitivity of 80 percent and a specificity of 98 percent versus 90 percent and 98 percent for each with digital subtraction sialography. The authors concluded that while MRI was not as accurate as sialography, the latter, which is an invasive technique, had a substantial procedural failure rate, particularly for the submandibular duct. A third comparative study was published in 2005, which examined 135 patients with various salivary gland diseases using ultrasonography, sialography, CT, and MRI.[41]

The authors used histopathologic examination as the gold standard and reported that ultrasonography was better at detecting neoplastic and inflammatory processes in small lesions (<5 mm diameter) while CT and MR were better at evaluating large tumors. Since that time, MRI has become the standard method since the method itself has increased its accuracy and it is far easier to perform. Final diagnosis is performed by cytology or biopsy, if needed. In fact, it is now almost impossible to find a radiologic laboratory that still performs sialography. Ultrasound combined with MRI is currently the standard of practice for evaluating salivary, lymphatic, and extraglandular palpable pathology.[42]

III.b. MRI for Temporomandibular Disk Position

MRI was initially introduced in the early 1980s and is used most often because it is noninvasive and does not result in patient exposure to ionizing radiation. Multiple digital slices can be manipulated and formatted like the CT information but with superior image detail of soft tissues.[43] Osseous changes can also be evaluated but a more detailed study of bone is usually reserved for CT.[44] Oblique sagittal and coronal images are usually required to evaluate the TMJ.[45] The slice thickness and the pixel size also can be manipulated to improve the image resolution.[46] Typically, a TMJ exam consists of both open- and close-mouth views in an oblique sagittal plane with the sections oriented perpendicular to the long axis of the condyle. These images are useful to evaluate the disk position with respect to the condyle. Images in coronal plane can also be used to identify lateral or medial displacement of the disk.[47] One of the main TMJ-based reasons to order an MRI is to discover the position and form of the disk. The problem with this is that disk displacement (in the closed-mouth view) is frequently seen in asymptomatic volunteers.[48] This problem (false-positives) would not be a concern if all patients could open wide since asymptomatic volunteers almost never show a nonreducing disc displacement in the open-mouth view.

Unfortunately, many of the patients who have a TMJ MRI assessment made cannot open wide thus, clinical correlation with image results are required to make the final determination as MRIs do give false-positives at times. In addition to disk-positioning abnormalities, MRI has value in detecting joint effusion and mandibular condyle marrow abnormalities. In a recent study, the authors reported that nearly 15 percent of TMD patients consecutively referred for TMJ MRI had joint effusion, and 30 percent of those will have bone marrow abnormalities.[49] They also reported that patients with TMJ effusion and/or abnormal bone marrow in the mandibular condyle seem to constitute only a minor portion (less than one-fourth) of consecutive TMD patients referred for diagnostic TMJ imaging and patients with rheumatoid arthritis and other arthritides TMJ involvement may

mimic the more common TMDs. What is lacking from the MRI-based diagnoses is a proper gold standard for effusion and/or abnormal bone marrow signals to see if this diagnosis also suffers from false-positive (**Figure 10**). ■■■■

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