The role of SPECT/CT with ^{99m}Tc-MDP image fusion to diagnose temporomandibular dysfunction

Alessandra Coutinho, DDS, MSc,[a] Marlene Fenyo-Pereira, DDS, MSc, PhD,[b] Luciano Lauria Dib, DDS, MSc, PhD,[c] and Eduardo Nóbrega Pereira Lima, MD, MSc, PhD,[d] São Paulo, Brazil
UNIVERSITY OF SÃO PAULO

Objective. The objective of this study was the evaluation of Single Photon Emission Computed Tomography with Technetium 99m Methylene Diphosphonate (SPECT with ^{99m}Tc-MDP) and computed tomography (CT), simultaneously acquired image in diagnosis of temporomandibular joint (TMJ) dysfunction.
Study design. A prospective study was conducted with 33 patients, 29 female and 4 male, all of then presenting signs and/or complaints suggestive of temporomandibular dysfunction. SPECT/CT with ^{99m}Tc-MDP was performed in all patients and imaging results compared with final diagnosis and clinical outcome.
Results. The correlation of signs and symptoms with SPECT/CT imaging showed sensitivity 100%, specificity 90.91%, and accuracy 96.97%.
Conclusions. SPECT/CT with ^{99m}Tc-MDP coregistered imaging fusion is a suitable method of temporomandibular dysfunction diagnosis, due to the sensitivity, specificity, and accuracy observed.
(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2006;101:224-30)

Orofacial pain resulting from temporomandibular disorders has a negative impact on the quality of life of patients.[1] Temporomandibular dysfunctions (TMD) are defined as a group of multifactorial disorders that involve a variety of clinical alterations and chronic pain in the masticatory muscles, temporomandibular joints (TMJ), and adjacent structures.[2] It is difficult to diagnose pain in the TMJ region because of the various signs and symptoms observed in patients; detailed physical and complementary examinations are required. Radiography, computed tomography (CT), and magnetic resonance imaging (MRI) how the anatomy of the region and aid diagnosis. However, they do not enable the observation of local metabolic alterations.

Nuclear medicine is the branch of medicine that deals with imaging diagnosis based on the detection of minimal concentrations of pharmacological substances labeled to radioactive isotopes known as radiopharmaceuticals. The equipment used is the gamma camera, an image device that converts the gamma rays originated from the isotopes into digital information by means of a sodium iodide crystal and an electronic arrangement of photomultipliers tubes.[3]

In 1971, the complex of Technetium 99m (^{99m}Tc) with phosphates in their different chemical forms, generally present in the bone, was introduced in the market. Thus, it became a useful radiopharmaceutical in bone metabolic studies. Because of its physical properties such as low radiation dose and short half-life, 6 hours, the use of this radiopharmaceutical became convenient and safe in patients with suspected benign or malignant bone alterations.[4]

Bone scintigraphy evaluates the rate of metabolic activity of the skeleton through the use of radiopharmaceuticals, whose concentration in the bone depends on the local blood flow, vascular permeability, enzymatic action, amount of mineral component of the bone, and of immature collagen. This concentration is proportional to the rate of bone remodeling. Diphosphonates are mainly located in the mineral portion of bone, at active sites of new bone formation or bone resorption, especially at the mineral-organic interface in sites of bone remodeling. Diphosphonates are chemically resorbed at the surface of the hydroxyapatite crystal and incorporated to its structure. Therefore, diphosphonates take the ^{99m}Tc isotope to osteoid mineralization sites, where it actively takes part in bone metabolism and enables assessment of the skeleton in its entirety with a small radiation dose and short half-life of 6 hours.[5]

Structural alterations result from osteometabolic alterations; thus, bone scintigraphy enables early detection of abnormalities, whereas radiographs will only show any bone alteration after 40% to 50% decalcification has occurred. An increase in the rate of bone

[a]School of Dentistry, University of São Paulo, Department of Stomatology, Oral Radiology Division.
[b]Professor of Oral Radiology, School of Dentistry, University of São Paulo, Department of Stomatology, Oral Radiology Division.
[c]Professor of Stomatology, School of Dentistry, Universidade Paulista - UNIP.
[d]Head of Nuclear Medicine Division of Image Department of Hospital do Câncer de São Paulo.
Received for publication Nov 5, 2004; returned for revision Mar 4, 2005; accepted for publication Mar 11, 2005.
1079-2104/$ - see front matter

doi:10.1016/j.tripleo.2005.03.018

remodeling of approximately 5% is enough to cause hyperconcentration of the radioactive compound in these areas. This concentration can be 3 times as high as that observed in the normal adjacent bone, greatly facilitating identification of the radioactive compound. In scintigraphy, hyperconcentration is the earliest, most sensitive, and most effective finding used to diagnose bone remodeling that could be seen in benign lesions, malignant tumors, or metastasis. Therefore, it is indispensable to know the normal anatomy and physiology of the studied area to correctly construe the exam.[3,6-9]

Planar bone scintigraphy enables the observation of 1 plan per image and has little specificity, but high sensitivity. This occurs because it is difficult to anatomically locate any possible metabolic alterations in the head and neck region due to the proximity of the structures.[10]

In nuclear medicine, SPECT with ^{99m}Tc-MDP (Single Photon Emission Computed Tomography with Technetium-99m methylene diphosphonate) is a special technique that, because of multiplane image acquisition, permits reconstruction of the transaxial, coronal, and sagittal planes and also 3D rendering images. When the radiopharmaceutical of choice is ^{99m}Tc-MDP it will reflect the rate of osteometabolic local activity, thus providing better metabolic localization of skeletal alterations.

The functional anatomical mapping (FAM) is obtained by combination of anatomic CT data and functional nuclear medicine data, fused in a single image for interpretation purposes. SPECT/CT may be a more accurate interpretation, than SPECT alone in several clinical situations.[11] The combination of metabolic and CT images enables early detection and precise location of bone remodeling as well as tridimensional reformatting of bone structures, which facilitates the observation of osteometabolic alterations.[12] SPECT/CT is a test that employs low radiation dose, and is highly sensitive and specific when compared with conventional radiography and tomography. The radiation dose for an adult patient weighing 70 kg is 0.00425 Gy for CT image, and 30 mCi of ^{99m}Tc-MDP are 0.0025 Gy for a total of 0.00675 Gy. The present study evaluates the diagnostic contribution of fused images obtained by ^{99m}Tc-MDP SPECT/CT in patients with signs and symptoms of TMD.

MATERIAL AND METHODS

Patients entered the study after it was approved by the Institutional Ethics Committee from A.C. Camargo Hospital, São Paulo, Brazil (protocol number: 611/04).

The analyzed sample comprised scintigrams of 33 patients, 29 females and 4 males, with clinical signs and symptoms suggestive of possible tempomandibular dysfunction who underwent ^{99m}Tc-MDP SPECT/CT.

Scintigraphy was carried out according to the protocol established by the Nuclear Medicine Sector, Diagnostic Imaging Department of A.C. Camargo Hospital, a tertiary unity for treatment and cancer research. An IV dose of 30 mCi (370 MBq) of Technetium-99m methylene diphosphonate was administered to patients and images were obtained using SPECT/CT performed by Millenium VG & Hawkeye (General Electric Medical Systems, Milwaukee, Wis). This equipment comprises a gamma camera with dual-head, variable angle detectors. The detectors are composed of a collimator, a 5/8-inch thallium-activated sodium iodine crystal (Nal[TI]) and 91 photomultiplier tubes. The equipment also features an x-ray tube with detectors at the opposite end of the gantry. This system is able to obtain an alternate sequence of CT and nuclear medicine images. The x-ray tube capacity is 140 kV and 2.5 mA during the acquisition of each axial image. Both the tube and the detectors simultaneously rotate around the patient and each image is obtained in 14 seconds. The table where the patient lies moves toward the gantry for the acquisition of each tomogram, totaling forty 10-mm slice images. After complete tomographic imaging acquisition, the patient is automatically repositioned for nuclear medicine image acquisition using SPECT. A high-resolution, low-energy collimator is used in studies with Technetium-99m methylene diphosphonate. The gamma ray detector rotates 360° around the observed area and images are obtained with a 128 × 128 word matrix. Data are transferred and the images are reconstructed in a workstation (eNTREGA, General Electric Medical Systems, Milwaukee, Wis). Transmission and emission data are fused, yielding images of SPECT combined with the corresponding anatomic planes.

The protocol for image acquisition is divided into 4 distinct stages:

1. The first stage consists of analyzing alterations in the arterial and venous blood flow through dynamic acquisition of 90 images, at the rate of 1 image per second. The time required for total image acquisition is thus 1 minute 30 seconds, in a 128 × 128 word matrix.
2. The second stage, known as the equilibrium stage, results in the acquisition of static planar images in a 256 × 256 word matrix for the anterior and posterior projections of the skull/mandible acquired 5 minutes after the end of the first stage. Total image acquisition lasts 5 minutes, and images show local vascular permeability.
3. The third stage, know as the late stage, consists of acquiring an image of the entire body in a

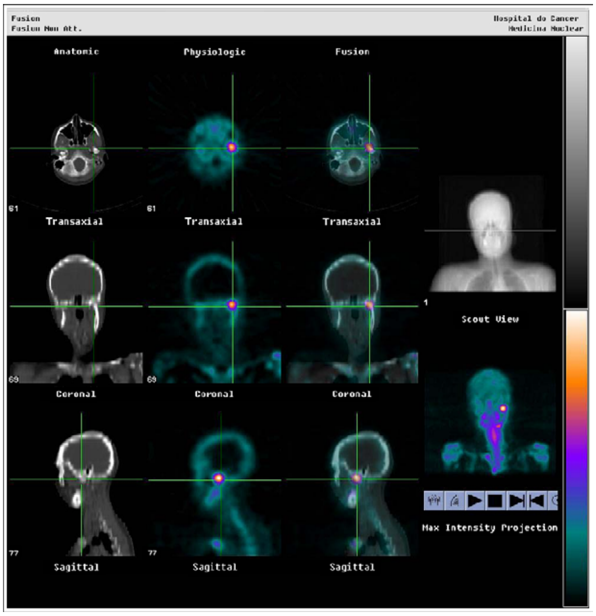

Fig. 1. Coregistered fused images obtained by ^{99m}Tc-MDP SPECT/CT in the transverse, coronal, and sagittal planes, showing focal hyperconcentration of the radiopharmaceutical in the left TMJ (SPECT/CT and left TMJ).

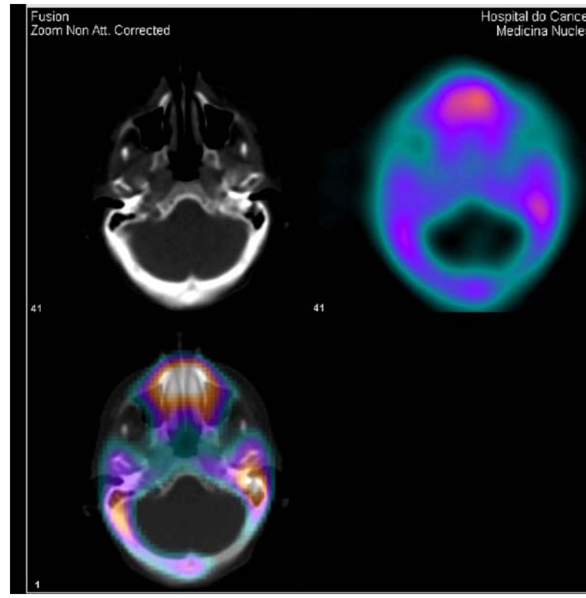

Fig. 2. Coregistered fused images obtained by ^{99m}Tc-MDP SPECT/CT in the transverse plane of a second patient, showing intense focal hyperconcentration of the radiopharmaceutical in the left inner ear and mastoid (SPECT/CT and extra TMJ).

256 × 1024 word matrix for the anterior and posterior projections 2 hours after the injection of the pharmaceutical. This stage lasts an average of 15 minutes.

4. The fourth stage begins soon afterward, and consists of acquiring transmission images, that is, CT by means of x-raying the analyzed region. This region must be selected within an area of 40 cm. The fourth stage lasts 10 minutes and 20 seconds. Emission images and nuclear medicine tomograms (SPECT) of the same region are then acquired in a 128 × 128 word matrix, which lasts 16 minutes 28 seconds. They are used for the observation of late alterations in local and systemic osteometabolic activities, which are topographically located.

At the end of image acquisition, the following were performed in the workstation: multiplanar reformatting in the transverse, coronal, and sagittal planes; fusion of coregistered images of anatomic data obtained with CT and physiologic and metabolic data obtained with ^{99m}Tc-MDP SPECT.

The images were interpreted by the nuclear physician, who used the visual comparative method in the various planes and had no previous knowledge of the clinical findings and patient complaints. This method consisted of evaluating the visible differences in concentrations of the radiopharmaceutical in the structures on the analyzed side and comparing them with the other side. When abnormal concentrations or hyperconcentration of the radiopharmaceutical were observed in one or both TMJs, the results of the exam were considered positive for TMJ dysfunction (SPECT/CT + TMJ) (Figure 1). When no abnormal or increased uptake concentrations of the radiopharmaceutical were observed in both TMJs, the results were considered negative for TMJ dysfunction (SPECT/CT − TMJ). When abnormal concentrations or hyperconcentration of the radiopharmaceutical were observed in regions other than the TMJ region, the results were considered positive extra TMJ (SPECT/CT + extra TMJ) (Figure 2).

STATISTICAL METHOD

The results obtained were tabulated and related to data from the patients, such as age, sex, main complaints, and clinical signs and symptoms evaluated in binary tests that indicated normal or abnormal and sick or healthy, that is, with or without TMD.

Sensitivity was calculated using the proportion of true positives (TP) over all positive results (TP+FN). Specificity was calculated using the proportion of true negatives (TN) over all negative results (TN+FP). Accuracy was calculated using the proportion of all true results (TP+TN) over all results obtained (TP+TN+FP+FN). Descriptive analyses were performed to determine the frequency and percentage of the analyzed variables.

The positive predictive value (PPV) was also calculated. It was determined using the proportion of TP over

Table I. Evaluation rates of the exam

Rate	*Formula*	*Percentage*
Sensitivity	TP/(TP+FN)	100.00
Specificity	TN/(TN+FP)	90.91
Accuracy	(TN+TP)/(TP+TN+FP+FN)	96.97
Positive predictive value	TP/(TP+FP)	95.00
Negative predictive value	TN/(TN+FN)	100.00

TP, True positives; *TP+FN,* all positive results; *TN,* true negatives; *TN+FP,* all negative results; *TN+TP,* all true results; *TP+TN+FP+FN,* all results obtained; *TP+FP,* all positive results to the SPECT/CT; *TN+FN,* all negative results to the SPECT/CT.

all positive results to the SPECT/CT (TP+FP). The negative predictive value (NPV) was determined using the proportion of TN over all negative results to the SPECT/CT (TN+FN). The reliability of the exam was determined with these values and indicated if the patient really suffered from TMD when the result of the test was positive for TMJ dysfunction or did not suffer from TMD when the result of the test was negative for TMJ dysfunction.

RESULTS

The results of this study can be observed in Table I to IV, which show the clinical signs and symptoms and SPECT/CT findings of the 33 patients. Female patients corresponded to 88% (29) of the sample, with an average age of 37 years, standard deviation of 14.74, aged 17 to 73 years. Male patients corresponded to 12% (4) of the sample, with an average age of 40 years, standard deviation of 22.6, aged 21 to 67 years.

The main complaints of patients and the clinical findings were analyzed and related to the results of the exams. Thus the true positives (TP = 22), true negatives (TN = 10), false positives (FP = 1), and false negatives (FN = 0) were obtained.

Based on TP, TN, FP, and FN, the following were calculated: sensitivity (100%), specificity (90.91%), accuracy (96.97%), positive predictive value (PPV = 95%), and negative predictive value (NPV = 100%) of the exam. These results are shown in Table I. The main complaints presented by patients were related to the analyses of TP, TN, FP, and FN, and are shown in Table II. The clinical findings obtained during clinical examination of the patients were related to the analyses of TP, TN, FP, and FN, and are shown in Table III. The clinical signs and symptoms observed in the TMJ, adjacent structures and/or related to the TMJ (extra TMJ) and the imaging findings obtained using SPECT/CT were related to analyses of TP, TN, FP, and FN. The results are shown in Table IV.

Table II. Main complaint by analyses of TP, TN, FP, and FN

Main complaint	*No. patients*	*TP*	*TN*	*FP*	*FN*
Pain in the TMJ	13	10	3	—	—
Diffuse facial pain	5	—	5	—	—
Headache	2	2	—	—	—
Joint noises (clicking and crackling)	1	1	—	—	—
Facial asymmetry	1	1	—	—	—
Limited mouth opening	2	2	—	—	—
Otalgia/referred pain	2	1	—	1	—
TMJ pain/otalgia	1	1	—	—	—
TMJ pain/cephalgia/otalgia	1	1	—	—	—
Hemifacial TMJ pain	2	—	2	—	—
Pain in region of masticatory muscles	2	2	—	—	—
TMJ pain/facial asymmetry/otalgia	1	1	—	—	—

TP, True positives; *TN,* true negatives; *FP,* false positives; *FN,* false negatives; *TMJ,* temporomandibular joint.

DISCUSSION

The advent of the SPECT improved observation and localization of metabolic alterations, and computer systems that were able to combine metabolic (SPECT) and anatomical (CT or MRI) images were developed. SPECT also improved spatial localization of alterations, in an attempt to reveal their cause, aid in diagnosis, and identify the stage of the disease. However, it was very difficult to obtain images through different equipment with different positioning of the patient and later fuse those images using computer information systems.

The solution came with the development of a device equipped with an x-ray system, enabling the acquisition of CT images, anatomical mapping, and the subsequent acquisition of SPECT images. By means of anatomical mapping, the equipment automatically adjusts the attenuation correction for the region of interest during the acquisition of SPECT images, improving image quality. However, due to the great width of the CT slice (10 mm), the exam presents limited diagnostic efficiency regarding anatomical changes. In some cases, thinner complementary CT slices are necessary. The major advantages of the fusion-mode imaging system are the precise localization of functional alterations when interpreting scintigrams and optimal diagnostic accuracy, which was confirmed in our study.[11,13,14]

The present study aimed at assessing the contribution of fused SPECT/CT images using ^{99m}Tc-MDP to diagnose patients with suspected TMD. The analyzed sample comprised more females (88%) than males (12%), which may be related to hormonal[15] and behavioral factors, as well as psychological, psychosomatic, and social factors[16-19] that were not relevant to this study.

The mean age of the patients analyzed in this study (38.09 years) is similar to that mentioned by some

Table III. Clinical findings x analyses of TP, TN, FP, and FN

Clinical findings	*Frequency*	*TP*	*TN*	*FP*	*FN*
Pain upon palpation of TMJ	11	9	2	0	0
Pain upon palpation of masticatory muscles	5	1	4	0	0
Referred pain	8	5	3	0	0
Headache	14	9	5	0	0
Joint noises (clicking and crackling)	15	12	3	0	0
Facial asymmetry	2	2	0	0	0
Hypermotility	4	4	0	0	0
Hypomotility	7	6	1	0	0
Mandibular deviation	15	14	1	0	0

TP, True positives; *TN,* true negatives; *FP,* false positives; *FN,* false negatives; *TMJ,* temporomandibular joint.

Table IV. Signs and symptoms in the TMJ, extra TMJ, findings of the exams by analyses of TP, TN, FP, and FN

Results	*Frequency*	*TP*	*TN*	*FP*	*FN*
Signs and symptoms in the TMJ	22	21	1	0	0
Signs and symptoms extra TMJ	11	1	9	1	0
Findings SPECT/CT + TMJ	23	22	0	1	0
Findings SPECT/CT − TMJ	10	0	10	0	0
Findings SPECT/CT + extra TMJ	15	10	5	0	0

TMJ, Temporomandibular joint; *TP,* true positives; *TN,* true negatives; *FP,* false positives; *FN,* false negatives; *SPECT/CT,* Single Photon Emission Computed Tomography/computed tomography.

authors.[17,19] The majority of the patients belonged to the age group that most suffers from everyday stress, which can make the symptoms more intense.[16] No significant difference was observed between the sexes. The primary disease of patients was researched, and also whether they had cancer or not, since the sample was collected from the Cancer Hospital. It was observed that 15 patients had had some type of treated tumor; some in regions very distant from the TMJ, such as breast cancer in 5 patients, and others in regions very close to the TMJ or that could influence the clinical picture of TMD due to surgery, chemotherapy, or radiotherapy. One female patient had undergone surgery to remove a squamous cell carcinoma of the scalp. Microsurgical reconstruction following excision was carried out using a sternocleidomastoid flap from the right side, followed by partial parotidectomy of the right side and thyroidectomy, resulting in facial nerve paralysis and mouth opening difficulty. Hyperconcentration of the radiopharmaceutical in the right TMJ and in the right sternoclavicular articulation was observed, indicating possible bone stress in these regions, related to sequelae or functional alterations caused by surgery. This led to a true positive result in this patient.

The main complaints of patients were analyzed in this study. Pain in the TMJ region ranked first among the main complaints, which justified the exam for metabolic evaluation of this region. Diffuse facial pain and headache were often observed, but were more frequent when related to other symptoms such as otalgia.[17]

In addition to the main complaints, the clinical findings obtained with the dental surgeon's clinical examination were evaluated. A high incidence of TMJ clicking and mandibular deviation during jaw movement was observed (15 patients), followed by headaches (14 patients), pain upon palpation of the TMJ (11 patients) and pain in the masticatory muscles (5 patients), as well as referred pain (8 patients). There was a higher prevalence of hypomotility, observed in 7 patients (21%), when compared with hypermotility, observed in 4 patients (12%). This fact may be due to surgery and/or cancer treatment in regions next to the TMJ, which limited mandibular movement of 4 patients.

The results of the exams were related to the main complaints of patients, determining TP, TN, FP, and FN. The main complaints that were specific to the TMJ region, such as pain in the TMJ region, joint clicking, facial asymmetry, limited mouth opening, pain in the masticatory muscles, and headaches, were determined. When the patient presented one of these complaints and the exam showed hyperconcentration of the radiopharmaceutical in the TMJ, the case was considered TP (22 patients). However, 3 patients reported TMJ pain and had a TN result. A possible explanation for this result is that one of the patients presented hormonal problems and sporadic pain in the TMJ during specific phases of her menstrual cycle. The second patient had reported TMJ pain but, upon clinical examination it was observed that the pain was actually located posteriorly to the maxillary tuberosity. The third patient whose result was TN, reported sporadic pain in the TMJ and tongue burning. She was, however, a patient who presented geographic tongue and multiple complaints, and had been submitted to 5 cancer surgeries, including complete thyroidectomy, and had difficulty swallowing.

When the patients presented complaints that were nonspecific to the TMJ, such as referred pain, diffuse facial pain, and otalgia, and the exam was negative for TMJ dysfunction they were considered TN (10 patients). Two patients had a TN result but reported TMJ and hemifacial pain. These results can be explained by the fact that one of the patients reported TMJ pain at night, hemifacial numbness of the same side, headache, hindered masticatory ability, diminished vertical dimension, and was a wearer of a removable partial prosthesis in poor condition. According to these signs and symptoms, it was observed that she had muscular problems with referred pain in the TMJ, but did not present any metabolic alteration in the TMJ. The second patient whose result was TN and reported TMJ and hemifacial pain had undergone tumor resection in the temporal lobe, differentiated neurotomy of the trigeminal nerve, and presented headache and referred pain. She was already under treatment with a bite plate and physiotherapy, which explained the normal concentrations of the radiopharmaceutical in the TMJ.

Patients were considered FP when they presented complaints nonspecific to the TMJ region, such as referred pain and otalgia, and had hyperconcentration of the radiopharmaceutical in the TMJ. In our sample, 1 patient presented this result, which was justified by the fact that she had presented squamous cell carcinoma of the larynx and had undergone radio and chemotherapy. She later suffered from dysphonia and dysphagia with exarcebated otalgia after mastication and was unable to swallow solids. During the exam, discreet hyperconcentration of the radiopharmaceutical was observed in the right TMJ. This could be related to overloaded muscles as a result of a functional alteration in swallowing or a late sequela of radiotherapy, since this treatment causes alterations in bone metabolism. Therefore, it is possible that the assessment of post-irradiated patients is a limitation of this exam, a fact that must be further investigated.

Patients were considered FN when they reported complaints specific to the TMJ region, such as TMJ pain, joint clicking, facial asymmetry, limited or excessive mouth opening, pain in the masticatory muscles, and headache, and there were normal concentrations of the radiopharmaceutical in their TMJ. In our sample, no patient was considered FN.

The results obtained with SPECT/CT were better than those obtained with SPECT alone. The evaluation of the results compared with the clinical conditions of the patients showed the sensitivity, specificity, and accuracy of the exam.

Sensitivity is the diagnostic capacity of the exam; that is, the number of true positive results to the exam (SPECT/CT + TMJ) that correspond to the presence of the disease (main complaint, signs, and symptoms specific to TMD). In the present study, sensitivity was 100%. This is a higher value than that obtained with SPECT alone in the studies of Collier et al.,[20] where a 94% value was observed; Kircos et al.,[21] where a 93% value was observed; and Krasnow et al.,[22] where a 76% value was observed.

Specificity shows how much the exam excludes patients who are not sick in fact, by analyzing the number of TN, negative results for the exam (SPECT/CT − TMJ), which correspond to the signs and symptoms nonspecific to TMD. A specificity of 90.9% was observed, making the results of this study more significant than those of Kircos et al.[21] and Collier et al.,[22] who observed a specificity of 86% and 70%, respectively, using SPECT alone.

Accuracy is determined by the proportion between all true results (TP+TN) and all the results obtained (TP+TN+FP+FN) in the exam. The high SPECT/CT accuracy value obtained, 96.7%, showed that SPECT/CT is superior to SPECT and other exams studied.[8,10,20-23]

The results of SPECT/CT extra TMJ were not considered in this study, since the same patient may present positive results in the TMJ and in other regions as well.

The high levels observed for positive predictive values (95%) and negative predictive values (100%) in this study corroborate the reliability of the SPECT/CT.

In conclusion, our results show that ^{99m}Tc-MDP SPECT/CT in the TMJ region is a relevant complementary exam, a useful, sensitive, specific, and accurate exam, and that it may be one of the methods of choice for TMD diagnosis. Thus, the applications of this method must be further investigated and compared with other imaging diagnostic methods. Also, the applications of ^{99m}Tc-MDP SPECT/CT to the evaluation of therapy results and follow-up of TMD patients must be further investigated.

REFERENCES

1. Segu M, Lobbia S, Canale C, Collesano V. Quality of life in patients with temporomandibular disorders. Minerva Stomatol 2003;52:279-87.
2. McNeill C. Temporomandibular disorders, guidelines for classification, assesment, and management. The American Academy of Craniomandibular Disorders. Chicago: Quintessence Publishing Co; 1993.
3. Lima ENP. Aspectos práticos de medicina nuclear em oncologia. In: Kowalski LP, Anelli A, Salvajoli JV, Lopes LF, editors. Manual de condutas diagnósticas e terapêuticas em oncologia. 2nd ed. São Paulo: Åmbito Editores; 2002. p. 69-74.
4. Subramanian G, McAfee JG. A new complex of ^{99m}Tc skeletal imaging. Radiology 1971;99:192-6.
5. Subramanian G. Radiopharmaceuticals for bone scanning. In: Collier BD Jr, Fogelman I, Rosenthall L, editors. Skeletal nuclear medicine, chapter 2. St Louis: Mosby-Year Book; 1996. p. 9-20.
6. Brooks SL, Brand JW, Gibbs SJ, Hollender L, Lurie AG, Omnell KA, et al. Imaging of temporomandibular joint: a position paper of the American Academy of Oral and Maxillofacial Radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1997;83:609-18.
7. Fogelman I, Maisey MN, Clarke SEM. An atlas of clinical nuclear medicine. 2nd ed. St Louis: Mosby; 1994.
8. Katzberg RW, O'Mara RE, Tallents RH, Weber DA. Radionuclide skeletal imaging and single photon emission computed tomography in suspected internal derangements of the temporomandibular joint. J Oral Maxillofac Surg 1984;42:782-7.
9. Lima ENP, Trevisan S. Medicina nuclear em oncologia. In: Brentani MM, Coelho FRG, Iyeyasu H, Kowalski LP, editors. Bases da oncologia, chapter 2. São Paulo: LEMAR; 1998. p. 313-50.
10. Pogrel MA, Kopf J, Dodson TB, Hattner R, Kaban LB. A comparison of single-photon emission computed tomography and planar imaging for quantitative skeletal scintigraphy of the

mandibular condyle. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1995;80:226-31.
11. Schillaci O, Danieli R, Manni C, Simonetti G. Is SPECT/CT with a hybrid camera useful to improve scintigraphic imaging interpretation? Nucl Med Commun 2004;25:705-10.
12. Ota T, Yamamoto I, Ohnishi H, Yuh I, Kigami Y, Teruyasu S, et al. Three-dimensional bone scintigraphy using volume-rendering technique and SPECT. J Nucl Med 1996;37:1567-70.
13. Lang TF, Hasegawa BH, Liew SC, Brown JK, Blankespoor SC, Reilly SM, et al. Description of a prototype emission-transmission computed tomography imaging system. J Nucl Med 1992; 33:1881-7.
14. Townsend DW, Cherry SR. Combining anatomy and function: the path to true image fusion. Eur Radiol 2001;11:1968-74.
15. LeResche L, Mancl L, Sherman JJ, Gandara B, Dworkin SF. Changes in temporomandibular pain and other symptoms across the menstrual cycle. Pain 2003;106:253-61.
16. Glaros AG. Emotional factors in temporomandibular joint disorders. J Indiana Dent Assoc 2000-01;79:20-3.
17. Al-Hasson HK, Ismail Al, Ash MM Jr. Concerns of patients seeking treatment for TMJ dysfunction. J Prosthet Dent 1986;56: 217-21.
18. Bates RE Jr, Gremillion HA, Stewart CM. Degenerative joint disease. Part I: diagnosis and management considerations. Cranio 1993;11:284-90.
19. Warren MP, Fried JL. Temporomandibular disorders and hormones in women. Cells Tissues Organs 2001;169:187-92.
20. Collier BD, Carrera GF, Messer EJ, Ryan DE, Gingrass D, Angell D, et al. Internal derangement of the temporomandibular joint: detection by Single-Photon Emission Computed Tomography. Work in progress. Radiology 1983;149:557-61.
21. Kircos LT, Ortendahl DA, Hattner RS, Faulkner D, Chafetz NI, Taylor RC. Emission imaging of patients with craniomandibular dysfunction. Oral Surg Oral Med Oral Pathol 1988;65: 249-54.
22. Krasnow AZ, Collier BD, Kneeland JB, Carrera GF, Ryan DE, Gingrass D, et al. Comparison of high-resolution MRI and SPECT bone scintigraphy for noninvasive imaging of the temporomandibular joint. J Nucl Med 1987;28:1268-74.
23. Hodder SC, Rees JIS, Oliver TB, Facey PE, Sugar AW. SPECT bone scintigraphy in the diagnosis and management of mandibular condylar hyperplasia. Br J Oral Maxillofac Surg 2000;38: 87-93.

Reprint requests:

Alessandra Coutinho, DDS, MSc
School of Dentistry
University of São Paulo
Department of Stomatology
Oral Radiology Division
Rua Castro Alves, 612 apto. 51
Aclimacao
São Paulo, SP 01532-000
Brazil
alecoutinho@terra.com.br