MRI features of mandibular osteomyelitis: practical criteria based on an association with conventional radiography features and clinical classification

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Objectives. The aims of this study were (1) to assess the diagnostic power of magnetic resonance imaging (MRI) for mandibular osteomyelitis through comparison with conventional techniques and (2) to establish practical MRI diagnostic criteria in relation to treatment and clinical outcome.
Study design. In 55 subjects, clinically suspected as mandibular osteomyelitis, signal intensities (SI) were evaluated on T1-weighted/short T1 inversion recovery (STIR) images.
Results. Forty-seven subjects were definitively diagnosed as having osteomyelitis by pathology studies or clinical course. For the acute or subacute stage, positively associated appearances were low SI on T1-weighted image and extensive high or focal high SI on the STIR image. For chronic stage, appearances of low SI on both T1-weighted and STIR images should be added to those for the acute or subacute stage. These findings support the at-present accepted imaging diagnostic criteria based on bony changes for detection of osteomyelitis.
Conclusion. This study confirms that T1-weighted/STIR images are useful for the detection of mandibular osteomyelitis. **(Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008;105:503-11)**

Osteomyelitis is defined as an inflammation of the cortical and cancellous bone and is commonly caused by bacterial invasion from contiguous foci.[1,2] Radiological examinations are required for diagnosis of mandibular osteomyelitis and for evaluation of the response to treatment. On conventional radiographs, osteomyelitis appears as an osteolytic or osteosclerotic lesion with various amounts of periosteal reaction. However, their utility is limited in the acute stage because of low sensitivity.[3,4] Bone scintigraphy can depict increased uptake even in the acute stage, whereas it shows low specificity in diagnosing as osteomyelitis and does not accurately identify the location of lesions.[4-6] Computed tomography (CT) is known to be the most effective tool for the evaluation of bony changes, such as cortical bone lesion, sequestra, and subperiosteal bone deposition, whereas it can hardly depict bone marrow changes in the acute stage or evaluate the early response to the treatment.[3,4,6-8]

Magnetic resonance imaging (MRI) can well demonstrate the bone marrow changes caused by edema or inflammatory tissue due to increase of water content, which often replaces the normal fatty marrow in the acute stage.[5] This change of the bone marrow is shown as a low SI area on the T1-weighted image and a marked high SI area on T2-weighted or short TI inversion recovery (STIR) images.[3,4,6,9,10] In the chronic stage, sequestration as a result of necrosis is observed, and its MRI appearance is somewhat different from that in the acute stage. It is characterized by a low SI area surrounded by high SI rim on both T1-weighted images and T2-weighted or STIR images.[4] Although MRI examination has the ability of early detection of osteomyelitis, almost like bone scintigraphy,[4,5,11,12] the role of MRI examination in the clinical workup of mandibular osteomyelitis has not still been established. There

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is a relative dearth of reports regarding MRI diagnostic criteria applicable to each clinical stage of osteomyelitis.[2] To establish practical criteria, the stage (acute, subacute, or chronic) should be taken into account.

The purposes of this study were (1) to analyze the relationship between the imaging features of MRI and conventional techniques and (2) to establish practical MRI diagnostic criteria in relation to the treatment outcomes.

METHODS

Subjects

Fifty-five subjects who were clinically suspected as having bacterial mandibular osteomyelitis and underwent MRI examination were enrolled in this study. They were 24 males and 31 females, ranging from10 to 97 years (median: 43 years) of age. All subjects were selected retrospectively from the files of our department and were imaged between August 1996 and July 2006. Criteria for inclusion into this study were recurrent and intolerable pain or swelling at the mandibular region and radiographic evidence of osteolytic and osteosclerotic lesion with variable amounts of periosteal reaction or sequestration. A widespread sclerosis extending inferiorly beyond the mandibular canal and posteriorly to the ramus was also included. Twenty-seven subjects had recurrent swelling and intolerable pain in the mandibular region. In 26 subjects, paralysis was accompanied at the lower lip, in addition to recurrent swelling and intolerable pain. In the remaining 2 subjects, the main symptoms were slight swelling and prolonged dull pain, but their radiographs showed a widespread sclerosis extending inferiorly beyond the mandibular canal and posteriorly to the ramus. Thirteen subjects were accompanied with trismus. Subjects with osteoradionecrosis or anamnesis of surgical procedure for osteomyelitis were not included in the study.

The period between the onset of symptoms and MRI examination ranged from 4 days to 5 years (median, 2 months). Based on this period, all subjects were classified into 2 groups: the acute or subacute group (23 subjects) with the period less than 1 month, and the chronic group (32 subjects) with the period more than 1 month.

Examinations

Magnetic resonance imaging examinations were performed with a 1.0-T Magnex-100XP (Shimadzu, Kyoto, Japan) and a head coil. Standard MRI sequences were performed: spin-echo T1-weighted images (450-500/11-18 [repetition time ms/echo time ms]) and STIR images (2800-3200/22/90-110 [repetition time ms/echo time ms/inversion time ms]). The section thickness was 5.0 mm with an intersection gap of 1.0 mm. The acquisition matrix was 256 × 256. Axial and coronal images were obtained.

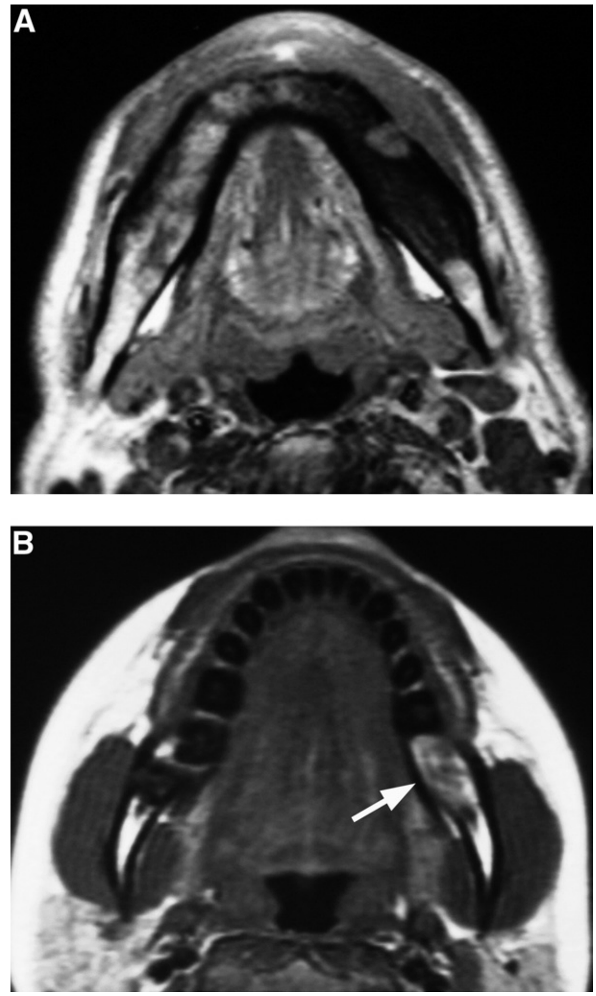

Fig. 1. Patterns based on the change of the signal intensity (SI) of the bone marrow on T1-weighted images. **A,** Low. The socket of the extracted tooth showing middle SI, extensive low SI area of the left mandible, and swelling of the adjacent buccal soft tissue. **B,** No change (arrow).

Prior to MRI examination, conventional radiographs (panoramic radiograph, lateral oblique mandible and posteroanterior view) were obtained for all subjects. Computed tomographic examination was added in 41 subjects. All subjects, excepting those with the definite bone changes and sequestrum, underwent CT examinations. Computed tomographic images were obtained with a Somatom ART (Siemens AG, Erlangen, Germany) or a HiSpeedNX/Ipro (GE Medical Systems, Tokyo, Japan). Scans were performed with a slice thickness of 2 or 3 mm, and the scan plane was parallel to the occlusal plane or inferior margin of the mandible.

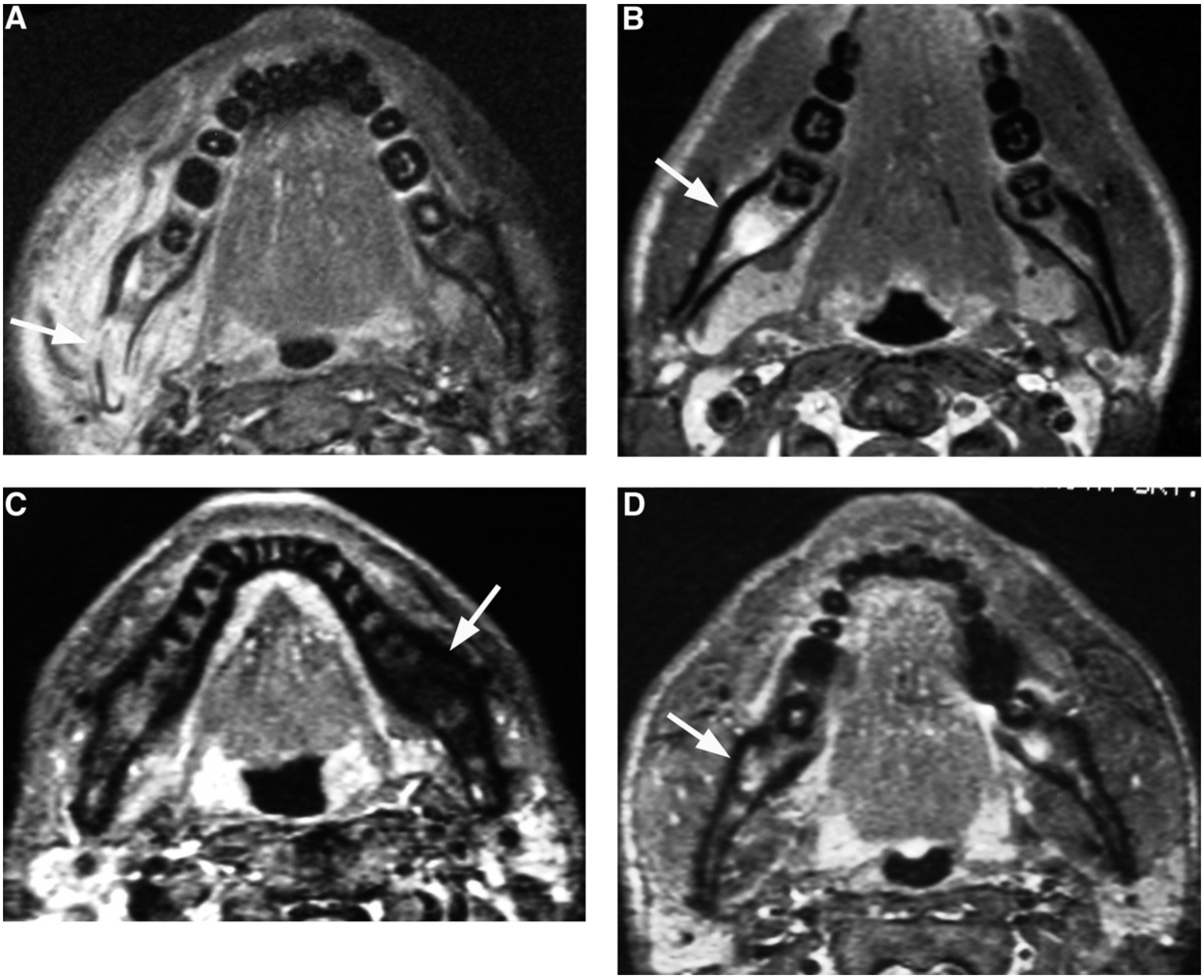

Fig. 2. Patterns based on the change of SI of the bone marrow on short T1 inversion recovery (STIR) images. **A,** Extensive high. Shows erosion of the cortical bone (arrow) and the adjacent soft tissue swelling with high SI. **B,** Focal high (arrow). **C,** Low (arrow). **D,** No change (arrow).

Evaluation of imaging features

According to previous reports,[3,4,6,9,10] T1-weighted images were classified into 2 patterns: low and no change (Fig. 1). The pathological changes of the bone marrow were evaluated by comparison with the SI of the contralateral side. *Low* was defined as a decline in the SI of the bone marrow, and *no change* as a mild change or no change in the SI of the bone marrow.

Short T1 inversion recovery images were classified into 4 patterns: extensive high, focal high, low, and no change (Fig. 2). Extensive high was defined as a strong and widespread increase in the SI of the bone marrow. Focal high was a limited area increase in the SI. Low was defined as a decline in the SI of the bone marrow, and no change as a mild change or no change in the SI of the bone marrow.

Bony changes on conventional images were evaluated with reference to the CT appearance (Fig. 3).[3,4,6-8] *Lytic pattern* was defined as having a feature that osteolysis was dominant. *Mixed pattern* was a feature that osteosclerosis was combined with an equal or lesser amount of osteolysis. *Sclerotic pattern* was a feature in which osteosclerosis was dominant. This included the cases in which the sclerotic change spread extensively under the mandibular canal or through the ramus. *Sequestrum pattern* was a feature in which sequestration was seen with or without other bony changes. The subjects without any such changes were recorded as no change.

These evaluations were performed by 2 radiologists who had sufficient experience in imaging diagnosis. The final determination was reached by consensus after discussion if the evaluations initially differed between the 2 observers.

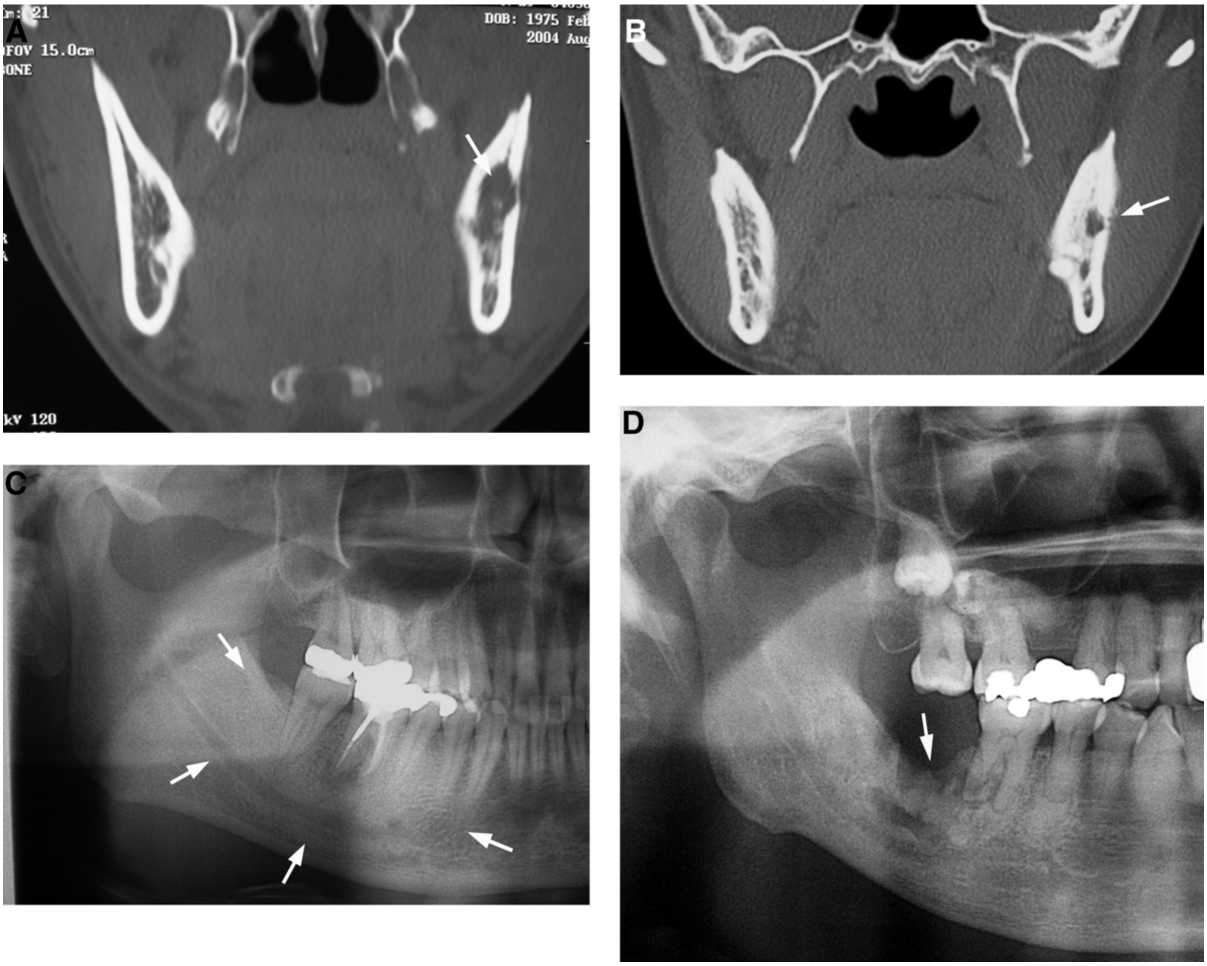

Fig. 3. Patterns of conventional imaging features. **A,** Lytic. **B,** Mixed. **C,** Sclerotic. **D,** Sequestrum. Ranges with changes in bone marrow are indicated with arrows.

Determination of the final diagnosis

The definitive diagnosis was confirmed by the pathological results or clinical course. All subjects were followed up for more than 6 months after the end of treatment. For example, subjects who achieved relief from symptoms after the surgical procedure for osteomyelitis, such as decortication and fenestration, were diagnosed as osteomyelitis.

RESULTS

Treatment and the final diagnosis

Forty-seven subjects were finally diagnosed as osteomyelitis of the mandible. Of them, 17 subjects underwent radical surgical procedure such as decortication or fenestration of the buccal cortical bone of the mandible, accompanied by curettage of the affected areas, intra-arterial use of antibiotics, or hyperbaric oxygen therapy. For 23 subjects, minor surgical procedure including curettage, sequestrectomy, extraction of the causative tooth, and incision of abscess, was performed. Seven subjects were treated only with internal use of antibiotics. Fifteen subjects who underwent surgical treatment were confirmed as osteomyelitis by pathological specimens. In 41 (87%) of these 47 subjects, symptoms disappeared or markedly reduced after the treatment and did not recur within the observation period. In 5 subjects, symptoms disappeared once but recurred. The remaining 1 subject was not cured by the treatment, but the pathological specimen obtained during surgical procedure verified the diagnosis of osteomyelitis.

In contrast, 8 subjects could not be diagnosed as osteomyelitis. Of these, 3 subjects were prescribed carbamazepine or received stellate ganglion block, leading to the symptoms temporarily disappearing or being reduced. In 3 subjects, the symptoms disappeared spontaneously within 2 months; their symptoms might have been due to localized periodontitis or the healing pro-

Table I. Relationship between MRI features and bony appearance in 23 patients in the acute or subacute group

MRI features		*Bony appearances on conventional radiography and CT*				
T1-weighted image	*T2-weighted or STIR image*	*Lytic*	*Mixed*	*Sclerotic*	*Sequestration*	*No change*
Low	Extensive high	2	4	3	1	6
	Focal high		1	4		
	Low					
	No change					
No change	Extensive high					
	Focal high					2*
	Low					
	No change					
Total		2	5	7	1	8

MRI, magnetic resonance imaging; *CT,* computed tomography; *STIR,* short TI inversion recovery.
*These 2 patients could not be diagnosed as osteomyelitis.

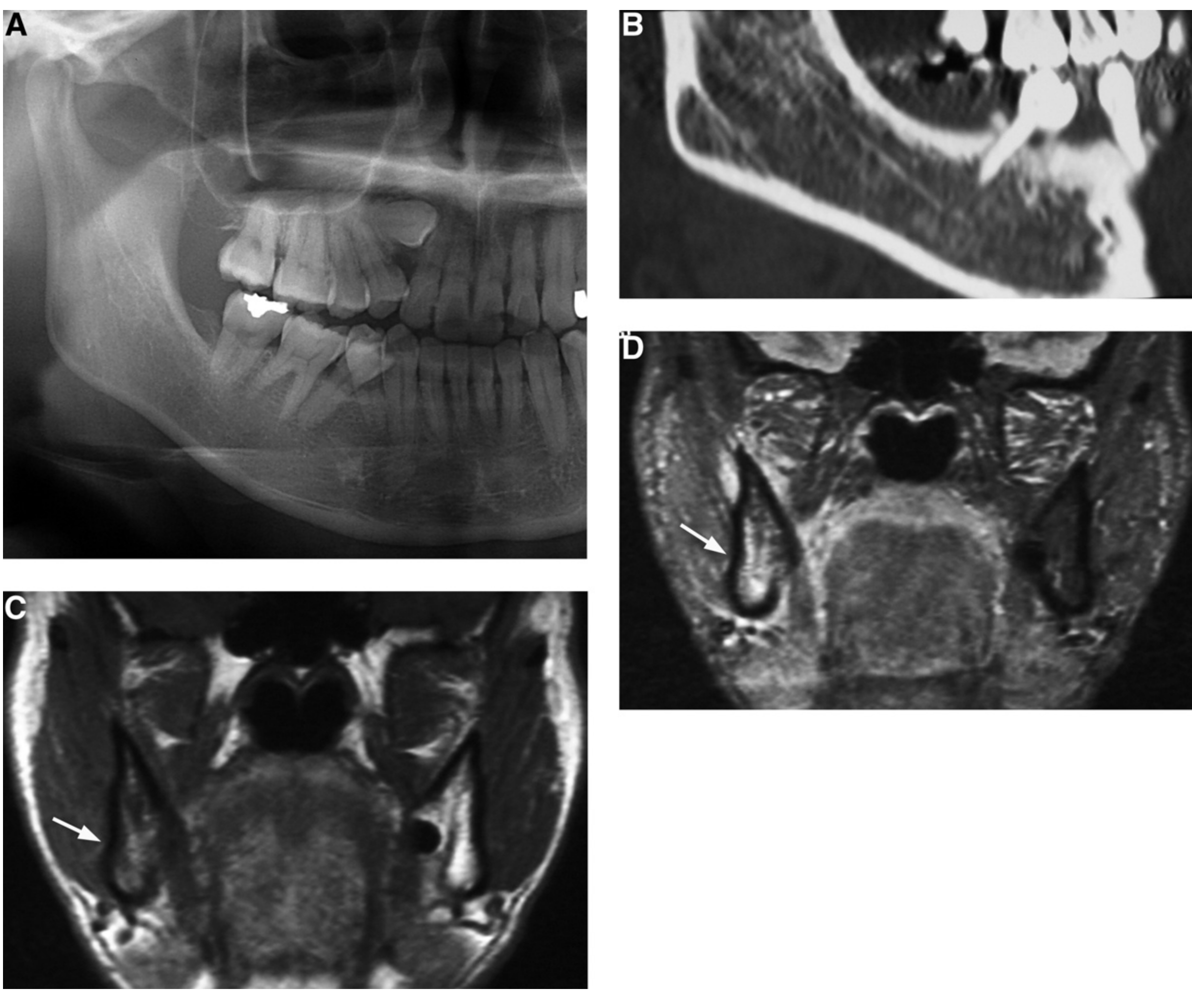

Fig. 4. 47-year-old man. The patient had dull pain in the cheek and the buccal gingiva of the right mandibular molar region for 2 weeks. He complained of paralysis in the lower lip from the day before admission. **A** and **B**, Panoramic tomography and computed tomographic image did not show any change of the cancellous and cortical bone in the right mandibular molar region. On the next day, MRI examination was done. **C,** The T1-weighted image showed a low SI area in the molar to ramus region of the right mandible (*arrow*). **D,** The STIR image showed an extremely high SI area in the same region (*arrow*).

Table II. Relationship between MRI features and bony appearance in 32 patients in the chronic group

MRI features		*Bony appearances on conventional radiography and CT*				
T1-weighted image	*T2-weighted or STIR image*	*Lytic*	*Mixed*	*Sclerotic*	*Sequestration*	*No change*
Low	Extensive high	7	4	6		2
	Focal high		1	1	2	2
	Low			1		
	No change					
No change	Extensive high					
	Focal high					4*
	Low					
	No change					2*
Total		7	5	8	2	10

MRI, magnetic resonance imaging; *CT,* computed tomography; *STIR,* short TI inversion recovery.
*These 6 patients could not be diagnosed as osteomyelitis.

cess after tooth extraction. The remaining 2 subjects probably had mental problems, such as cancer phobia. In all these subjects, there were no definitive appearances of osteomyelitis on conventional radiographs.

Relationship between MRI and conventional imaging features

The relationships between MRI and conventional imaging features in 23 subjects of the acute or subacute group are shown in Table I. Twenty-one subjects had low SI on T1-weighted imaging. Of these, 16 subjects had extensive high SI and 5 had focal high SI on T2-weighted or STIR imaging. These 21 subjects were diagnosed as having osteomyelitis based on pathological specimens or clinical outcome. In 6 of these subjects, MRI appeared to be an effective tool for the diagnosis because there were no apparent bony changes on conventional radiography and CT (Fig. 4). Two subjects, who could not be diagnosed definitively as having osteomyelitis, showed no change on T1-weighted imaging and focal high SI on STIR imaging. No bony changes were observed in these 2 subjects.

In the chronic osteomyelitis group, 26 of 32 subjects had low SI on T1-weighted imaging (Table II). Of these, 19 subjects had an extensive high, and 6 subjects had focal high SI on STIR imaging (Fig. 5). One subject showed low SI both on T1-weighted and STIR imaging (Fig. 6). This appearance could not be observed in the acute or subacute stage and might well have been caused by widespread sclerotic change, which was characteristic in the chronic osteomyelitis. These 26 subjects could be diagnosed definitively as having osteomyelitis. Four of them showed significant findings for the diagnosis solely on MRI. The remaining 6 subjects, who could not be diagnosed as osteomyelitis, showed no change on T1-weighted imaging and in CT bony appearance. Two of them had no findings in any of the images evaluated.

Proposal of criteria for MRI

Based on the aforementioned results, we propose the following diagnostic criteria, using MRI, for osteomyelitis: for the acute or subacute stage, the positive appearance of osteomyelitis is low SI on T1-weighted imaging, together with extensive high or focal high SI on T2-weighted or STIR imaging; for the chronic stage, appearance of low SI on both T1-weighted imaging and T2-weighted or STIR image is found.

DISCUSSION

Osteomyelitis embraces a wide spectrum and shows different features, depending on the clinical stage. Treatment requires a multidisciplinary approach. Acute osteomyelitis usually responds to antimicrobial therapy, whereas chronic osteomyelitis usually requires surgical procedure such as curettage of the necrotic bone and granulation tissue, and sequestrectomy.[13,14] Radical surgical procedure, such as decorticotomy, is effective in the treatment of diffuse sclerosing osteomyelitis of the jaw.[15,16] The diagnostic criteria should ideally be discussed in relation to the treatment procedures and clinical outcomes. In the present study, however, no relationship was found between MRI findings and selection of treatment procedures. It will be necessary in the future to examine whether MRI image can contribute to the choice of therapeutic method.

Various imaging features have been reported according to the activity of inflammation.[2-6,10,11,17] Magnetic resonance imaging examination would be effective to differentiate osteomyelitis from other diseases with similar clinical symptoms; MRI images of osteomyelitis have been characterized by changes in SI of the bone

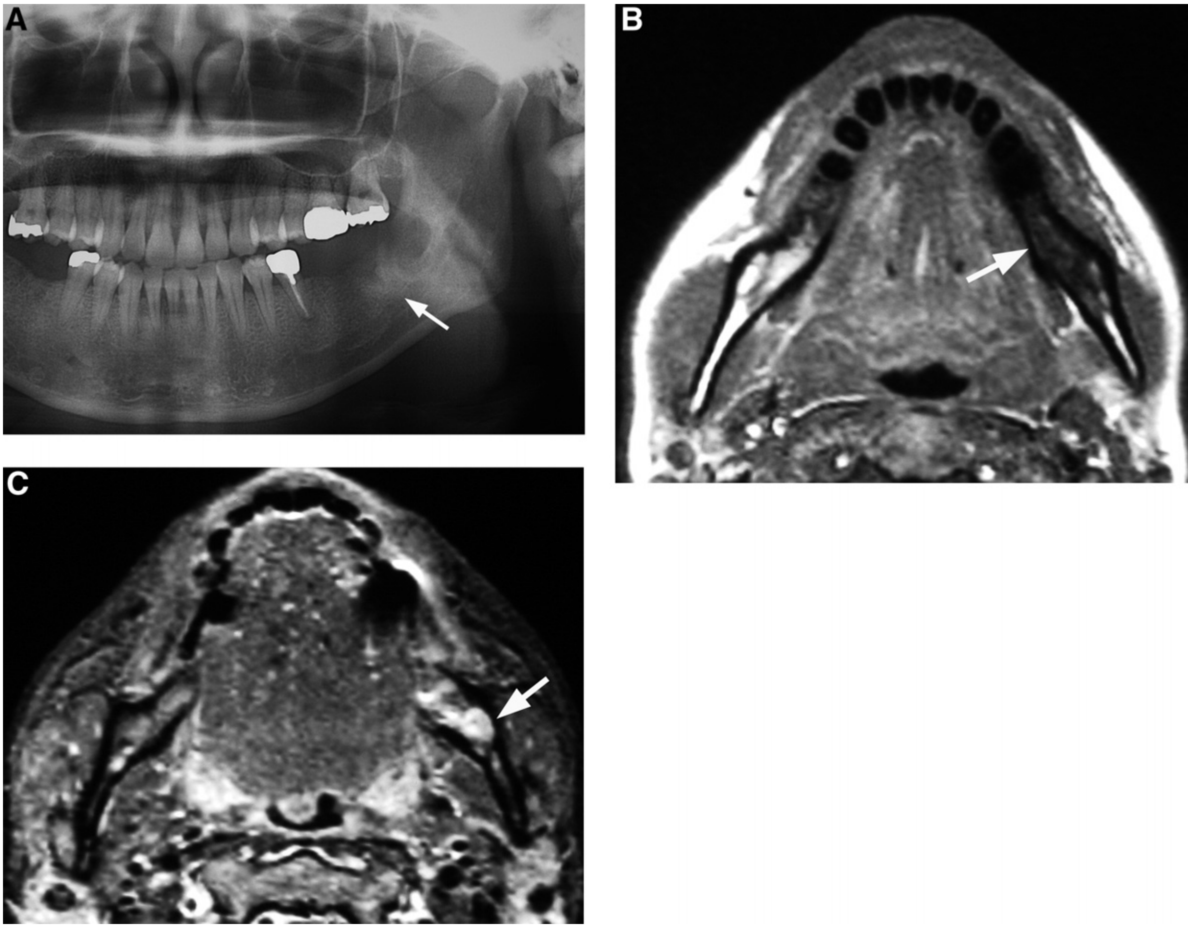

Fig. 5. 39-year-old woman. She felt spontaneous pain and gingival swelling in the molar region of the left mandible for 4 months. She underwent extraction of the second and third molars of the left mandible 1 month previously, but her subjective symptoms persisted. Her trismus increased gradually. **A,** Panoramic tomography showed sclerotic change in the area limited around the socket of the extracted teeth (*arrow*). Magnetic resonance imaging examination was performed 1 week later. **B,** The T1-weighted image showed a low SI area in the premolar to molar region of the left mandible (*arrow*). **C,** The STIR image showed a focal high SI area in the molar region (*arrow*).

marrow, such as decrease on T1-weighted images and increase on T2-weighted images.[2-4,6,10] The authors emphasize the utility of MRI to depict the bone marrow changes in the acute stage before bony changes are visualized on conventional radiography. As for the chronic stage, Schuknecht et al.[3] have reported low SI both on T1- and T2-weighted images in some of the subjects. Their conventional images demonstrate extensive sclerosis of the cancellous bone. These imaging features, which were also observed in one of the present cases, can be a characteristic feature in the chronic stage. The STIR image is a recently introduced sequence.[18] This technique enables us to evaluate T2 signals more easily with fat tissue suppression.[9,10] Administration of gadolinium-DTPA may add very important information, such as a noncalcified periosteal reaction, definition of the limit of the sequestrum, and extension of the inflammation to soft tissue.[3] These features were also detectable on STIR image, and therefore sequence with gadolinium-DTPA was not always used for making of MRI diagnostic criteria.

Although various MRI features have been clarified, no practical criteria that can be applied to all clinical stages have been proposed for the diagnosis of mandibular osteomyelitis. This may be attributable to the lack of studies, which include these subjects without osteomyelitis but who were initially suspected as having osteomyelitis. Almost all of the previous studies investigated only those subjects with a definitive diagnosis of osteomyelitis. So features that can differentiate osteomyelitis from other diseases showing similar clinical features have not been reported. The finding clar-

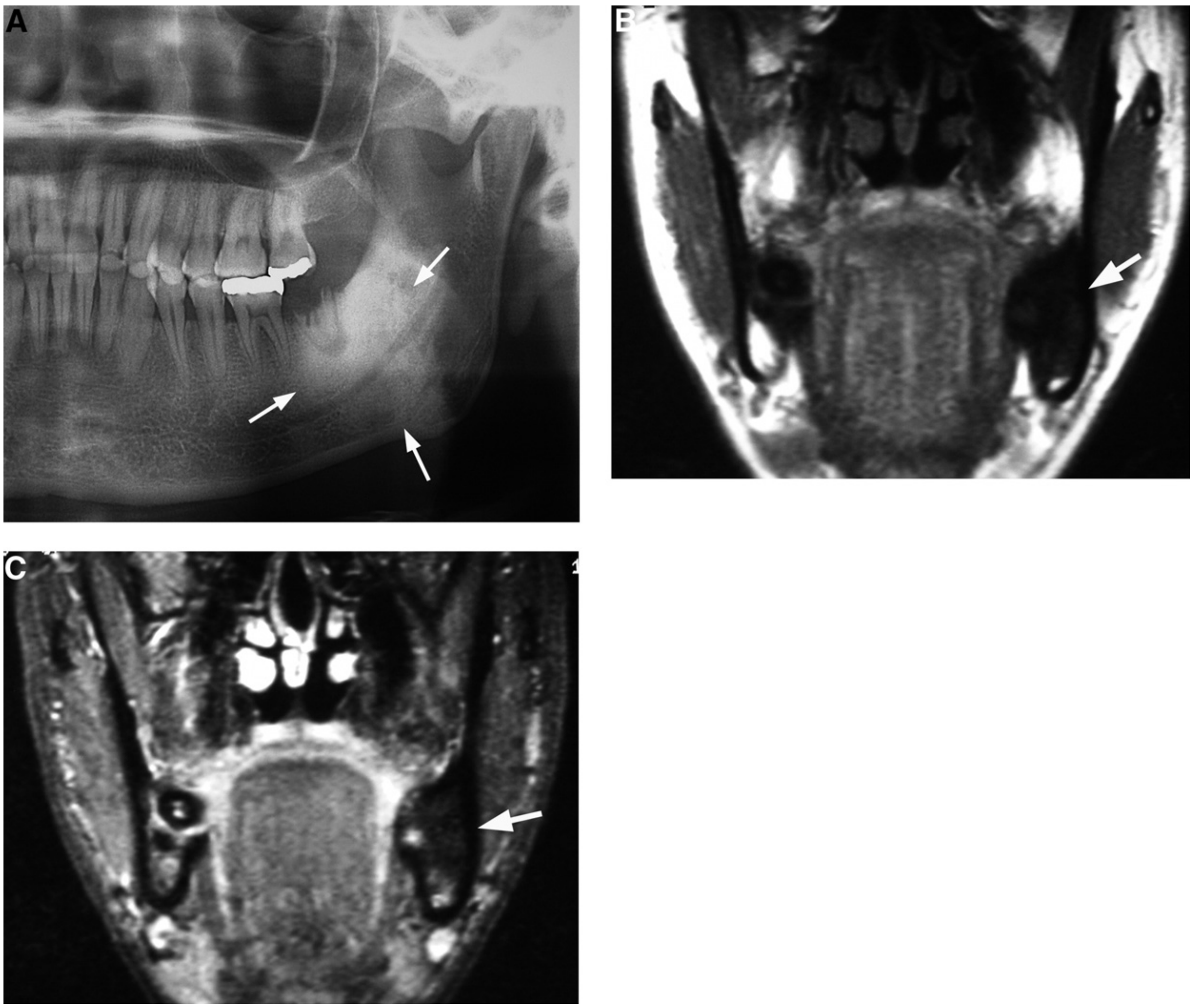

Fig. 6. 36-year-old man. He felt dull pain in the molar region of the left mandible following removal of a full crown of the second molar 3 months previously. **A,** Panoramic tomography showed diffusely sclerotic change in the left mandibular molar region (*arrows*). The range extended from the mandibular notch of the ramus to the lower margin of the mandible. Magnetic resonance imaging examination was performed 1 week later. Both T1-weighted image (**B**) and STIR image (**C**) showed low SI in the widespread area of the ramus (*arrows*).

ified in the present study, focal high SI on T2-weighted or STIR image without definitive changes on T1-weighted image, can be a significant feature that indicates a localized inflammation, such as marginal periodontitis, that should not be diagnosed as osteomyelitis.

The criteria proposed here support almost all of the traditional criteria that have been reported previously.[1,2,7,8,17,19-21] However, an effective use of these criteria requires 2 sequences, T1-weighted and T2-weighted or STIR, in imaging. At present, MRI with 2 sequences is the first-choice examination when osteomyelitis is clinically suspected. However, advanced techniques such as diffusion-weighted MRI are constantly being developed for MRI and should be examined as they come available.

For evaluation of response to treatment and long-term follow-up, another protocol may be required. In such an instance, MRI examination with administration of gadolinium-DTPA[5] and FDG-labeled positron emission tomography may be effective.[22-24]

In conclusion, when osteomyelitis is suspected, especially for subjects without positive features of osteomyelitis on CT and conventional images, MRI with the 2 sequences used in this study should be performed.

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