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The imaging characteristics of odontogenic myxoma and a comparison of three different imaging modalities

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Abstract:
Objective. To report the imaging characteristics of odontogenic myxoma (OM) and compare the different imaging modalities used.
Study design. The radiological images of 33OMcases were retrospectively analyzed. The radiographs were severally examined to describe the features of OM as seen on conventional radiographs (CRs), computed tomography (CT) scans, and magnetic resonance images (MRIs).
Results. MRI was effective in displaying the true extension and contents of OMs. CT scans demonstrated the extensions of OMs, expansion, growth pattern, and rendered it possible to compare density of OM with that of surrounding muscles. Assessment of CRs revealed great limitations about the diagnostic values and failed to display important features.
Conclusions. All 3 radiographic techniques, conventional radiography, CT, and magnetic resonance imaging (MRI), have inherent advantages and disadvantages; however, all 3 should be routinely used in the diagnosis of OM. The results of CTand MRI can accurately reveal margins of tumors and greatly aid in diagnosis. (Oral Surg Oral Med Oral Pathol Oral Radiol 2013;116:492-502)

Odontogenic myxoma (OM) is a rare, nonencapsulated benign but locally invasive odontogenic tumor first described by Thoma and Goldman in 1947.[1-4] It represents 3%-6% of all odontogenic tumors and has been reported to be the second most common odontogenic tumor after ameloblastoma in some countries.[5,6]

In the facial region,OMoccurs mostly within the bone and radiologic examination is therefore important.[7] Generally, diagnosis of OM is made by the examination of conventional radiographs (CRs) and confirmed by histopathology. Advanced technologies such as computed tomography (CT) and magnetic resonance imaging (MRI) may offer diagnostic options, which could overcome some of the limitations of CR. Hence, recognizing the paucity of relevant research, the aim of this study was to report the imaging characteristics of OM and compare the different imaging modalities used.

Materials and methods

The radiological records of 33 OM cases presenting over a period of 42 years (1967-2009) were included in the study. The study was exempt from obtaining ethical approval because of its retrospective nature. In all cases, the diagnosis was histopathologically confirmed before enrolment in the study. All images, which had been determined to be of a good standard, were examined independently by 2 oral and maxillofacial radiologists. A third examiner was invoked when there was a dispute between the 2 observers and the decision of the majority was accepted.

All 3 imaging techniques were viewed under the same conditions using a viewing box of sufficient size that was bright and evenly illuminated. Adjunctive tools such as magnifying glasses and opaque masks were used to allow proper examination of the images.

This retrospective study undertook, in the first place, the description of the radiologic features of OM as seen on CR. Then the radiologic information provided by CT scans and magnetic resonance images (MRIs), respectively, was studied and analyzed. Finally the 3 modalities were compared in terms of how comprehensive were the descriptive diagnostic data which could be obtained from each to determine which was superior.

The patients were grouped according to the type of imaging available in their records. A comparison of all 3 imaging modalities was done for patients with complete sets of all 3 imaging modalities. Conventional radiography had been performed in 30 cases; MRIs were available in 10 cases, whereas CT images had been recorded in 8 cases. Demographic data were recorded and analyzed for age, gender, and ethnic origin. Conventional radiography included panoramic radiographs, occlusals, lateral obliques, and posteroanteriors (PAs). The radiological features examined included location, appearance of the internal structures, locularity, expansion, and borders/margins of the tumor, and the association with unerupted or impacted teeth. In addition, the study included the effects that the tumors exerted on surrounding tissues, such as displacement of teeth, root resorption, encroachment upon the mandibular canal, and maxillary sinus as well as the influence that some maxillary tumors had on the nasal cavity and floor of the orbit.

The tumors, located in either the maxilla or the mandible, were divided into 5 categories based on their internal structure: (i) unilocular radiolucency with no internal trabeculation; (ii) radiolucent area with a few strands of delicate or coarse intratumoral trabeculae; (iii) radiolucency with straight and angular trabeculation (tennis-racket appearance); (iv) radiolucency with round or oval compartments formed by curved trabeculation (honeycomb appearance); and (v) tumors that showed a combination of any 2 or more of the above. Locularity of tumors was described as either unilocular or multilocular. Expansion of the tumor was recorded as (i) no cortical expansion; (ii) expansion with visible margin; (iii) cortical destruction (perforation); and (iv) cortical destruction with extension outside the bone. The margins of tumors were classified as (i) uncorticated; (ii) poorly corticated; (iii) moderately corticated; and (iv) well corticated.

For CT images, the features examined, in addition to those assessed on the CR films, included locularity in 3 dimensions. The content of the tumor was compared with the surrounding muscles using CT attenuation values (Hounsfield number) and accordingly the tumor was categorized as hypodense or isodense. The pattern of growth of the tumor was investigated to show whether lobulation, budding, nodulation, and/or crevice formation or a mixed pattern were present.

MRIs of OMs were examined for signal intensities in the tumor and these were compared with those of the surrounding structures. The degree of homogeneity was recorded for all images. The internal composition of the tumor and pattern of enhancement were also assessed. The pattern of growth was investigated to show whether lobulation, budding, nodulation, and/or crevice formation or mixed pattern were present. As before, the border of the tumor, status of the cortex (thinning and/ or perforation), and/or soft tissue extension were also evaluated.

Results

Patient demographics Of the 33 records from this sample, which were reviewed, 23 (69.7%) cases were reported in females and 10 (30.3%) cases occurred in males. For females, the ages ranged from 12 to 44 years (average of 23.7), whereas in males the ages ranged from 8 to 28 years (average of 24.6 years) (Table I).

Location

Seventeen cases occurred in the mandible, whereas 16 cases were observed in the maxilla. The majority of the tumors appeared in the posterior regions of the jaws within the body and ramus for the mandible, whereas for the maxilla, the premolar, molar, and tuberosity areas were most affected.

Radiological features of OM on CR

Thirty cases had been examined radiographically using panoramic radiographs and/or PA mandible, occipitomental, and/or occlusal views. In the majority of cases teeth were missing in the area of the tumor. A summary of the radiological features disclosed by CR examination is recorded in Table II.

The internal structures of the tumors (Table III) were found to show varying radiological appearances and appeared as clear unilocular in 2 (6.7%) cases (Figure 1A), multilocular in 13 (43.3%) cases (Figure 1B), whereas radiolucent tumors with fine delicate or sometimes coarse trabeculae (Figure 1C and D) appeared to be the most common form in this regard and was reported in 50% of cases.

OM is an expansile tumor that demonstrated in this sample a tendency to displace teeth in 24 (80%) cases, 3 cases showing migration and severe displacement of the teeth. Root resorption appeared to be uncommon in the present study and was reported in only 3 (10%) cases. Involvement of impacted teeth within the tumors occurred in 3 (10%) instances, whereas 5 (16.7%) cases showed involvement of unerupted teeth.

Table I. Distribution of OM by age, gender, and ethnic groups

Age group (years)	*Male*	*Female*	*Ethnicity*		*Total*
0-10	2	0	Negroid	2	2 (6.1%)
			Caucasian	1	
11-20	5	5	Mixed	6	10 (30.3%)
			Negroid	3	
			Caucasian	3	
21-30	3	10	Mixed	7	13 (39.4%)
			Negroid	3	
31-40	0	6	Caucasian	1	6 (18.1%)
			Mixed	5	
41-50	0	2	Mixed	2	2 (6.1%)
Total	10 (30.3%)	23 (69.7%)			33 (100%)

Both unerupted and impacted teeth suffered some degree of displacement. The effects of the tumor on adjacent structures are shown in Table II.

Radiological features of OM on CT

CT images were available in 8 of the 33 cases. On the soft tissue window settings, the attenuation values of OM were compared with the surrounding muscles and appeared as hypodense in 4 (50%) cases and isodense masses in 4 (50%) cases.

On CT assessment, expansion of OMs was detected in 7 (87.5%) of the 8 cases, 5 (62.5%) cases showing expansion with interruption of the cortical margin and 2 (25%) cases showing expansion but with a visible cortical margin. In 1 (12.5%) case the margin was indistinct. In the maxillary tumors, especially at the level of the maxillary sinus, expansion appeared to be limited as the tumors tended to fill the maxillary sinus (Figures 2 and 3).

The cortical margins of OMs were detected on bone window settings in 7 (87.5%) cases; 3 (42.9%) cases showed moderate cortication, whereas 4 (57.1%) cases were well corticated. One case lacked a distinct cortical margin.

Multilocularity of the tumors was shown in 4 (50.0%) of the 8 cases. In 3 (37.5%) cases, the tumor appeared unilocular with fine lace-like trabeculae, most of which were observed toward the border of the tumor. One (12.5%) case appeared indistinct with coarse trabeculae.

OM is known for its distinctive growth behavior. In the present study, we found that in 7 (87.5%) tumors there is indeed a distinctive pattern of growth (95% exact confidence interval: 0.4735, 0.9968). The patterns ranged from lobulations (2 cases), budding (2 cases), and crevice formation in 3 cases (Figure 3). CT assessment disclosed extension of the tumors into surrounding structures in 6 (75.0%) cases (95% exact confidence interval: 0.3491, 0.9681). These structures included the maxillary sinus (Figures 2 and 3), the orbit and nasal cavity (Figure 2). In 2 tumors, it was difficult to delineate the tumors from the surrounding tissues. The summary of the radiological features discerned on CT is presented in Table IV.

Radiological features of OM on MRI On MRI, 90% of cases appeared as well-defined expansile multiloculated masses, generally with lobulated growth pattern, small crevices, and/or partial septation. The summary of the radiological features on MRI is presented in Table V.

The internal composition of the tumors was deduced based upon analysis and interpretation of the signal characteristics, and the intensities and pattern of contrast uptake. On T1 weighted image (T1WI), Oms appeared as heterogenous tumors with mixed hypo/isointensity in 90% of cases (95% exact confidence interval: 0.5550, 0.9975). On T1WI with gadolinium (Figure 4), the images displayed varying patterns of contrast uptake/enhancement. Some areas of the tumors were enhanced markedly and were assumed to be collagenous.

Table II. Radiological features of OM on CR ($n = 30$)

Radiologic feature	*Maxilla*	*Mandible*	*Total*
Internal structure of the tumor			
Unilocular clear	1	1	2 (6.7%)
Unilocular with trabeculae	10	5	15 (50.0%)
Multilocular	3	10	13 (43.3%)
Cortication			
Uncorticated	7	2	9 (30.0%)
Poorly corticated	3	5	8 (26.7%)
Moderately corticated	4	8	12 (40.0%)
Well corticated	1	0	1 (3.3%)
General features			
Presence of tooth displacement	9	12	21(70.0%)
Presence of tooth migration*	2	1	3 (10.0%)
Presence of root resorption	1	2	3 (10.0%)
Association with impacted teeth	2	1	3 (10.0%)
Association with unerupted teeth	2	3	5 (16.7%)
Extension into the maxillary sinus	12	NA	12 (40.0%)
Obliteration and displacement of inferior alveolar canal	NA	14	14 (46.7%)
Extension into the surrounding tissues			
Orbit	1	NA	1 (3.3%)
Nasal cavity	1	NA	1 (3.3%)

NA, not applicable.
*Migration denotes severe displacement.

Table III. Classification of OM according to the internal structure ($n = 30$)

Radiological features	*Maxilla*	*Mandible*	*No. of cases*
Type i			
Radiolucent tumors with no trabeculation	1	1	2 (6.7%)
Type ii			
Radiolucent tumors with trabeculation (mostly fine, sometimes coarse)	10	5	15 (50%)
Type iii			
Straight and angular trabeculation which frequently forms square or triangular compartments	0	1	1(3.3%)
Type iv			
Round or oval compartments formed by curved trabeculation	2	1	3 (10%)
Type v			
Tumor that shows combination of any of types i to iv	1	8	9 (30%)

In other areas, we found that tumor tissues did not enhance and were accordingly deduced as being myxomatous and/or bony septae. In the mandibular tumors, the tumors extended into floor of the mouth and pterygoid space (Figure 5).

In the present study, 9 (90.0%) of the tumors (95% exact confidence interval: 0.5550, 0.9975) appeared to contain both components, whereas in 1 case the tumor appeared predominantly as myxomatous. T2WIs clearly defined the extent of the tumors in all tumors. The tumors appeared heterogenous with mixed areas of high signal intensity and hypo-intensity in 90% of the cases (Figure 6). In 1 case the tumor appeared homogenously hyperintense (Figure 7).

Expansion of all the tumors was clearly shown on MRI, 60% having cortical perforation in some areas with extension into the surrounding tissues. Forty percent showed expansion with preservation of the cortical margin in most areas of the tumor. The tumors were well corticated in 3 (30%) cases and 7 (70%) cases showed moderate cortication.

Tumors appeared as multilocular in 6 (60%) cases, whereas 3 (30%) cases showed a unilocular tumor with fibrous or bony trabeculae. One (10%) case appeared as a unilocular clear tumor.

In the present study, growth patterns ranged from lobulations (4 cases) (Figure 5), crevice formation (2 cases) (Figure 6), and budding (1 case). The pattern of growth was reported as mixed with 2 or more types in 3 cases.

On MRI, all tumors (95% exact confidence interval: 0.6915, 1.0000) showed some degree of extension into the surrounding structures. In the maxillary tumors, the tumor extended variously into the maxillary sinus (Figure 5), nasal cavity (Figure 5), nasal turbinates, infratemporal fossa, and floor of the orbit.

Evaluation of the 3 imaging modalities In the present study, 5 records had complete sets of CRs, CT scans, and MRIs. These images were evaluated and contrasted with regard to how explicit the film was in terms of depicting the demarcation, cortication, expansion, extension into the surrounding tissues, and locularity of the tumors and their effects on the dentition.

On both CT and MRI, 4 (80%) of the tumors were well demarcated, whereas in 1 (20%) case the tumor was moderately demarcated. On panoramic radiographs, 80% of the tumors appeared as poorly or undemarcated tumors and 20% (only 1 case) was moderately demarcated.

All tumors (5 cases) showed moderate to good cortication when assessed on CT scans and MRIs. CR on the other hand demonstrated that 60% of the tumors were moderately corticated and 40% showed no cortication, which indicates a clear discrepancy.

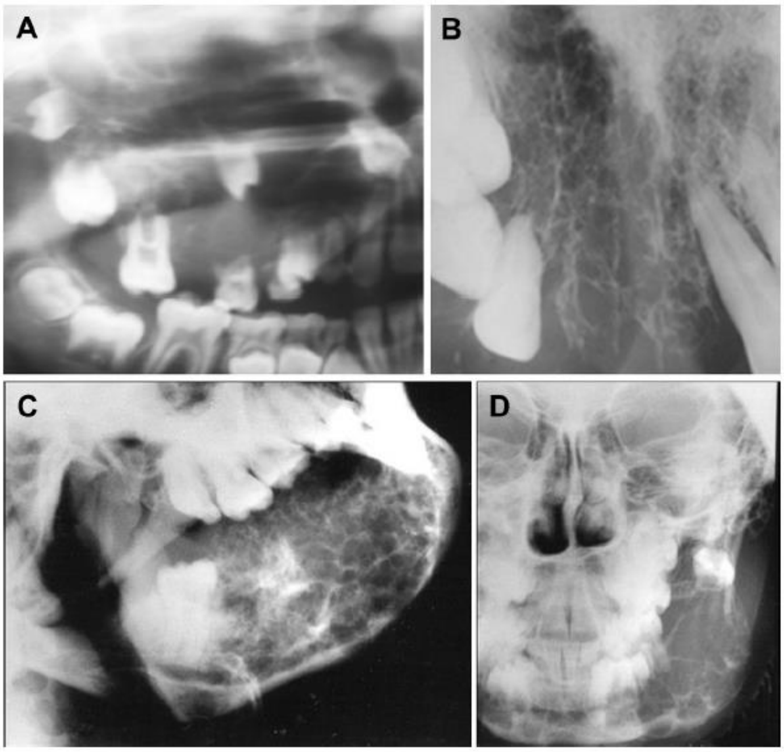

Fig. 1. (A) Panoramic radiograph showing radiolucent lesion with no trabeculation. (B) Occlusal radiograph demonstrating a fine delicate trabecular pattern in the maxillary anterior region. (C) Lateral oblique projection showing angular septa within the lesion. (D) PA projection demonstrating the coarse trabecular pattern.

All tumors, as seen on the CT and MRI records, showed some degree of expansion and 80% (4 cases) displayed cortical perforation. However on CR, 40% of the tumors were diagnosed as not having expanded and just 20% showed expansion of the tumor with cortical perforation. One of the cases that appeared to the observers as multilocular on CR was found to be unilocular on CT and MRI assessments.

Displacement and migration of the teeth were shown easily on CR, but were not so readily demonstrated on the specific slices and planes of the CT and MRI assessments. The contents of all tumors were deduced on MRIs as the process produces different signal intensities from different tissue areas. Hounsfield numbers on CT differentiate the densities of the tumors compared with muscles, but the modality in this study was shown to be deficient in this regard. MRIs displayed distinctive patterns of the growth in all 5 tumors, whereas CT showed it in 4 of the cases. Panoramic radiographs were unable to display such a feature.

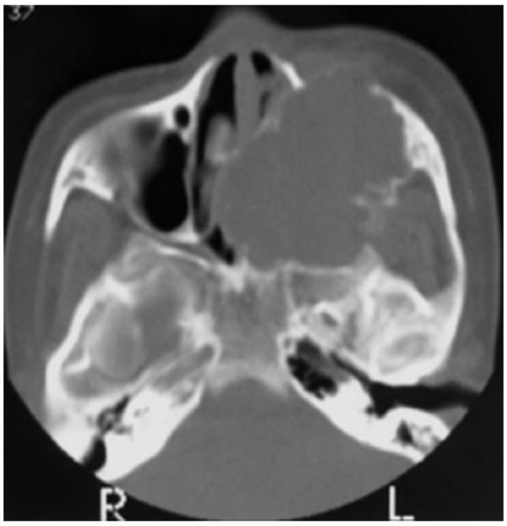

Fig. 2. Axial CT (bone window settings) showing the tumor in the left side of the maxilla. The tumor obliterates the maxillary sinus and part of the nasal cavity. Note the scalloping nature of the growth of the tumor.

Fig. 3. Axial CT (bone window settings) showing tumor in the right side of the maxilla. The tumor shows crevice formation on the buccal wall anteriorly and periosteal reaction on posterior border of tumor.

Discussion

The study assessed different imaging modalities for the diagnosis of OM and is unique in that in addition to CR, both CT and MRI records were included. The total number of MRI records at 10 is considered relatively large compared with studies resourced in the literature in which sparse case reports were described. To our knowledge only 2 CT studies have reported on a sample size of any consequence. One was a multicenter study with 17 patients undertaken in Japan by Koseki et al.8 and the other study involved 8 patients that was completed in China by MacDonald-Jankowski et al.9

OM has been reported to occur over a wide age interval. In our study, we found that the mean age was younger than the average reported by other series, with prevalence in the second (10 cases) and third (13 cases) decades of life. In the present study, we found that OMs had a predilection for females (69.7%) compared with males (30.3%). This finding is in agreement with the results obtained by many authors6,9,10 and together with those contradicts the results of equal gender frequency reported by Regezi et al.11 and male predominance as claimed by van Rensburg et al.12 and Brannon.13

In both jaws (17 mandible and 16 maxilla) the tumors were predominately seen in the posterior regions, in concurrence with the findings reported by Simon et al.,6 Noffke et al.,14 Brannon,13 and van Rensburg and Nortje.15

Radiological features of OM on CR The radiological appearance of the OM is more complicated than has generally been thought, supporting the claims of Peltola et al.10 Indeed, there is considerable debate and controversy regarding the internal structure and locularity of the tumor. Some authors have claimed that the presence or absence of loculation describes the stage of tumor development.[13,16] These authors believe that the tumor starts out as a multilocular tumor that increases in size together with ongoing resorption of the trabeculae and subsequent conversion to a unilocular format.

Table IV. Radiologic features of OM on CT ($n = 8$)

No.	*Attenuation value*	*Expansion*	*Cortication*	*Locularity and internal structure*	*Growth pattern*	*Extension into surrounding tissues*
1	Hypodense	Visible margin	Well corticated	Multilocular	Budding	Yes
2	Isodense	Interruption	Moderate corticated	Multilocular	Crevices	Yes
3	Hypodense	None	Uncorticated	Coarse trabeculae	Indistinct	Indistinct
4	Isodense	Visible margin	Well corticated	Uni + FT*	Budding	No
5	Isodense	Interruption	Moderately corticated	Multilocular	Crevices	Yes
6	Isodense	Interruption	Moderately corticated	Multilocular	Lobulation	Yes
7	Hypodense	Interruption	Well corticated	Uni + FT*	Crevices	Yes
8	Hypodense	Interruption	Well corticated	Uni + FT*	Lobulation	Yes

**FT*, fine trabeculae; *Uni*, unilocular.

This concept seems attractive and logical and goes some way in explaining the appearance, for instance, of a tumor having the combined appearance of honeycomb together with radiolucency with fine trabeculae. However, this study has shown on MRI and CT that some trabeculae appeared as fibrous or collagenous, suggesting that these trabeculae developed within the tumor. On the other hand, some investigators believe that these 2 forms, trabeculated or not, occur independently and this may be supported by the fact that in our study some tumors appeared as small radiolucent tumors with no trabeculae, whereas others appeared as large multilocular tumors. Therefore based on our findings, we agree to the postulate that both forms occur independently. Furthermore, it may be assumed that trabeculae can develop within a unilocular tumor and convert it into a multilocular tumor.

In our study, we have chosen to describe the radiological features of the internal structure of the tumor as radiolucent tumor that contains no trabeculae (clear cystic), or composed of trabeculae that can be thin or thick. This classification was adapted from the studies of Koseki et al.[8] and modified in this study to include other features such as the appearance of a fishnet or wispy pattern. Furthermore a new category (type v) was developed in which a combination of 2 or more types was present (Table III).

The boundary between the tumor and surrounding normal tissues represents a critical zone that reflects the biologic behavior of the tumor. In this regard results for the 30 cases assessed by conventional radiography seemed to be consistent with the distinctive invasive behavior of OM as it demonstrated frequent interruption of the cortex (Table II). The reason for the association between the tumors and loss of teeth is uncertain because the study was retrospective in nature. Progressive mobility leading to extraction or exfoliation of the teeth could be an explanation for this finding. Nevertheless misdiagnosis of the local swelling as being of dental origin and a subsequent decision to remove the teeth should also be considered as a possible reason.

On panoramic radiographs, expansion of the tumor was assessed visually, taking into consideration the 2-dimensional (2-D) nature of the images and was evaluated by degree of displacement of the associated teeth. In the present study, we found that expansion with or without the cortical margin was detected in 25 (83.3%) cases. Expansion ranged from minimal which led to mild displacement of the teeth to a large expansile mass which was associated with severe displacement and migration of teeth, together with buccal, lingual, and palatal swelling accompanied by distortion, thinning, and/or perforation of the cortex. However, in some of the maxillary tumors the tumors had grown silently inside the maxillary sinus, resulting in opacification, also reported by other investigators.[17]

Tooth displacement was a common finding and was detected in 80% of cases, whereas root resorption was found in only 10% of cases (Table II). These findings corresponded to results obtained by Noffke et al.[14] and Peltola et al.[10] and correlated well with the fact that OM is a slowly growing tumor. Nevertheless these findings contradicted the high incidence of root resorption reported by Simon et al.[6]

The occasional association with missing, impacted, and/or unerupted teeth (27% of cases, Table II) supports the assumption by Noffke et al.,[14] Simon et al.,[6] and many others that intra-osseous myxoma is odontogenic in origin.

Radiologic features of OM on CT In this study, half of the sample had tumors which were hypodense compared with muscle, whereas the remainder were isodense (Table IV), in comparison with Koseki et al.[8] who reported an incidence of hypodensity of 76.9% and isodensity of 23.1%. Similarly, half of the current sample showed multilocularity with definite bony septae, whereas the unilocular tumors (37.5%) showed some trabeculae which were observed mostly toward the periphery of the tumor. This finding is in agreement with previous observations by other authors that on CT, a characteristic finding in OM is strands of trabeculae of fine lace-like density.[8,18,19]

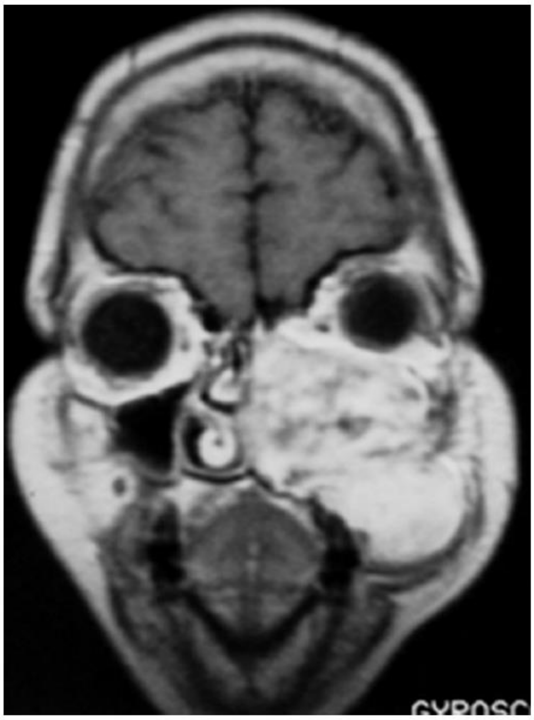

Fig. 4. T1 post-contrast MRI displayed various patterns of contrast uptake/enhancement. Some areas of the tumor enhanced markedly and were assumed to be collagenous, the unenhanced areas being deduced as myxomatous and/or bony septae.

Table V. Radiologic features of OM on MRI ($n = 10$)

No.	*Cortication*	*Expansion*	*Locularity*	*T1*	*T2*	*Enhancement*	*Composition of the tumor*	*Extension into the surrounding tissue*	*Growth pattern*
1	Moderately corticated	Interruption	Multilocular	Mixed	HH	Yes (periphery)	Mixed	Yes (FOM)	Lobulations and crevices
2		Interruption	Multilocular	Hypointense	H2	No	Myxomatous	Yes	Crevices + budding
3		Visible margin	Multilocular	Mixed	HH	Yes (periphery)	Mixed	Yes	Lobulation
4	Moderately corticated	Visible margin	Multilocular	Mixed	HH	Yes (mild)		Yes	Lobulations
5	Well corticated	Interruption	Fine trabeculae	Mixed	HH	Yes (periphery)		Yes (MA)	Crevices
6		Visible margin	Multilocular	Mixed	HH	Yes (periphery)		Yes (MA, NC)	Lobulations
7		Visible margin	Fine trabeculae	Mixed	HH	Yes (mild)		Yes (ITF)	Budding
8	Moderately corticated	Interruption	Multilocular	Mixed	HH	Yes (periphery)		Yes (MA, FOO, NC, AS)	Crevice formation
9		Interruption	Fine trabeculae	Mixed	HH	Yes (bottom)		Yes (MA. Maxilla)	Budding and crevice formation
10		Interruption	Unilocular	Mixed	HH	Yes (bottom)		Yes (MA, FOO, NC, AS)	Lobulations

HH, heterogenous hyperintense; *H2*, hyperintense; *FOM*, floor of the mouth; *MA*, maxillary sinus; *NC*, nasal cavity; *ITF*, infratemporal fossa; *FOO*, floor of the orbit; *AS*, air sinuses.

The CT scans, being more precise, revealed that all the tumors demonstrated cortical interruption in at least focal or localized areas, but that in 6 (75%) of the 8 cases the tumors were still well delineated from the surrounding tissue. This indicates that not all cases with cortical interruption denote soft tissue invasion. This observation was explained by van Rensburg for ameloblastomas, which share virtually the same biologic behavior as OM.[20] Janse Van Rensburg[20] stated that the periosteum acts as a barrier and prevented extension of the tumor into the soft tissue. This may result in compression of the soft tissue, which may act as a pseudocapsule so that the tumor can be easily defined from surrounding tissues even in the absence of cortex. That being the case, soft tissue invasion of the tumors may be diagnosed by focal interruption and absence of the smooth pseudocapsule. Nevertheless, 2 tumors showed cortical interruption which was difficult to distinguish from the surrounding soft tissues, despite the claim made by Koseki et al.[8] that OMs are completely delineated by a smooth margin from the surrounding structures at the area of cortical disruption.

Fig. 5. Axial T2 MRI showing a large mass that extends lingually into the floor of the mouth extending buccally and posteriorly, involving the ramus of the mandible. A small locule of the tumor presented as a hyperintense area in the ramus of the mandible and extends lingually into the pterygoid muscle.

Fig. 6. Axial T1 post(gadolinium)-contrast MRI at the level of the alveolus. Peripheral areas markedly enhanced, whereas the center and anterior area of the mass enhanced weakly. Differences in the pattern of contrast uptake reflect different composition of the mass, which is mostly collagenous at the periphery and myxomatous toward the center and anterior area at this level.

Hounsfield values (HN) were evaluated for 4 cases and ranged from 10 to 121, which gave an indication of the consistency of the tumor. According to Morgan,[21] these tumors ranged from thick but watery consistency (HN for water: 0, for CSF: 15) to a tissue that is denser than muscle (HN: 50) and bone marrow (HN: 300).

An advantage of CT is the ability for 3-D modeling and the authors agree with Shah and Patel[22] that such models are valuable in assessing the true extent of the tumor, particularly with reference to planning reconstructive procedures. On 3-D CT, it was found that in one of the tumors the cortex was indeed interrupted (perforated) but that the tumor remained contained within the bone. In another case that underwent 3-D modeling the macroscopic appearance of the tumor and its relation to surrounding tissues were vividly demonstrated. The procedure is complicated and is performed by a computer system of the CT scanner.

Radiologic features of OM on MRI To our knowledge, this study is the first to describe the features of OM as seen on a series of MRIs. Although the number of cases is admittedly low, nevertheless it is almost equal to the sum of all the cases reported in the English literature since 1994.

MRI has the ability to demonstrate the tumors vividly with precise determination of the margins. All the tumors appeared as well to moderately defined tumors, findings which correspond with observations made by Sumi et al.[23] and Kawai et al.[7]

MRI and enhanced MRI differentiate myxomatous and collagenous parts within the tumor by assigning different signal intensities to different tissues. We found that the majority of cases (90%) showed a mixture of both tissues, whereas only 1 tumor appeared as predominantly myxomatous (Table V). Although in cases where the tumor extended into soft tissues such as floor of the mouth, MRI was able to differentiate between the tumor tissue and normal tissues of the floor of the mouth. This property is one of the major advantages of MRI over the other radiologic modalities.

Contrary to the findings reported by Kawai et al.,[7] the results in the present study showed mixed low to intermediate signal intensity on T1WIs. When the T2WIs were assessed, the tumors appeared as hyperintense masses, which were heterogenous in 90% of the cases.

These results corresponded with the findings by many authors.[17,18,23-26] Variation in the contrast uptake (enhancement) of the various parts of the tumor reflected different histological composition within the tumors. Asaumi et al.[18] stated that collagen bundles were enhanced markedly. In the present study, 50% showed marked enhancement in the peripheral areas, whereas the center did not enhance. This finding is consistent with the results obtained by Asaumi et al.[18] In 3 of the tumors, enhancement appeared at the bottom of the tumor on the coronal section.

Fig. 7. Axial T2 MRI of the same level as Figure 6 showing well-defined hyperintense mass. The tumor showed lobulated margins with crevices on the palatal side.

On the basis of histological examination and according to the amount of fibrous or myxomatous tissue within the tumor, many terms had been assigned such as myxofibroma, fibromyxoma, and OM. However, it is generally believed that all types of the tumor share similar biologic behavior and differentiation appears to be of academic interest. This concept is not totally accepted by the authors as we found that the fibrous part is usually toward the periphery or lower part of the tumor. Since the biologic behavior of a tumor is concentrated toward the periphery, we assume that aggressiveness is inversely related to the quantum of fibrous component of the tumor. However, this assumption needs further confirmation.

Asaumi et al.18 claimed that unlike ameloblastoma, OM is not a consistent mass and is able to invade between the roots of the teeth. This finding was actually observed on MRI in 2 of the cases.

MRI also shows great reliability in determining the vascular nature of a lesion, for example, hemangioma and the major feeder vessels without a need for a contrast agent.12 Thus, it differentiates hemangioma from OM, which may share similar radiological appearance. Some investigators also use dynamic MRI or contrast enhancement to differentiate benign from malignant tumors and in differentiating between benign tumors, for instance ameloblastoma from OM.18

On MRI, the walls of the tumors and patterns of the growth were clearly depicted. Although the tumors displayed predominantly a smooth wall, however in focal areas scalloping, crevices, budding, and/or lobulations were detected. These features supported the distinctive infiltrative nature of the tumor. However, a prospective correlative radiologic/histological study is needed to confirm the assumption that areas of crevices, scalloping, and budding represent the imaging features characterizing the invasive part of the tumor.

Correlation of the 3 imaging techniques For 5 of the patients a complete set of CRs, CT scans, and MRIs were available. These images were evaluated and compared according to the radiologic information, which could be gleaned from each.

All 3 imaging modalities were able to demonstrate the presence of the pathology. However the multiplanar facility of CT and MRI offered the advantage of determining the extension of the tumor in the different planes. This benefit greatly affects the management of maxillary tumors where extension of the tumor into the cranial base or floor of the orbit and paranasal sinuses is a frequent occurrence.

On MRI and CT, all tumors appeared as well or moderately defined, whereas on the panoramic radiographs only 20% were well defined and 80% of the cases appeared as poorly or undefined tumors.

Cortication was best shown on CT with 80% of cases appearing as well circumscribed tumors with a radiopaque margin, whereas on MRI it appeared dark. Panoramic radiographs showed cortication in only 60% of cases.

Panoramic radiographs displayed the general topography of the tumor and surrounding area, showing displacement of the teeth. When using MRI or CR, displacement was only discernible when the slices and planes were specific to the tooth. The high spatial resolution available on CT accounted for the ability of the radiograph to show resorption of the teeth. Regarding locularity of the tumor, 20% of the cases, which appeared as multilocular on CR, were found on MRI and CT scan as unilocular tumors with trabeculae that did not separate the tumor completely. This finding concurs with the claim by Koseki et al.8 that digital imaging showed the tumors in 3 dimensions unlike CR which has the limitation of only 2-D representation. The contents of the tumors were deduced in all cases from MRI data, which allocated different signals to various tissues. CT on the other hand was able to determine densities of the tumors. Conventional radiography lacks this advantage and failed to differentiate between various components of the tumor.

Distinctive patterns of growth of the tumors were observed in all cases on MRI and CT, and appeared as lobulations, budding, and crevice formation. We assume that these parts of the tumors may account for high recurrence rate associated with OM. Since CR failed to show the growth pattern of the tumors, this also confirms the superiority of advanced imaging and may dictate the necessity of using these techniques in diagnosis and presurgical assessment of the tumor. In conclusion, the importance of radiology in the diagnosis of OM cannot be overemphasized because the tumor occurs inside the bone and can reach a considerable size with little or no clinical manifestations. In addition, good imaging to show the tumor's boundaries before treatment is important to avoid incomplete or deficient surgical removal. Despite the many limitations of CR, it is still easily accessible, feasible, affordable, and easy to interpret, making it a basic and essential tool in the investigation process. Indeed, given the silent nature of some OMs, it may well be a fortuitous discovery on routine CR assessment. CT was found to show the extension of the tumors, status of cortication, expansion, locularity, and extension into the surrounding structures. Moreover CT, by determining the attenuation values of the tumors, was able to compare the densities of the tumor with the surrounding muscles.

MRI showed the extension of the tumor, contents, and pattern of growth of the tumor. Additionally, MRI was found to differentiate between various soft tissues and to determine any invasion of the tumor into adjacent soft tissues. The use of CR, CT, and MRI wherever possible should be routine in the diagnosis of OM because of its soft tissue invading features. CT and MRI can accurately reveal the true margins and extent of tumors, and greatly aid in diagnosing the tumor and differentiating OM from other tumors with similar presentation.

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