Usefulness of MRI signal of the mandibular condyle

下顎頭の MRI 信号の有用性

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本論文は、

1) Characteristic MR Imaging Findings in Rheumatoid Arthritis of the Temporomandibular Joint: Focus on Abnormal Bone Marrow Signal of the Mandibular Condyle, Pannus, and Lymph Node Swelling in the Parotid Glands
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2) Change in the Magnetic Resonance Imaging Signal of the Mandibular Condyle Due to Bisphosphonate-Related Osteonecrosis of the Jaw
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をまとめたものである。

Abstract

Purpose:

The purpose of this study was to assess the usefulness of MRI signal of the mandibular condyle by determining 1) the characteristic MRI findings indicating bone and soft tissue involvement in patients with rheumatoid arthritis (RA) of the temporomandibular joints (TMJs), and 2) changes in the magnetic resonance imaging (MRI) signal of the mandibular condyle that could have been due to the presence of the bisphosphonate-related osteonecrosis of the jaw (BRONJ).

Materials and Methods:

The university ethics committee approved this study (EC15-12-009-1).

1) Twenty-one patients (2 men, 19 women; 42 TMJs; age range, 30–76 years; mean age, 55 ± 15.5 years) with RA and TMJ pain who underwent MRI examination of the TMJs at our hospital from August 2006 to December 2014 were included in this retrospective study. Twenty-two patients (6 men, 16 women; 44 TMJs; age range, 30–78 years; mean age, 58 ± 13.1 years) with normal TMJs who underwent MRI examination at our hospital from November to December 2014 were included as controls. MRI findings were compared between the 2 groups. In particular, we focused 1) on abnormal bone marrow signal, pannus of the mandibular condyle, and swelling of the parotid gland lymph nodes in patients with RA.

2) Twenty-eight patients (11 men, 17 women; 56 TMJs; Maxilla: 4patients, Mandible: 24patients;

age range, 48–88 years; mean age, 72.9±9.4 years) with BRONJ and jaw pain who underwent MRI examination of the jawbone at our hospital from August 2006 to December 2015 were included in this retrospective study. In particular, we focused on the relation of bone marrow signals of the mandibular condyle in BRONJ patients on the same side of the face that exhibited jaw symptoms versus on the side with no symptoms.

Results:

1. MRI findings of RA in the TMJ included 1) abnormal disk position (95.2%), 2) abnormal disk morphology (83.3%), 3) joint effusion (30.9%), 4) osseous changes in mandibular condyle (83.3%), 5) synovial proliferation (pannus) (85.7%), 6) erosion of articular eminence/glenoid fossa (9.5%), 7) deformity of articular eminence/glenoid fossa (16.6%), 8) abnormal bone marrow signal in the mandibular condyle (83.3%), and 9) swelling of lymph nodes in the parotid glands (78.5%). The abnormal bone marrow signal and pannus in the mandibular condyle and the lymph node swelling in the parotid glands were significantly more common among patients with RA than among controls.

2. Overall, 83.3% of the patients diagnosed with BRONJ exhibited an abnormal bone marrow signal in the mandibular condyle on the same side of the face that suffered jaw pain. This abnormal signal was present significantly more frequently on the side of the face with the jaw symptoms than on the side without symptoms.

Conclusions:

MRI findings in RA of the TMJs were characterized by bone and soft tissue involvement, including abnormal bone marrow signal of the mandibular condyle, pannus, and swelling of lymph nodes in the parotid glands. And, patients with BRONJ displayed an abnormal MRI signal in the mandibular condyle on the side of the face with jaw symptoms, suggesting that MRI findings could be useful clinically for detecting BRONJ in the mandibular condyle. These results suggested that MRI signal of the mandibular condyle could be very useful informations in clinical situations.

Key Words:

Magnetic resonance imaging (MRI), Mandibular condyle, Rheumatoid arthritis (RA),

Bisphosphonate-related osteonecrosis of the jaw (BRONJ), Bone marrow signal

Introduction

Rheumatoid arthritis (RA) is an autoimmune disease that develops not only in elderly people, but also in individuals in their third decade of life[1, 2]. Bone destruction in the joints of patients with RA occurs within 2 to 3 years after the onset of the disease and rapidly progresses[3]. Therefore, early detection of RA is very important for patients with the disease.

RA is mainly characterized by inflammation of the synovial membrane, which leads to long-term joint damage, resulting in chronic pain, loss of function, and disability[4]. The average age of RA onset in adults is 40 years, with a 3:1 female-to-male ratio[5]. The incidence of temporomandibular joint (TMJ) involvement ranges from 5% to 86%[6]. Involvement of the TMJ can occur concurrently with other joint lesions or can arise at any subsequent time point.

MRI, which can identify both osseous and soft-tissue abnormalities, has become the primary imaging technique for the TMJ. MRI is the only imaging technique that allows visualization of the bone marrow signal and joint damage[7, 8]. Many previous studies worldwide have reported about RA. However, few studies have used MRI to systematically evaluate RA in the TMJ. Likewise, few studies have used MRI to evaluate the abnormal bone marrow signal in the TMJ and swelling of lymph nodes in the parotid glands in patients with RA.

Bisphosphonate-related osteonecrosis of the jaw (BRONJ) is the result of an adverse drug reaction. It manifests as progressive destruction and death of bone that affects the mandible or

maxilla of patients treated with nitrogen-containing bisphosphonates (BPs) in the absence of previous radiation treatment[9]. The mandible is more commonly affected than the maxilla (2:1 ratio), and 60% of cases are preceded by a dental surgical procedure. The signs and symptoms that may occur before the appearance of clinically evident osteonecrosis include changes in the health of periodontal tissues, non-healing mucosal ulcers, loose teeth, and an unexplained soft tissue infection[10].

Marx was the first to report osteonecrosis of the jaw due to administration of BPs in 2003[11]. Since then, many studies have confirmed that BRONJ is an adverse side effect of BP therapy. In 2009, the American Association of Oral and Maxillofacial Surgeons (AAOMS)[12] stated that the diagnosis of BRONJ is primarily determined by the presence of exposed necrotic bone in the oral cavity during an 8-week period, a history of current or previous BP intake, and the absence of irradiation of the jaws. In addition to bone exposure, common features are pain, swelling of soft tissues, ulceration, suppuration, and the development of sinus tracts[13]. Moreover, many studies worldwide have reported an association between a range of serious dental diseases and the use of BPs.

BRONJ is usually diagnosed radiologically—e.g., panoramic radiography, dental cone beam computed tomography (CBCT), spiral CT. When clinically unexposed necrotic bone is seen, further examinations—e.g., bone scintigraphy, positron emission tomography, magnetic resonance imaging

(MRI)—may help identify early areas of bone involvement[14]. Among these modalities, MRI provides the best direct evaluation of all bone marrow components[7, 8]. Few studies, however, have evaluated BRONJ based on an abnormal signal detected by MRI in the bone marrow of the mandibular condyle.

The purpose of this study was to assess the usefulness of MRI signal of the mandibular condyle by determining 1) the characteristic MRI findings indicating bone and soft tissue involvement in patients with rheumatoid arthritis (RA) of the temporomandibular joints (TMJs), and 2) changes in the magnetic resonance imaging (MRI) signal of the mandibular condyle that could have been due to the presence of the bisphosphonate-related osteonecrosis of the jaw (BRONJ).

Materials and Methods

1. Characteristic MR imaging findings in rheumatoid arthritis of the temporomandibular joint: focus on abnormal bone marrow signal of the mandibular condyle, pannus, and lymph node swelling in the parotid glands

Subjects

This study was approved by the ethics committee at our university (EC15-12-009-1). Twenty-one patients with TMJ pain (2 men, 19 women; 42 TMJs; age range, 30–76 years; mean age, 55 ± 15.5 years) who underwent MRI examination of the TMJs in our department from August 2006 to December 2014 were included in this retrospective study. The patients all had rheumatic symptoms in one or more joints and had been diagnosed with RA according to the diagnostic criteria of the American College of Rheumatology (ACR). Twenty-two patients (6 men, 16 women; 44 TMJs; age range, 30–78 years; mean age, 58 ± 13.1 years) who underwent MRI examination in our department from November to December 2014 were included as controls. These patients visited our hospital with a chief complaint of TMJ pain, and were diagnosed as normal based on clinical and radiological findings, according to the criteria of the American Academy of Orofacial Pain. None of the patients in the control group met the ACR criteria for RA. And, exclusion criteria were temporomandibular disorders, inflammatory diseases, leukemias and lymphomas.

MRI evaluation

MR imaging was performed with a 1.5-Tesla superconductive MR unit (Intera Achieva 1.5T; Philips Medical Systems, Netherlands) with a TMJ surface coil and a neck coil for the TMJ. The imaging techniques used included oblique sagittal proton density and T2-weighted spin echo imaging of the TMJ and axial STIR imaging from neck to skull base. Proton density and T2-weighted images were collected using the following parameters: TR/TE = 2000/20 and 100 msec, 3.5-mm slice thickness, 192×256 matrix, 120×120-mm field of view, and 1 acquisition using the TMJ surface coil. Axial STIR images were collected using the following parameters: TR/TE/TI = 1500/30/100 msec, 6-mm slice thickness, 192×256 matrix, 200×200-mm field of view, and 1 acquisition using the neck coil. The following characteristics of the TMJ were evaluated on MR images: disk position, disk morphology, joint effusion, abnormal bone marrow signal in the mandibular condyle, osseous changes, synovial proliferation (pannus), erosion and deformity of articular eminence/glenoid fossa, and swelling of the lymph nodes in the parotid glands. The present study categorized marked inflammation of the synovial membrane as synovial proliferation (pannus). The scoring options were presence or absence. Swelling of the lymph nodes in the parotid glands was identified when the glands were larger than the average maximum diameter for normal patients. All images were independently evaluated by 2 specialists in oral radiology; any differences were resolved by forced consensus. Findings in the TMJs of patients with RA and normal patients were assessed.

Statistical analysis

Two oral radiologists independently evaluated the MR images of the RA group and control group. The images were evaluated for the presence or absence of abnormal bone marrow signal in the mandibular condyle, swelling of lymph nodes in the parotid glands, and pannus. The χ^2 test and Fisher's exact test were used to compare abnormal bone marrow signal in the mandibular condyle, swelling of lymph nodes in the parotid glands, and pannus in RA patients versus normal patients. Statistical analyses were performed with SPSS version 21.0 (SPSS Japan, Tokyo, Japan). *P*-values less than .05 were considered to indicate statistical significance. Mean values were used in data analysis.

2. Change in the magnetic resonance imaging signal of the mandibular condyle due to bisphosphonate-related osteonecrosis of the jaw

Subjects

Altogether, 28 patients (11 men, 17 women; 56 TMJs; Maxilla: 4patients, Mandible: 24patients; age range, 48-88 years; mean age, 72.9±9.4 years) with jaw pain who underwent MRI examination of the jawbone at our hospital between August 2006 and December 2015 were examined in this retrospective study. They comprised the study groups in this study. They all had been diagnosed with BRONJ according to established diagnostic criteria (e.g., AAOMS criteria). And, exclusion criteria were edentulous patients, tumors and periodontitis.

MRI evaluation

MRI was performed with a 1.5-T superconductive MRI unit (Intera Achieva 1.5-T Nova; Philips Medical Systems, Best, The Netherlands) and head coil. Short tau inversion recovery (STIR) images were obtained using a spin echo sequence with the following parameters: repetition time, echo time, and inversion time were set at 1500, 30, and 100 ms, respectively; 6 mm slice thickness; 192×256 matrix; 200×200 mm field of view. MRI scans were evaluated for abnormal bone marrow signals in the mandibular condyle. The scoring options were “Present” or “Absent.” The present study classified them into four types (Fig. 1).

Type I: normal bone marrow signal in the mandibular condyle (Fig. 2-B)

Type II: a spot of abnormal bone marrow signal in the mandibular condyle (Fig. 3-B)

Type III: ranging from a spot to one-half abnormal bone marrow signal in the mandibular condyle (Fig. 4-B)

Type IV: between one-half and completely abnormal bone marrow signal in the mandibular condyle (Fig. 5-B)

These images were obtained using the axial plane of the maximum slice of the mandibular condyle. Any differences were resolved by forced consensus. These findings were then assessed in the BRONJ patients on the side of the face with symptoms and on the side with no symptoms. For

cases of the signal crossing the midline or of symptoms on both sides, the present study assessed the images for both sides.

Statistical analysis

Two oral radiologists independently evaluated the MRI scans for the presence or absence of the abnormal bone marrow signal from the mandibular condyle. Statistical analyses of the abnormal bone marrow signal regarding its relation to the side that displayed symptoms or the side with no symptoms was performed using the χ^2 test with Fisher's exact test (version 21.0; SPSS Japan, Tokyo, Japan). A value of $P < .05$ was considered to indicate statistical significance. Another method of data analysis was the average value.

Results

1. Characteristic MR imaging findings in rheumatoid arthritis of the temporomandibular joint: focus on abnormal bone marrow signal of the mandibular condyle, pannus, and lymph node swelling in the parotid glands

These data showed a significant difference in the occurrence of abnormal bone marrow signal in the mandibular condyle, swelling of lymph nodes in the parotid glands, and pannus in RA patients versus normal patients ($P < .01$) (Table 1). Abnormal bone marrow signal and pannus of the mandibular condyle and swelling of the lymph nodes in the parotid glands were significantly more common among patients with RA than among normal patients. And, the lymph nodes in the parotid glands of the average maximum diameter for normal patients were 2.77±0.74mm.

Table 2 shows characteristic MR findings of RA in the TMJ: 1) abnormal disk position (95.2%) (Fig. 6), 2) abnormal disk morphology (83.3%) (Fig. 6), 3) joint effusion (30.9%), 4) osseous changes of mandibular condyle (83.3%) (Fig. 6), 5) synovial proliferation (pannus) (85.7%) (Fig. 7), 6) erosion of articular eminence/glenoid fossa (9.5%), 7) deformity of articular eminence/glenoid fossa (16.6%), 8) abnormal bone marrow signal in the mandibular condyle (83.3%) (Fig. 8), and 9) swelling of lymph nodes in the parotid glands (78.5%) (Fig. 9).

2. Change in the magnetic resonance imaging signal of the mandibular condyle due to bisphosphonate-related osteonecrosis of the jaw

This study assessed changes in the MRI signal from the mandibular condyle in BRONJ patients on the side of the face with jaw symptoms versus the MRI signal on the side with no symptoms. The results showed that 83.3% of the 25 mandibular condyles showed an abnormal bone marrow signal on the side of the face with symptoms. In contrast, only 3 mandibular condyles (11.5%) of the BRONJ patients showed an abnormal bone marrow signal of the mandibular condyle on the side with no symptoms.

These data showed that an abnormal bone marrow signal of the mandibular condyle in BRONJ patients was significantly related to the appearance of symptoms ($P < .05$) (Table 3).

Among the 30 patients who had an abnormal bone marrow signal from the mandibular condyle on the same side as the symptoms, 5 (16.6%) were type 1, 16 (53.3%) were type 2, 3 (10.0%) were type 3, and 6 (20.0%) were type 4 (Table 4).

Discussion

1. Characteristic MR imaging findings in rheumatoid arthritis of the temporomandibular joint: focus on abnormal bone marrow signal of the mandibular condyle, pannus, and lymph node swelling in the parotid glands

The characteristic MRI findings of RA in the TMJ in the present study included abnormal disk position, abnormal disk morphology, joint effusion, osseous changes of the mandibular condyle, synovial proliferation (pannus), erosion of the articular eminence/glenoid fossa, deformity of the articular eminence/glenoid fossa, abnormal bone marrow signal in the mandibular condyle, and swelling of lymph nodes in the parotid glands. This study also showed a significant difference in the presence of abnormal bone marrow signal in the mandibular condyle, swelling of lymph nodes in the parotid glands, and pannus in RA patients versus normal patients.

Current RA remission definitions are based on clinical criteria; guidelines from the European League Against Rheumatism (EULAR) and the ACR identify the clinical remission criteria that are the goal of treatment. The new 2011 ACR/EULAR remission criteria were developed to predict good radiographic and functional outcomes[15]. Although, MRI is considered useful in the early detection of RA, MRI findings in RA of the TMJ have not been discussed in detail.

Kretapirom et al. reported that TMJ disc displacement in RA patients occurs because of changes in the topographic relationship between the articular disc and the condyle caused by the rapid bone

resorption of the latter. In contrast, disk displacement in non-RA patients with TMJ disorders is considered a gradual process with deformation of the articular disc[1, 16]. In this study, abnormal disk position was observed in 95.2% of the TMJs in RA patients.

Osseous changes in the condyle and articular eminence/fossa were frequently observed in the RA patient group, as previously reported by other investigators. In this study, erosion of the articular eminence/glenoid fossa was observed in 9.5% of the TMJs. Osseous changes of the mandibular condyle were observed in 83.3% of the TMJs.

RA is characterized by prominent inflammation of the synovial membranes. As in other involved joints, villous synovitis in the TMJs can lead to the formation of synovial granulomatous tissue (pannus) that grows into the fibrocartilage and bone[16]. In this study, pannus was observed in 85.7% of the TMJs.

In this study, abnormal bone marrow signal in the mandibular condyle was observed in 83.3% of the TMJs. Abnormal bone marrow signal in the mandibular condyle on MRI has not previously been discussed in detail. The present study suggested that this finding is one element in the early detection of RA.

This study found swelling of lymph nodes in the parotid glands in 78.5% of RA patients. MRI findings of swelling of lymph nodes in the parotid glands have not previously been discussed in detail. The present study suggested that this finding is another element in the early detection of RA.

2. Change in the magnetic resonance imaging signal of the mandibular condyle due to bisphosphonate-related osteonecrosis of the jaw

The MRI signal from the mandibular condyle on the same side as the symptoms had been changed by the presence of BRONJ in this study. This study also showed a significant difference in the abnormal bone marrow signal of the mandibular condyle in these BRONJ patients in regard to the abnormal signal appearing on the same side as the symptoms or on the side with no symptoms. Although a correlation between the use of intravenously injected BPs and the development of BRONJ is now widely affirmed in the literature after being reported in 2003 by Marx[11], the correlation between BRONJ and orally administered BPs is less clear or predictable[17].

The AAOMS described the diagnosis of BRONJ in 2009[14] and later suggested a staging system for BRONJ based on four stages[18].

Stage zero: represented by a nonexposed variant, in which other symptoms and signs are present (e.g., pain, formation of sinus tracts, radiologic markers)[19].

First stage: includes asymptomatic bone exposure.

Second and third stages: include patients with exposed bone of various extents with other concomitant symptoms and signs that are mainly a result of secondary infection of the necrotic bone. The symptoms may include increased tooth mobility, formation of sinus tracts, suppuration and

traumatic ulceration of oral mucosa adjacent to exposed bone, mandibular fracture, and/or cervical lymphadenopathy[20].

In the past, many studies worldwide have reported the diagnosis of BRONJ. Panoramic radiography and CT can be considered the most widely available imaging techniques for BRONJ evaluation[21], which explains why most of the selected studies have used those imaging modalities. MRI of BRONJ typically shows low signal intensity on T1-weighted images, medium-to-high signal intensity on T2-weighted images or STIR images[22], and high signal intensity on contrast-enhanced T1-weighted images. In the advanced stage, the periphery of the necrotic bone is surrounded by osteomyelitic bone, for which T1-weighted images show low signal intensity and T2-weighted images and STIR images show high signal intensity. These signals indicate increased cellular components, osteogenesis, and vascular proliferation[23].

Kaneda et al. described the MRI appearance of mandibular bone marrow at different ages. In the mandibular body, complete conversion from red marrow to yellow marrow occurs after 20 years of age. Therefore, normal mandibular bone marrow should have low signal intensity on STIR images[24]. STIR imaging is useful for detecting mandibular osteomyelitis, identifying the extent of inflammation, investigating the spread of inflammation to soft tissues, and detecting postoperative recurrence of disease[25]. The present study used STIR for bone marrow evaluation because it is the principal MRI examination technique for fat suppression[26].

Many studies worldwide have reported an association between BPs and a range of serious dental diseases. There have been few studies, however, that evaluated BRONJ with an abnormal bone marrow signal of the mandibular condyle using MRI. In this study, abnormal bone marrow signals of the mandibular condyle were observed in 83.3% of BRONJ patients on the side of the face with symptoms. To date, MRI findings of an abnormal bone marrow signal of the mandibular condyle in BRONJ patients have not been discussed in detail. The present study suggested that this discovery could contribute to the early detection of BRONJ.

Conclusion

MRI findings of RA in the TMJs were characterized by bone and soft tissue involvement, including osseous changes in the mandibular condyle, pannus, and abnormal bone marrow signal in the mandibular condyle. Second study showed that MRI signals of the mandibular condyle bone marrow on the same side that symptoms had occurred had been altered by the presence of BRONJ. These results suggested that MRI signal of the mandibular condyle could be very useful informations in clinical situations.

References

1. Kretapirom K, Okochi K, Nakamura S, et al. MRI characteristics of rheumatoid arthritis in the temporomandibular joint. Dentomaxillofac Radiol. 42:31627230, 2013
2. Vliet Vlieland TP, Buitenhuis NA, van Zeben D, et al. Sociodemographic factors and the outcome of rheumatoid arthritis in young women. Ann Rheum Dis. 53:803-6, 1994
3. Sugimoto H, Takeda A, Hyodoh K. Early-stage rheumatoid arthritis: prospective study of the effectiveness of MR imaging for diagnosis. Radiology. 216:569-75, 2000
4. Sabine W. Whole-body MR imaging for patients with rheumatism. Eur J Radiol. 70:431-41, 2009
5. Pier NS, Carlo O. Rheumatoid arthritis: sequences. Eur J Radiol. 27:S31-S38, 1998
6. Uchiyama Y, Murakami S, Furukawa S. Temporomandibular joints in patients with rheumatoid arthritis using magnetic resonance imaging. Clin Rheumatol. 32: 1613-8, 2013
7. Vande Berg BC, Maighem J, Lecouvet FE, Maldague B. Magnetic resonance imaging of the normal bone marrow. Skeletal Radiol. 27: 471-483, 1998
8. Lieberman JM, Gardner CL, Motta AO, Schwartz RD. Prevalence of bone marrow signal abnormalities observed in the temporomandibular joint using magnetic resonance imaging. J Oral Maxillofac Surg. 54: 434-439, discussion 439-440, 1996
9. Campisi G, Lo Russo L, Agrillo A, et al. BRONJ expert panel recommendation of the Italian

Societies for Maxillofacial Surgery (SICMF) and Oral Pathology and Medicine (SIPMO) on bisphosphonate-related osteonecrosis of the jaw: risk assessment, preventive strategies and dental management. Ital J Maxillofac Surg. 22: 103-124, 2011

10. Ficarra G, Beninati F. Bisphosphonate-related osteonecrosis of the jaws: the point of view of the oral pathologist. Clin Cases Miner Bone Metab. 4: 53-57, 2007
11. Marx RE. Pamidronate (Aredia) and zoledronate (Zometa) induced avascular necrosis of the jaws: a growing epidemic. J Oral Maxillofac Surg. 61: 1115-1117, 2003
12. Ruggiero SL, Dodson TB, Assael LA, et al. American Association of Oral and Maxillofacial Surgeons position paper on bisphosphonate-related osteonecrosis of the jaws—2009 update. J Oral Maxillofac Surg. 67: 2-12, 2009
13. Paulo S, Abrantes AM, Laranjo M, et al. Bisphosphonate-related osteonecrosis of the jaw: specificities. Oncol Rev. 8: 254, 2014
14. O'Ryan FS, Khoury S, Liao W, et al. Intravenous bisphosphonate-related osteonecrosis of the jaw: bone scintigraphy as an early indicator. J Oral Maxillofac Surg. 67: 1363-1372, 2009
15. Bykerk VP, Massarotti EM. The new ACR/EULAR remission criteria: rationale for developing new criteria for remission. Rheumatology. 51:16-20, 2012
16. McQueen FM, Benton N, Perry D, et al. Bone edema scored on magnetic resonance imaging scans of the dominant carpus at presentation predicts radiographic joint damage of the hands and

feet six years later in patients with rheumatoid arthritis. Arthritis Rheum. 48:1814-27, 2003

17. Manzon L, Ettorre E, Viscogliosi G, et al. Bisphosphonate therapy and osteonecrosis of the jaw complicated with a temporal abscess in an elderly woman with rheumatoid arthritis: a case report. Clin Interv Aging. 9: 1409-1413, 2014
18. McLeod NM, Brennan PA, Ruggiero SL. Bisphosphonate osteonecrosis of the jaw: a historical and contemporary review. Surgeon. 10: 36-42, 2012
19. Fedele S, Porter SR, D'Aiuto F, et al. Nonexposed variant of bisphosphonate-associated osteonecrosis of the jaw: a case series. Am J Med. 123: 1060-1064, 2010
20. Otto S, Schreyer C, Hafner S, et al. Bisphosphonate-related osteonecrosis of the jaws: characteristics, risk factors, clinical features, localization and impact on oncological treatment. J Craniomaxillofac Surg. 40: 303-309, 2012
21. Stockmann P, Hinkmann FM, Lell MM, et al. Panoramic radiograph, computed tomography or magnetic resonance imaging: which imaging technique should be preferred in bisphosphonate-associated osteonecrosis of the jaw? A prospective clinical study. Clin Oral Investig. 14: 311-317, 2010
22. Raje N, Woo SB, Hande K, et al. Clinical, radiographic, and biochemical characterization of multiple myeloma patients with osteonecrosis of the jaw. Clin Cancer Res. 14: 2387-2395, 2008
23. Bedogni A, Blandamura S, Lokmic Z, et al. Bisphosphonate-associated jawbone osteonecrosis: a

correlation between imaging techniques and histopathology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 105: 358-364, 2008

24. Kaneda T, Minami M, Ozawa K, et al. Magnetic resonance appearance of bone marrow in the mandible at different ages. Oral Surg Oral Med Oral Pathol Radiol Endod. 82: 229-233, 1996

25. Kaneda T, Minami M, Ozawa K, et al. Magnetic resonance imaging of osteomyelitis in the mandible: comparative study with other radiologic modalities. Oral Surg Oral Med Oral Pathol Radiol Endod. 79: 634-640, 1995

26. Lee K, Kaneda T, Mori S, et al. Magnetic resonance imaging of normal and osteomyelitis in the mandible: assessment of short inversion time inversion recovery sequence. Oral Surg Oral Med Oral Pathol Radiol Endod. 96: 499-507, 2003

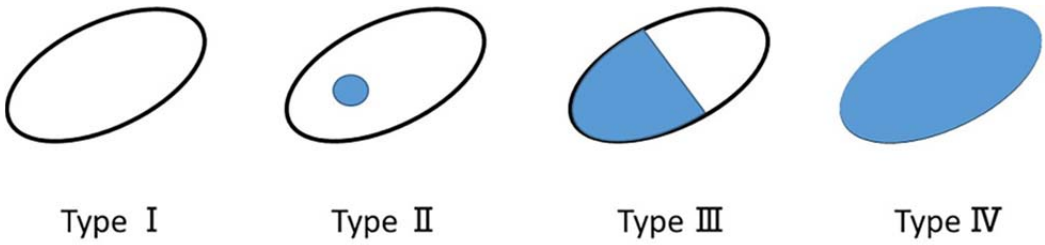
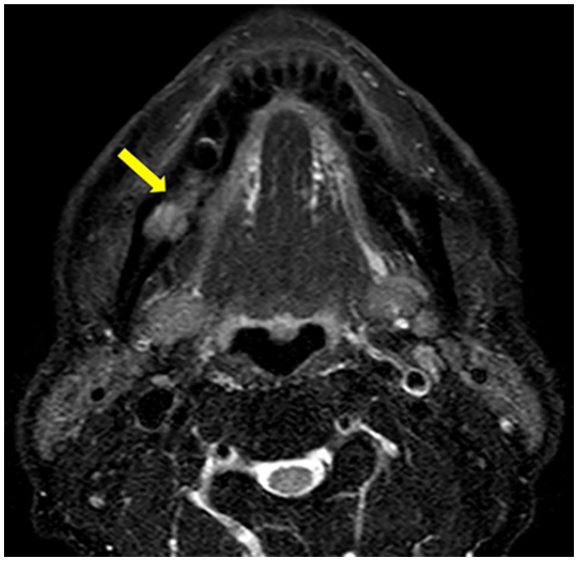


Fig.1

Four signal patterns of the mandibular condyle bone marrow detected by MRI. Type I: normal signal from the mandibular condyle bone marrow. Type II: a spot of abnormal signal from mandibular condyle bone marrow. Type III: between a spot and half of the abnormal signal from mandibular condyle bone marrow. Type IV: one-half to completely abnormal signal from mandibular condyle bone marrow.

Fig.2-A 65-year-old woman with BRONJ.



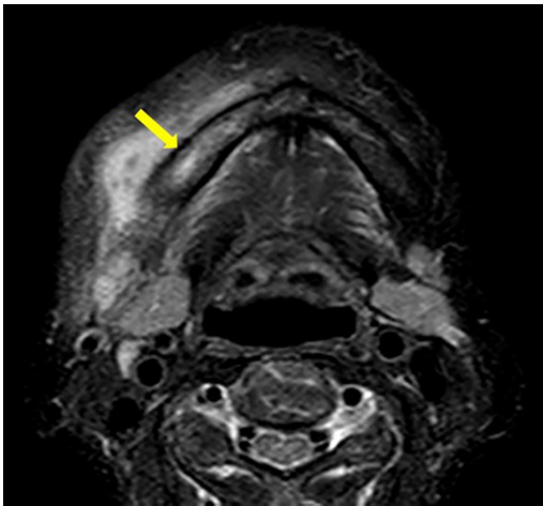
Axial STIR MRI shows inflammation of the mandible (**A**, *arrow*).

Fig.2-B 65-year-old woman with BRONJ.

Axial STIR MRI shows a normal signal from the mandibular condyle bone marrow (**B**,

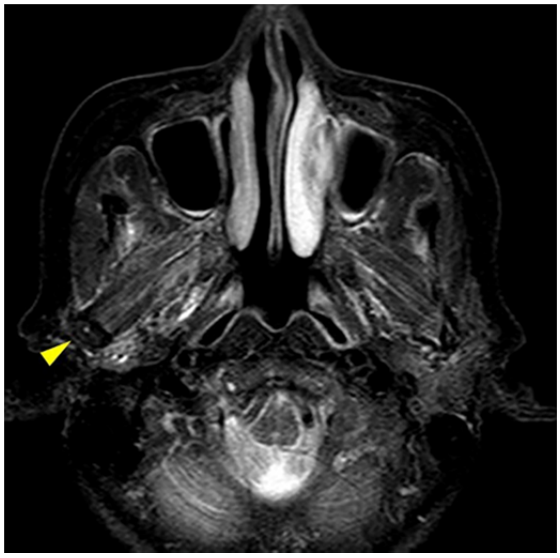
arrowhead).

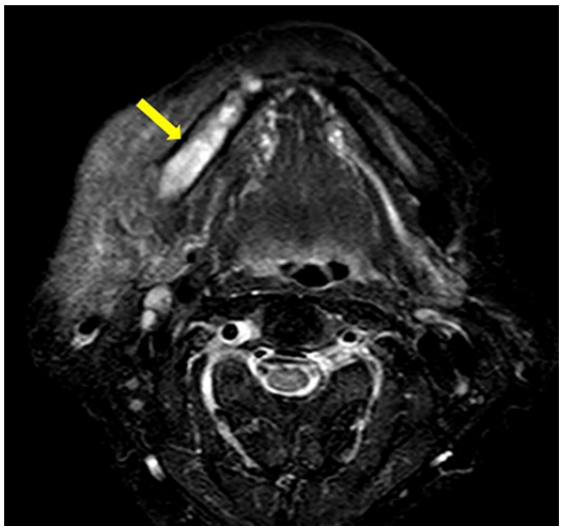
Fig.3-A 77-year-old woman with BRONJ.



Axial STIR MRI shows inflammation of the mandible (**A**, *arrow*).

Fig.3-B 77-year-old woman with BRONJ.





Axial STIR MRI shows a spot of abnormal signal from the mandibular condyle bone marrow (**B**, *arrowhead*).

Fig.4-A 82-year-old woman with BRONJ.

Axial STIR MRI shows inflammation of the mandible (**A**, *arrow*).

Fig.4-B 82-year-old woman with BRONJ.

Axial STIR MRI shows one-half abnormal signal from the mandibular condyle bone marrow (**B**, *arrowhead*).

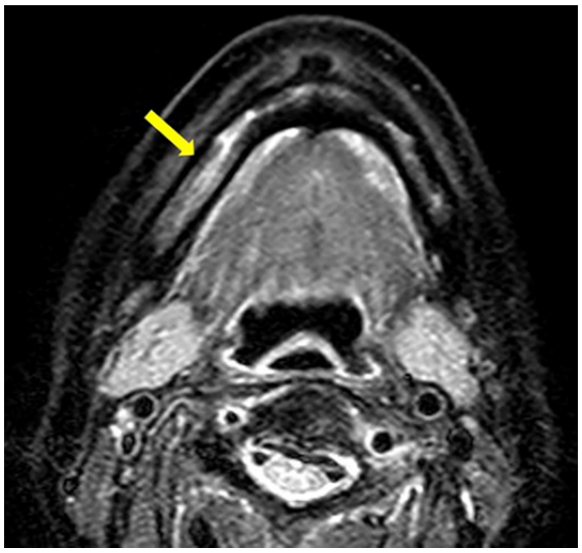


Fig.5-A 57-year-old woman with BRONJ.

Axial STIR MRI shows inflammation of the mandible (**A**, *arrow*).

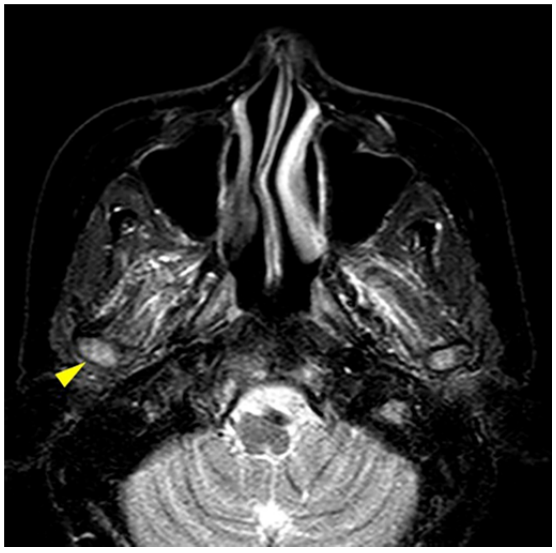


Fig.5-B 57-year-old woman with BRONJ.

Axial STIR MRI shows a completely abnormal signal of the mandibular condyle bone marrow (**B**, *arrowhead*).

Fig.6 RA in a 54-year-old woman.

Oblique sagittal proton-density weighted image shows osseous changes in mandibular condyle (arrow) and abnormal disk position and morphology (arrowhead).

Fig.7 RA in a 51-year-old woman.

Axial STIR MR image shows synovial proliferation (pannus) (arrow).

Fig.8 RA in a 34-year-old woman.

Axial STIR MR image shows abnormal bone marrow signal in the mandibular condyle (arrow).

Fig.9 RA in a 37-year-old woman.

Axial STIR MR image shows swelling of lymph nodes in the parotid glands (arrows).

Table 1. Abnormal bone marrow signal in the mandibular condyle, pannus, and swelling of lymph nodes in the parotid glands in RA patients and controls

	RA patients	Controls
Synovial proliferation (pannus)	36 (85.7%)	1 (2.3%) $P < .01$
Abnormal bone marrow signal in the mandibular condyle	35 (83.3%)	3 (6.8%) $P < .01$
Swelling of lymph nodes in the parotid glands	33 (78.5%)	13(29.5%) $P < .01$

Values shown are number (%).

Table 2. MR findings in rheumatoid arthritis

	RA patients (number)	%
Abnormal disk position	40	95.2%
Synovial proliferation (pannus)	36	85.7%
Abnormal disk morphology	35	83.3%
Osseous changes in mandibular condyle	35	83.3%
Abnormal bone marrow signal in the mandibular condyle	35	83.3%
Swelling of lymph nodes in the parotid glands	33	78.5%
Joint effusion	13	30.9%
Deformity of articular eminence/glenoid fossa	7	16.6%
Erosion of articular eminence/glenoid fossa	4	9.5%

Table 3. Abnormal MRI signal, according to the side of symptoms in BRONJ patients

Abnormal signal on the side of the jaw symptoms	No. of patients	*P*
Present	25 (83.3%)	–
Absent	3 (11.5%)	< .05*

MRI: magnetic resonance imaging; BRONJ: bisphosphonate-related osteonecrosis of the jaw

*Significance of the difference between Present vs. Absent.

Table 4. Type of mandibular condyle bone marrow signal in BRONJ patients with an abnormal signal and symptoms on the same side

Type	%	Maxilla	Mandible	Total
I	16.6	1	4	5
II	53.3	2	14	16
III	10.0	0	3	3
IV	20.0	1	5	6

BRONJ of the maxilla: 4 cases

BRONJ of the mandible: 26 cases