Dental Traumatology

Dental Traumatology 2013; **29**: 185–196; doi: 10.1111/edt.12028

Pathological mandibular fractures: a review of the literature of the last two decades

Paolo Boffano, Fabio Roccia, Cesare Gallesio, Sid Berrone

Division of Maxillofacial Surgery, Head and Neck Department, San Giovanni Battista Hospital, University of Turin, Turin, Italy

Key words: pathological fractures dento-alveolar trauma; bone; treatment

Correspondence to: Dr Paolo Boffano, Maxillofacial Surgery Unit, Head and Neck Department, San Giovanni Battista Hospital, University of Turin, Corso Dogliotti 14, 10126 Torino, Italy
Tel.: +39 011 6335125
Fax: +39 011 6335125
E-mail: paolo.boffano@gmail.com

Accepted 30 November, 2012

Abstract – Pathological mandibular fractures are rare, accounting for fewer than 2% of all fractures of the mandible. They could be defined as fractures that occur in regions where bone has been weakened by an underlying pathological process. Pathological fractures usually may follow surgical interventions such as third molar removal or implant placement, result from regions of osteomyelitis, osteoradionecrosis, and bisphosphonate-related osteonecrosis of the jaw, occur because of idiopathic reasons or be facilitated by cystic lesions, benign, malignant, or metastatic tumors. Pathological mandibular fractures may be challenging to treat because of their different etiology and peculiar local and general conditions, often requiring a more rigid fixation. In patients with poor medical conditions, simpler and more limited options may be preferred.

Pathological mandibular fractures are rare, accounting for fewer than 2% of all fractures of the mandible (1–3).

They could be defined as fractures that occur in regions where bone has been weakened by an underlying pathological process (1–4).

Pathological fractures usually may be determined by surgical interventions (third molar removal and implant placement), result from regions of osteomyelitis, osteoradionecrosis (ORN), and bisphosphonate-related osteonecrosis of the jaw (BRONJ), occur because of idiopathic reasons or be facilitated by cystic lesions, benign, malignant, or metastatic tumors (1–109).

Treatment of pathological fractures that are associated with such conditions can be challenging, and it should differ according to etiology (4–7).

Materials and methods

A systematic review of articles published between January 1990 and August 2011 using Medline and the MeSH Term 'Mandibular fractures' in combination with the following terms 'pathological,' 'iatrogenic,' 'tooth removal,' 'cysts,' 'osteomyelitis,' 'osteoradionecrosis,' 'Bisphosphonate-Associated Osteonecrosis of the Jaw,' 'Tumor,' and 'Gorham disease'.

Articles presenting cases and populations of patients affected by pathological fractures were identified and included. Only articles in English language were included.

Articles regarding mandibular fractures in patients with extreme mandibular atrophy and/or long-standing edentulism were excluded.

Data were collected on age, sex, associated pathological condition, time of fracture in relation to eventual interventions, and treatment.

Mandibular fractures following tooth removal

Pathological mandibular fracture associated with the removal of teeth can occur either during the procedure or in the immediately postoperative weeks. It can be considered a rare event with a reported incidence between 0.0034% and 0.0075% (8–25) (Table 1).

In the recent literature review, almost all pathological mandibular fractures following tooth removal were due to third molar removal (1, 8–23). This appears to be related to the particular characteristics of third molar extraction that often require higher forces or more extensive ostectomy than other extractions, weakening the mandible for a period of time (24, 25, 110–113).

Several risk factors can be associated with this type of pathological fracture, such as age, gender, types of impaction, existing infection or bony lesions, surgical technique, and patient's compliance (in particular, chewing of hard foods after extraction) (1, 14, 21, 26, 27).

Age seems to be an important risk factor for pathological mandibular fractures following third molar removal. In the recent literature (Table 1), increased rates of fractures were observed in patients over 40 years of age (1, 14, 21, 27). In particular, many

Table 1. Reports on pathological fractures of the mandible associated with tooth removal

Authors	Year	Number of teeth	Teeth	Mean age	Timing of fracture after tooth removal	Etiological factor of fracture
Iizuka et al. (8)	1997	13	13 × 3M	52.9	1 immediate 9 late 3 unknown	1 luxation 9 biting hard food 3 unknown
Dunstan and Sugar (9)	1997	2	2 × 3M	22	2 late	2 trauma (MVA and Rugby)
Krimmel and Reinert (10)	2000	6	6 × 3M	45	6 late	5 chewing 1 unknown
Perry and Goldberg (11)	2000	28	28 × 3M	39	28 late	18 chewing 2 assault 1 fall 1 sport 1 exercise 1 yawning 4 unknown
Libersa et al. (12)	2002	27	27 × 3M	40	17 immediate, 10 late	17 luxation 6 chewing 4 unknown
Werkmeister et al. (13)	2005	1	1 × 3M	NA	1 late	NA
Wagner et al. (14)	2005	17	17 × 3M	49.4	17 late	NA
Komerik and Karaduman (15)	2006	1	1 × 3M	53	1 late	1 chewing
Wagner et al. (16)	2007	1	1 × 3M	NA	1 late	NA
Kunkel et al. (17)	2007	11	11 × 3M	46	NA	NA
Woldenberg et al. (18)	2007	1	1 × 3M	37	1 immediate	1 luxation
Coletti and Ord (1)	2008	2	2 × 3M	NA	NA	NA
Khan et al. (19)	2009	1	1 × 3M	44	1 late	NA
Valiati et al. (20)	2009	1	1 × 3M	40	1 immediate	1 luxation
Kao et al. (21)	2010	1	1 × 3M	54	1 late	1 chewing
Grau-Manclús et al. (22)	2011	11	11 × 3M	42.8	7 immediate 4 late	7 luxation 4 chewing
Cankaya et al. (23)	2011	2	2 × 3M	34	2 immediate	1 luxation 1 unknown

NA, not available data; 3M, third molar; MVA, motor-vehicle accident.

studies report values of mean age ranging from 22 to 53 (1, 8–23). However, most of the case series showed a mean age $\geq$39 years (Iizuka et al. (8), 52.9 years; Krimmel and Reinert (10), 45 years; Perry and Goldberg (11), 39 years; Libersa et al. (12), 40 years; Wagner et al. (14), 49.4 years; Kunkel et al. (17), 46 years; Grau-Manclus et al. (22), 42.8 years). Reasons for this finding could be a decrease in elasticity of the mandibular bone during advancing age, an increase in narrowing of the periodontal ligament and the increased ankylosis of third molars in older patients that may require extensive osteotomy (1, 14, 21).

The incidence of this event is higher in male patients with a general male-to-female ratio of 2.2:1 (21, 26).

Deeply impacted third molars have a greater incidence of associated pathological mandibular fractures as they usually require massive bone removal that might weaken the mandible and predispose to fracture. Therefore, it is advisable to perform the minimal possible ostectomy with eventual tooth sectioning, to reduce the amount of removed bone and lessen the force required to luxate and extract the molar, although it is sometimes necessary to remove considerable amounts of bone (1, 22, 26, 27). In fact, in the recent literature review, several authors observed that full bony impactions were implicated more commonly in pathological fractures than partial impactions (8, 10, 11, 22).

Although the severity of anteroposterior tooth location does not seem to have a significant correlation with pathological fractures (10), in the recent literature review, a horizontal/mesioangular position of involved third molars was more frequently observed, followed by distoangular angulation (8, 10–12, 14, 22).

As for associated infections (periodontitis and pericoronitis) or pre-existing bony lesions (cysts), some authors referred that they may alter the adjacent bone and weaken the mandible, thus predisposing it to fracture (21, 22, 26, 114).

Seventy-four percentage of fractures in the recent literature review (Table 1) occurred postoperatively, whereas just 26% of pathological mandibular fractures were observed intraoperatively.

In fact, in the first postoperative weeks, the granulation tissue is replaced by connective tissue in the extraction zone; therefore, an increased risk of fracture can be expected and patients' compliance during postoperative course appears to be fundamental to avoid postoperative pathological mandibular fractures. To this end, it is particularly interesting to notice that in the recent literature review 71% of postoperative pathological occurred during chewing (11, 12, 15, 21, 22). A soft diet should be recommended for 4 weeks postoperatively, especially in patients with full dentition (12).

Table 2. Reports on pathological fracture of the mandible associated with dental implants in the English literature

Authors	Year	Number of patients	Age	Gender	No. placed implants	Mandibular dentition	Region	Inferior Alveolar Nerve transposition	Treat
Mason	1990	3	78	F	5	Edentulous	Symphysis	No	ORIF
et al. (29)			65	F	4	Edentulous	Symphysis	No	Conservative (acrylic splint)
			10	F	7	Edentulous (mandible resection)	Symphysis	No	Conservative (ivy loops)
Tolman and	1991	6	75	F	5	Edentulous	Symphysis	No	Conservative
Keller (30)			30	F	3	Partially edentulous	Symphysis	No	ORIF + lingual splint and circum-mandibular wires
			58	F	6	Edentulous	Symphysis	No	Conservative (splint + IMF with dentures)
			56	F	5	Edentulous (mandible resection)	Symphysis	No	Conservative (acrylic resin splint secured to the 4 remaining implants)
			51	F	6	Edentulous	Symphysis + body	No	Conservative
			53	F	5	Edentulous	Symphysis	No	Conservative
Shonberg et al. (31)	1992	1	59	M	5	Edentulous	Symphysis	No	Conservative (maxillary denture + mandibular splint + IMF)
Kan et al. (32)	1997	1	47	M	3	Partially edentulous	Right body	Yes	ORIF
Raghoebar	2000	4	67	F	2	Edentulous	Symphysis	No	ORIF (reconstrunction plate)
et al. (33)			56	F	4	Edentulous	Symphysis	No	Bone grafts
			51	F	4	Edentulous	Symphysis	No	Bone grafts
			68	F	4	Edentulous	Symphysis	No	Bone grafts
Karlis et al. (34)	2003	1	67	M	2	Partially edentulous	Right body	Yes	First Conservative, then ORIF (reconstruction plate)
Meijer et al.(35)	2003	1	57	F	4	Edentulous	Symphysis	No	ORIF + bone graft
O' Sullivan et al.(28)	2006	1	72	M	1	Edentulous	Symphysis	No	Conservative
Luna et al. (37)	2008	1	51	F	3	Partially edentulous	Right body	Yes	ORIF (reconstruction plate)
Coletti and Ord (1)	2008	4	53	F	NA	NA	NA	NA	NA
			55	F					
			51	F					
			55	F					
Romanos (38)	2009	1	65	F	4	Edentulous	Symphysis	No	Immobilization of the fragmented bones via a bar restoration
Oh et al. (39)	2009	1	63	M	2	Edentulous	Symphysis	No	ORIF
Chrcanovic and	2009	4	75	F	3	Edentulous	Symphysis	No	ORIF (reconstruction plate)
Custodio (7)			43	F	3	Partially edentulous	Left body	Yes	ORIF
			64	F	4	Edentulous	Symphysis	No	ORIF
			62	M	5	Edentulous	Symphysis	No	ORIF

ORIF, open reduction and internal fixation; IMF, intermaxillary fixation; NA, not available data.

Clinical expertise of the operating clinician does not seem to be a significant factor in the epidemiology of pathological mandibular fractures (26).

As for diagnosis, a panoramic radiograph is usually suited to correctly identify pathological mandibular fractures. Therefore, it can still be considered the first radiographic examination to assess patients with such suspected injuries, with CT scans reserved for uncertain cases (22). However, the symptom of a cracking noise is frequently referred by patients with pathological fractures, as reported in the recent literature review (10, 14, 22).

Finally, both closed and open reduction have been frequently performed to treat pathological fractures: about 46% of pathological fractures were treated by open reduction and internal fixation, 40% of fractures underwent close reduction (maxilla–mandibular fixation for 1 or more weeks), and 14% of patients were conservatively treated with a recommendation of soft diet (1, 8–23).

Of course, different types of treatment may be considered case by case according to general conditions and age of the patient, dentition status, dislocation of the fracture, and patient's compliance.

Mandibular fractures following implant placement

Pathological mandibular fractures following the placement of endosseous implants have been rarely reported in the literature (1). They can occur during the surgical intervention of implant placement or, more frequently, because of implant failure and subsequent osteomyelitis

Table 3. Reports on pathological fracture of the mandible associated with dentigerous cysts in the English literature

Authors	Year	Number of patients	Age	Gender	Type	Timing of fracture	Site	Treatment
Ezsias and Sugar (43)	1994	3	41	M	Residual cyst	Before cyst removal	Symphysis	Marsupialization + external fixator
			27	M	Odontogenic keratocyst	Before cyst removal	Angle	Enucleation + ORIF (RP)
			76	M	Residual cyst	Before cyst removal	Body	Enucleation + ORIF (RP)
Gerhards et al. (3)	1998	3	72	M	Follicular cyst	NA	Angle	ORIF
			38	M	Radicular cyst	NA	Angle	ORIF
			24	M	Radicular cyst	NA	Symphysis	ORIF
Motamedi (44)	1998	1	NA	NA	Aneurismal bone cyst	Before cyst removal	Body	NA
Goddard and Patel (45)	2007	1	NA	NA	Aneurismal bone cyst	Before cyst removal	Body	Enucleation + intermaxillary fixation
Coletti and Ord (1)	2008	1	56	F	Odontogenic cyst	Before cyst removal	NA	Enucleation + ORIF
Choi et al. (2)	2011	1	16	M	Aneurismal bone cyst	Before cyst removal	Condyle	Enucleation + ORIF

NA, not available data; ORIF, open reduction and internal fixation; RP, reconstruction plate.

in atrophic mandibles (28). In the recent literature review, 29 cases of mandibular fractures associated with dental implants have been described (1, 7, 28–39) (Table 2).

The incidence of this event is higher in female patients with a general male-to-female ratio of 1:3 (1, 7, 28–39). Mean age of patients with pathological mandibular fractures following implant placement is 57.9 years, ranging between 51 and 78 years.

This rare event is most likely to occur in severely resorbed mandibles with an anterior mandibular bone lower than 12 mm, when the ratio between implant length and the distance to the occlusal plane is compromised, resulting in unfavorable biomechanics (7).

Mandibular symphysis seems to be the most frequent site of implant-related mandibular fracture. In fact, numerous pathological fractures followed the placement of dental implants in the symphysis region because of the absence of bone in the mandibular body regions to perform an overdenture prosthetic rehabilitation (7, 28, 29, 31, 33, 38, 39).

In several cases of mandibular fractures in the body regions, an inferior alveolar nerve transposition had been performed to allow the implant placement in severely resorbed mandibles (7, 32, 34, 37). This intervention may weaken the atrophic mandible, making it more susceptible to masticatory forces and fractures.

Marginal bone loss around a dental implant may be an area of stress concentration and weakness, thus representing a predisposing factor for a fracture in the atrophic mandible too (7, 40). Therefore, assessing both the height and the width of available bone is fundamental before performing implant therapy. In fact, a minimum height of 4–5 mm and width of 7 mm are required to consider implant placement (1). Eventually, a bone graft could be considered to increase available bone for the implant placement. However, the high position of the inferior alveolar nerve in posterior regions of an atrophic mandible could make even the bone graft extremely difficult. Instead, in symphyseal regions, a bone graft could be more easily considered. Nevertheless, in some cases, it is also necessary to consider the possibility of an extremely atrophic mandible to sustain important masticatory forces when they are just applied to the symphysis.

Periodic clinical and radiological follow-ups are necessary, as well as recommending the patient to avoid occlusal overloading during the osseointegration period, because routine oral functioning could cause a fracture without any trauma to the mandible (41).

As for the fate of the implant in the fracture line, the presence or absence of infection, implant mobility, and the importance of the fixture in the overall treatment plan should determine whether an implant in the line of fracture should be removed (31). In the literature, implants were left in place when they were osseointegrated, not mobile, not infected and did not present nearby areas of osteomyelitis (29, 31).

Finally, it should be remembered that both the use of wide-diameter implants and bicortical penetration may jeopardize the integrity of severely atrophic mandibles, as inadequate remaining bone volume after placement of implants may increase stress concentration from functional loading (39).

The timing of implant-related mandibular fractures is extremely variable, with most fractures occurring either 3–6 weeks or 3 months after implant placement, although some cases have been reported immediately after surgery (before and after loading) (7).

Reasons for early implant failures are mainly insufficient bone volume and lack of osseointegration, whereas peri-implantitis and trauma are associated with fractures occurring 1 year or more after implant placement (42).

Several methods have been reported to treat the fractured mandibles. With this kind of pathological fracture, treatment is individualized and chosen on a case-by-case basis. Open reduction and internal fixation via an extraoral approach is the most frequently adopted treatment option (7, 29, 32, 33, 37, 39), followed by conservative management with a soft diet (28, 29, 31, 34), and bone grafts with fixation (33).

Table 4. Reports on pathological fracture of the mandible associated with malignant and benign tumors in the English literature

Authors	Year	N pts	Age	Sex	Location	Histologic type	Fracture treatment
Karr et al. (46)	1991	2	41	F	Body	MTS – synovial sarcoma	Chemotherapy
			63	F	Condyle	MTS – synovial sarcoma	Radiotherapy
Bhaskar et al. (47)	1993	1	44	M	Condyle	Eosinophilic granuloma	Curettage and condylectomy
Stavropoulos and Ord (48)	1993	1	55	F	Condyle	MTS – lobular breast adenocarcinoma	Condylectomy and TMJ arthrotomy
Johal et al. (49)	1994	1	65	F	Condyle	MTS – clear cell carcinoma	Condylectomy
Furutani et al. (50)	1994	1	83	F	Body	Multiple myeloma	Management postponed
Ezsias and Sugar (43)	1994	1	40	M	Body	Intraosseous squamous cell carcinoma	Resection + radial forearm free flap
Takinami et al. (51)	1995	1	58	M	Ramus	MTS – hepatocellular carcinoma	Radiotherapy
Plath and Marks (52)	1996	1	64	M	Angle	MTS – oesophageal squamous cell carcinoma	Radiotherapy
Wright et al. (53)	1997	1	72	F	Angle, bilaterally	Chronic lymphocytic leukemia	Radiotherapy
Ong and Siar (54)	1998	1	15	M	Body	Cemento-ossifying fibroma	Resection + wire
Gerhards et al. (3)	1998	8	15	M	Condyle	Giant cell tumor	Resection with reconstruction
			19	M	Angle	Fibrous dysplasia	ORIF
			66	F	Body	Odontoma	ORIF
			77	F	Body	Multiple myeloma	Radiotherapy
			82	F	Body	Squamous cell carcinoma	Radiotherapy
			75	F	Body	MTS – breast cancer	Resection + RP
			76	M	Condyle	MTS – bronchial carcinoma	Condylectomy
			80	F	Condyle	MTS – colon carcinoma	Condylectomy
Rosenberg et al. (55)	1999	1	74	F	Body	Ossifying fibroma	Resection + iliac crest bone graft
Gibson et al. (56)	2002	1	73	M	Angle	MTS – melanoma	Octreotide
Zachariades et al. (57)	2004	1	50	M	Angle	MTS – small cell carcinoma	Chemotherapy
Kobayashi et al. (58)	2005	1	28	M	Angle	Ameloblastic fibrosarcoma	Resection + scapular flap
Khodayari and Khojasteh (59)	2005	1	56	F	Body	MTS – angiosarcoma	Chemotherapy
Jia et al. (60)	2006	1	46	F	Condyle	MTS – breast adenocarcinoma	Radiotherapy
Coletti and Ord (1)	2008	7	5	M	NA	Epithelioid hemangioendothelioma	Resection + rib graft
			47	F		MTS – lung cancer	Resection + RP
			48	M		MTS – lung cancer	No treatment
			49	M		Squamous cell carcinoma	Unresectable
			85	F		Squamous cell carcinoma	Resection + RP + pectoralis major flap
			70	F		Squamous cell carcinoma	Resection + RP + sternocleidomastoid
			76	F		Squamous cell carcinoma	Resection + RP
Li et al. (61)	2008	1	55	M	Body	MTS – hepatocellular carcinoma	Resection
Hansen et al. (62)	2009	1	64	F	Angle	Hemangioma	Resection + iliac crest bone graft
Garas et al. (63)	2009	1	78	F	Angle	MTS – breast ductal carcinoma	Resection + RP
AlGahtani et al. (4)	2009	1	66	F	Angle	MTS – follicular thyroid carcinoma	Resection + RP
Pandey et al. (64)	2009	5	NA	NA	NA	Squamous cell carcinoma	NA
Esen et al. (65)	2010	1	25	M	Symphysis	Langerhans' cell histiocytosis	Intralesional steroid injection
Moore et al. (66)	2010	1	75	M	Body	MTS – hepatocellular carcinoma	Chemotherapy
Boffano et al. (67)	2011	1	71	M	Angle	Multiple myeloma	Resection + RP

N pts, number of patients; MTS, metastasis; RP, reconstruction plate; NA, not available data.

Immobilization of the fragmented bones via a bar restoration that was screwed onto the abutments of the remaining implants splinting them together was reported too (38).

Mandibular fractures associated with benign cystic pathology

Pathological fractures associated with benign cystic lesions are very rarely reported with 10 cases in the recent literature review (1–3, 43–45) (Table 3). Mean age was 43.75 years, ranging between 16 and 76 years. Almost all patients were men. Different benign cystic lesions were involved in pathological mandibular fractures, such as aneurismal bone cysts, follicular cysts, residual cysts, radicular cysts, and odontogenic keratocysts (1–3, 43–45).

This peculiar kind of pathological fractures usually occurred before cyst removal (1, 2, 43–45).

Mandibular angle and body were the most frequently observed locations of fractures associated with benign cysts (3, 43–45). The remaining reported pathological fractures occurred in correspondence of the mandibular symphysis and condyle (2, 3, 43).

If there is sufficient bone left to buttress the fracture, traditional open reduction and internal fixation was performed, in association with cyst enucleation or marsupialization that happened in almost all reported cases (1–3, 43–45). When remaining healthy bone is not sufficient or it is separated by a great defect, it could be necessary to resect the involved mandibular region, eventually followed by immediate or secondary reconstruction (1).

Table 5. Reports on pathological fracture of the mandible associated with osteomyelitis in the English literature

Authors	Year	Number of patients	Age	Sex	Location	Medical history	Treatment
Schmitz et al. (68)	1996	1	46	M	Body	Pyknodysostosis	Resection; reconstruction plate; IV antibiotic
Gerhards et al. (3)	1998	6	45	M	Angle		Closed reduction in 5 cases
			54	M	Angle		ORIF in a case
			52	F	Angle		
			55	M	Angle		
			59	M	Body		
			59	F	Angle		
Alibhai et al. (69)	1999	1	30	M	Body	Pyknodysostosis	Arch bars; IV antibiotic
De Jong et al. (70)	2004	1	1	F	Ramus		IV antibiotic
Kato et al. (71)	2005	1	48	M	Angle	Pyknodysostosis	Resection; vascularized iliac bone free flap; hyperbaric oxygen therapy
Scolozzi et al. (72)	2005	2	59	F	Angle	Hysteria and depression	IV antibiotic; 2.4 mm mandibular plate
			61	M	Angle		IV antibiotic; mandibular reconstruction plate
Ogasawara et al. (5)	2007	1	43	M	Angle		IV antibiotic; conservative treatment
Coletti and Ord (1)	2008	4	66	M	NA		Resection; locking reconstruction
			75	F			plate in all cases
			74	F			
			55	F			
Jain et al. (73)	2010	1	65	M	Angle	Tuberculosis; Herpes Zoster	IV antibiotic; 2.5 mandibular plate
Frota et al. (74)	2010	1	45	F	Body	Pyknodysostosis	IV antibiotic; sequestrectomy; 2.4 mm mandibular plate
Rajkumar et al. (75)	2010	1	18	M	Condyle		IV antibiotic; condylectomy

NA, not available data; IV, intravenous.

Mandibular fractures associated with a malignant pathology/benign tumors

The treatment of pathological mandibular fractures associated with malignant or benign neoplasms has to be directed toward the disease process that must be considered the first priority (1). Pathological fractures are more frequently associated with metastatic tumors or primary oral squamous cell carcinoma (1, 4, 46–67) (Table 4).

Mean age of patients included in this category is 57.20 years, ranging between 5 and 85 years (Table 4) Pathological fractures associated with malignant/benign neoplasms are almost equally distributed between men and women with a general male-to-female ratio of 1:1.17.

The most frequently involved site is mandibular angle (4, 52, 53, 56, 57, 62, 63, 67), followed by body (3, 43, 46, 50, 54, 55, 59, 61, 66) and condyle (3, 46–49, 60).

Treatment of pathological fractures caused by primary or secondary malignancies is often limited by the patients' general health, as a pathological fracture may represent an advanced stage of neoplastic disease. Therefore, the aim of the treatment is the maintenance of oral function and pain control to maintain quality of life (3).

Primary radical surgery (with segmental resection of the mandible and selective or radical neck dissection) is the gold standard treatment if the tumor is resectable. Primary reconstruction with a fibular flap can preferred for mandibular reconstruction, with postoperative radiation or chemo/radiation therapy depending on the final pathology (1). However, as shown by the recent literature review (Table 4), it is often difficult to perform a gold standard treatment. In fact, resection with reconstruction plate or resection with bone grafts were frequently performed because of poor medical conditions of the patients.

As for secondary metastatis, treatment depends on the tumor type and patient's general condition: frequently radiation therapy or chemotherapy is administered as palliation (1).

Unfortunately, the outcome of these patients is frequently fatal, with a frequently observed lethal exitus in most patients.

Mandibular fractures associated with osteomyelitis

Osteomyelitis of the mandible may develop if a primary infection is not eliminated by proper treatment or if concurrent immunodeficiencies are present (5, 7). This condition may determine weakening of the mandibular bone and subsequent pathological fractures. Several predisposing diseases may be associated with osteomyelitis, such as diabetes, osteogenesis imperfecta, and pyknodysostosis (1, 3, 5, 68–75) (Table 5).

Mean age of patients included in this category is 50.5 years, ranging between 1 and 75 years (Table 5) The incidence of fractures associated with osteomyelitis is higher in male patients with a general male-to-female ratio of 1.5:1. The most frequently involved site is mandibular angle (3, 5, 71–73), followed by mandibular body (3, 68, 69, 74).

The first step of treatment is antibiotic therapy that, if possible, has to be directed against the causative organism by culture and sensitivity; a minimum of 6 weeks of intravenous therapy is recommended (1). Then, treatment of the fracture should depend on how much viable bone is present following sequestrectomy or resection, on a case-by case-basis (1). The continuity defect created can be maintained with 2.4-mm mandibular plates or thinner plates and then eventually reconstructed primarily or secondarily, depending on the patient condition and disease.

Table 6. Reports on pathological fracture of the mandible associated with osteoradionecrosis in the English literature

Authors	Year	Number of patients	Age	Gender	Fracture site	Reason for RT	RT dose	Treatment
Van Merkesteyn et al. (76)	1994	1	38	F	Subcondylar	Parotid gland adenocarcinoma	67 Gy	40 total HBO sessions + soft diet + occlusal splint + physical therapy
Ioannides et al. (77)	1994	12	NA	NA	NA	NA	NA	Resection + free iliac crest composite flap
Hermans et al. (78)	1996	3	53	M	NA	Carcinoma of the floor of the mouth	70 Gy	NA
			75	M	NA	Tonsil carcinoma	70 Gy	NA
			57	M	NA	Tongue carcinoma	72 Gy	NA
Shaha et al. (93)	1997	2	NA	NA	NA	NA	NA	Resection + fibula free flap reconstruction
Gerhards et al. (3)	1998	9	63	M	Body	NA	NA	Hemimandibulectomy, antibiotics
			63	M	Body	NA	NA	Hemimandibulectomy, antibiotics
			46	M	Body	NA	NA	Hemimandibulectomy, antibiotics
			53	M	Body	NA	NA	Sequestrotomy, antibiotics
			57	M	Body	NA	NA	Hemimandibulectomy + immediate reconstruction, antibiotics
			52	M	Body	NA	NA	Hemimandibulectomy, antibiotics
			40	M	Body	NA	NA	Liquid diet, antibiotics
			54	M	Body	NA	NA	Liquid diet, antibiotics
			50	M	Angle	NA	NA	Hemimandibulectomy + secondary econstruction, antibiotics
Jisander et al. (79)	1999	2	46	NA	Body	NA	65 Gy	NA
			56	NA	Body	NA	65 Gy	NA
Chang et al. (80)	2001	13	NA	NA	NA	NA	NA	Radical resection + immediate reconstruction in all cases
Ang et al. (81)	2003	4	NA	NA	NA	NA	NA	Radical resection + immediate free-flap reconstruction in all cases
Maurer and Meyer (82)	2006	1	61	F	Angle	Parotid gland adenocarcinoma	70 Gy	Limited continuity resection + reconstruction plate
Coletti and Ord (1)	2008	19	46	F	NA	NA	NA	Resection + RP + bone graft
			63	M	NA	NA	NA	ORIF
			71	M	NA	NA	NA	Resection + external fixator
			53	M	NA	NA	NA	Resection + RP
			60	M	NA	NA	NA	Resection + RP
			53	M	NA	NA	NA	Resection + RP
			60	M	NA	NA	NA	Resection + RP
			46	F	NA	NA	NA	ORIF
			70	M	NA	NA	NA	Resection + RP
			49	M	NA	NA	NA	Resection + RP
			56	M	NA	NA	NA	Resection + RP + fibula flap
			50	M	NA	NA	NA	Resection + RP + fibula flap
			57	M	NA	NA	NA	Resection + RP + sternocleidomastoid flap
			49	M	NA	NA	NA	Resection + RP + pectoralis major flap
			78	M	NA	NA	NA	Resection + RP + pectoralis major flap
			47	M	NA	NA	NA	Resection + external fixator
			59	M	NA	NA	NA	Resection + RP + temporal parietal flap
			63	M	NA	NA	NA	Resection + RP
			43	M	NA	NA	NA	Resection + RP
Alam et al. (83)	2009	9	NA	NA	NA	NA	NA	Radical resection + immediate free-flap reconstruction in all cases
Oh et al. (84)	2009	12	NA	NA	NA	NA	NA	Radical resection + reconstruction

HBO, hyperbaric oxygen therapy; NA, not available data; RP, reconstruction plate; ORIF, open reduction and internal fixation.

However, according to Ogasawara et al. (5) and Chrcanovic et al. (7), closed reduction with intermaxillary fixation should be considered as the ideal treatment in pathological fractures associated with osteomyelitis to avoid further ischemic necrosis by plate placement.

Mandibular fractures associated with ORN and BRONJ

Pathological mandibular fractures associated with ORN are not uncommonly reported in the literature (1, 76–93) (Table 6). Patients with ORN are often elderly and they may frequently present comorbidities or swallowing and nutritional problems because of previous surgery and/or radiotherapy (1). First of all, surgeons should deal with the patient's systemic problems, ruling out recurrent cancer and nutritional issues before managing the fracture.

In such patients, the aim of the treatment is to restore the function of the mandible, allowing food processing, swallowing and speech production, and if possible to restore the appearance of the lower face (81).

Table 7. Reports on pathological fracture of the mandible associated with bisphosphonate-related osteonecrosis of the jaw in the English literature

Authors	Year	N pts	Age	Sex	Location	Medical history	Treatment
Coletti and Ord (1)	2008	4	72	F	NA	NA	Resection + reconstruction plate in all cases
			54	M			
			75	F			
			76	M			
Aarabi et al. (100)	2008	1	63	F	Angle	Breast cancer; Pamidronate	ORIF with reconstruction plate first; resection with hardware removal after 2 years
Arribas-Garcia et al. (101)	2009	1	50	F	Body	Breast cancer; zoledronate	Resection + reconstruction plate; antibiotic therapy; secondary reconstruction with iliac crest bone graft
Wongchuensoontorn et al. (6)	2009	3	48	M	Symphysis	Prostate cancer; zoledronate	Resection + reconstruction plate; antibiotic therapy
			61	M	Symphysis	Multiple myeloma; zoledronate	Resection + reconstruction plate; antibiotic therapy
			83	F	Body	Osteoporosis; alendronate	ORIF with reconstruction plate; antibiotic therapy
Seth et al. (96)	2010	8	56	F	NA	Breast cancer; zoledronate	Resection + fibula free flap and reconstruction plate in all cases
			50	F		Breast cancer; zoledronate	
			72	F		Osteoporosis; alendronate	
			48	F		Prostate cancer; zoledronate	
			71	F		Multiple myeloma; ibandronate	
			60	F		Osteoporosis; alendronate	
			51	F		Multiple myeloma; zoledronate	
			60	F		Breast cancer; zoledronate	

NA, information not available; N pts, number of patients; ORIF, open reduction and internal fixation.

Table 8. Reports on pathological fracture of the mandible associated with Gorham's syndrome in the English literature

Authors	Year	Number of patients	Treatment
Fisher and Pogrel (102)	1990	1	Surgery (reconstruction with crest bone graft)
Hirayama et al. (103)	2001	1	Surgery and bisphosphonate
Ricalde et al. (104)	2003	1	Radiation therapy
Tsang et al. (105)	2004	1	Curettage; bisphosphonate
Raghuveer and Jayalekshmy (106)	2009	1	Transosseous wiring
Pedroletti et al. (107)	2010	1	Erich arch bar
Tong et al. (108)	2010	1	Intravenous bisphosphonate; Secondary reconstruction with fibula free flap

Patients with ORN-related pathological mandibular fractures are classified as advanced ORN: in these cases, conservative treatment including hyperbaric oxygen therapy (HBO) is inadequate (85–90). As Gal et al. (91) and Buchbinder et al. (89) stated, HBO therapy does not revive dead bone or resuscitate impaired bone and, in advanced disease, will only delay more definitive therapy.

Currently, radical resection of the involved necrotic mandibular segment up to normal bone followed by vascularized bone free flap reconstruction has been recommended as the treatment of choice in patients with ORN-related pathological mandibular fractures (80, 81, 83, 84, 89, 92–95).

However, advanced stage ORN reconstructions are uniquely challenging surgical procedures (83). Placement of a nonviable graft in an irradiated bed is contraindicated as it is associated with significant complications (81). Instead, free tissue transfer imports nonirradiated well-vascularized tissue into an irradiated and diseased area (81).

For patients who are in poor health have a poor tumor prognosis or have a posterior mandibular defect, reconstruction with bone may not be indicated (80). In such cases and for salvage procedures after major free flap complications, regional soft tissue flaps, such as the pectoralis major myocutaneous flap can be used. However, in some patients, particularly if the resulting surgical defect is limited to the posterior body or ramus and if mortality from the underlying disease process is relatively rapid, even the sole use of bridging plates remains an important alternative.

Furthermore, continued long-term surveillance is needed despite successful surgery as new sites of ORN may arise (83).

The optimum management of fracture in BRONJ is currently not standardized. While patients with a diagnosis of early-stage BRONJ are typically treated in a more conservative manner, in cases with associated pathological mandibular fracture (and therefore with advanced stage BRONJ), the current management strategy includes segmental mandibular resection followed by rigid plate fixation without osseous reconstruction (1, 6, 96, 97).

According to Wongchuensoontorn et al. (6) a primary or secondary reconstructive option with a microvascular free flap can be considered when the postoperative follow-up is uneventful for at least 6 months. Several authors have argued against bony reconstruction of segmental defects among patients with BRONJ owing to the perceived high risk of

complications, recurrence of BRONJ at resection margins, and nonunion (98, 99). Nevertheless, recently Seth and Futran obtained good outcomes in the treatment of end stage BRONJ with immediate reconstruction using the fibula free flap (96).

In the current literature review, mean age of patients with BRONJ-associated pathological fractures is 61.76 years, with an age range of 48–83 years (1, 6, 96, 100, 101) (Table 7). Incidence of such fractures is much more common in females with a male-to-female ratio of 1:3.25. In most cases, BRONJ-associated pathological fractures occur in patients affected by breast cancer or osteoporosis. The most frequently responsible bisphosphonate drug was zoledronate (eight cases), followed by alendronate (three cases).

Periodic and long-term follow-up is necessary in these patients too.

Mandibular fractures associated with Gorham's disease (vanishing bone disease)

A particular extremely rare type of pathological mandibular fracture is associated with Gorham's disease. Gorham's disease is an uncommon syndrome of unknown etiology (102–108) (Table 8). Massive osteolysis is usually asymptomatic until a pathologic fracture occurs from minor trauma. The process rapidly progresses in most cases until the bone is replaced by fibrous tissue (109). There is no specific treatment for the disease. Radiation therapy, surgical treatment, and the use of bisphosphonate have been reported.

Conclusion

Pathological mandibular fractures are complex and challenging to treat because of their different etiology and peculiar local and general conditions. Surgeons often have to deal with systemically immunocompromised individual with grossly infected bone. Treatment of the underlying pathology always takes precedent, with fracture management dependent on the resulting bony defect.

In patients who are in poor health or have a poor tumor prognosis, simpler and more limited options may be preferred, keeping in mind that the aim of the treatment is to provide the best possible quality of life in such patients.

Conflict of interest

All authors disclose any financial and personal relationships with other people or organizations that could inappropriately influence their work.

References

1. Coletti D, Ord RA. Treatment rationale for pathological fractures of the mandible: a series of 44 fractures. Int J Oral Maxillofac Surg 2008;37:215–22.
2. Choi BJ, Choi SC, Kwon YD. Aneurysmal bone cyst causing a pathologic fracture of the mandibular condyle. J Oral Maxillofac Surg 2011;69:2995–3000.
3. Gerhards F, Kuffner HD, Wagner W. Pathological fractures of the mandible. A review of the etiology and treatment. Int J Oral Maxillofac Surg 1998;27:186–90.
4. Algahtani M, Alqudah M, Alshehri S, Binahmed A, Sándor GK. Pathologic fracture of the mandible caused by metastatic follicular thyroid carcinoma. J Can Dent Assoc 2009;75:457–60.
5. Ogasawara T, Sano K, Hatsusegawa C, Miyauchi K, Nakamura M, Matsuura H. Pathological fracture of the mandible resulting from osteomyelitis successfully treated with only intermaxillary elastic guiding. Int J Oral Maxillofac Surg 2008;37:581–3.
6. Wongchuensoontorn C, Liebehenschel N, Wagner K, Fakler O, Gutwald R, Schmelzeisen R et al. Pathological fractures in patients caused by bisphosphonate-related osteonecrosis of the jaws: report of 3 cases. J Oral Maxillofac Surg 2009;67:1311–6.
7. Chrcanovic BR, Custódio AL. Mandibular fractures associated with endosteal implants. Oral Maxillofac Surg 2009;13:231–8.
8. Iizuka T, Tanner S, Berthold H. Mandibular fractures following third molar extraction. A retrospective clinical and radiological study. Int J Oral Maxillofac Surg 1997;26:338–43.
9. Dunstan SP, Sugar AW. Fractures after removal of wisdom teeth. Br J Oral Maxillofac Surg 1997;35:396–7.
10. Krimmel M, Reinert S. Mandibular fracture after third molar removal. J Oral Maxillofac Surg 2000;58:1110–2.
11. Perry PA, Goldberg MH. Late mandibular fracture after third molar surgery: a survey of Connecticut oral and maxillofacial surgeons. J Oral Maxillofac Surg 2000;58:858–61.
12. Libersa P, Roze D, Cachart T, Libersa JC. Immediate and late mandibular fractures after third molar removal. J Oral Maxillofac Surg 2002;60:163–6.
13. Werkmeister R, Fillies T, Joos U, Smolka K. Relationship between lower wisdom tooth position and cyst development, deep abscess formation and mandibular angle fracture. J Craniomaxillofac Surg 2005;33:164–8.
14. Wagner KW, Otten JE, Schoen R, Schmelzeisen R. Pathological mandibular fractures following third molar removal. Int J Oral Maxillofac Surg 2005;34:722–6.
15. Komerik N, Karaduman AI. Mandibular fracture 2 weeks after third molar extraction. Dent Traumatol 2006;22:53–5.
16. Wagner KW, Schoen R, Wongchuensoontorn C, Schmelzeisen R. Complicated late mandibular fracture following third molar removal. Quintessence Int 2007;38:63–5.
17. Kunkel M, Kleis W, Morbach T, Wagner W. Severe third molar complications including death—lessons from 100 cases requiring hospitalization. J Oral Maxillofac Surg 2007;65:1700–6.
18. Woldenberg Y, Gatot I, Bodner L. Iatrogenic mandibular fracture associated with third molar removal. Can it be prevented? Med Oral Patol Oral Cir Bucal 2007;12:E70–2.
19. Khan AA, Banerjee A, Mbamalu D. Mandibular fracture caused by mastication. Emerg Med J 2009;26:153.
20. Valiati R, Ibrahim D, Poli VD, Heitz C, Pagnoncelli RM, Silva DN. Mandibular fracture during mandibular third molar extraction. Internet J Dent Sci 2009. Available from: http://www.ispub.com/journal/the internet of dental science/volume 6 number 2 25/article/mandibular fracture during mandibular third molar extraction.html.
21. Kao YH, Huang IY, Chen CM, Wu CW, Hsu KJ, Chen CM. Late mandibular fracture after lower third molar extraction in a patient with Stafne bone cavity: a case report. J Oral Maxillofac Surg 2010;68:1698–700.
22. Grau-Manclús V, Gargallo-Albiol J, Almendros-Marqués N, Gay-Escoda C. Mandibular fractures related to the surgical extraction of impacted lower third molars: a report of 11 cases. J Oral Maxillofac Surg 2011;69:1286–90.

23. Cankaya AB, Erdem MA, Cakarer S, Cifter M, Oral CK. Iatrogenic mandibular fracture associated with third molar removal. Int J Med Sci 2011;8:547–53.
24. Boffano P, Ferretti F, Giunta G, Gallesio C. Surgical removal of a third molar at risk for mandibular pathologic fracture: case report and clinical considerations. Oral Surg Oral Med Oral Pathol Oral Radiol 2012;114:e1–4.
25. Boffano P, Gallesio C, Bianchi F, Roccia F. Surgical extraction of deeply horizontally impacted mandibular second and third molars. J Craniofac Surg 2010;21:403–6.
26. Bodner L, Brennan PA, McLeod NM. Characteristics of iatrogenic mandibular fractures associated with tooth removal: review and analysis of 189 cases. Br J Oral Maxillofac Surg 2011;49:567–72.
27. Al-Belasy FA, Tozoglu S, Ertas U. Mastication and late mandibular fracture after surgery of impacted third molars associated with no gross pathology. J Oral Maxillofac Surg 2009;67:856–61.
28. O'Sullivan D, King P, Jagger D. Osteomyelitis and pathological mandibular fracture related to a late implant failure: a clinical report. J Prosthet Dent 2006;95:106–10.
29. Mason ME, Triplett RG, Van Sickels JE, Parel SM. Mandibular fractures through endosseous cylinder implants: report of cases and review. J Oral Maxillofac Surg 1990;48:311–7.
30. Tolman DE, Keller EE. Management of mandibular fractures in patients with endosseous implants. Int J Oral Maxillofac Implants 1991;6:427–36.
31. Shonberg D, Stith HD, Jameson LM, Chai JY. Mandibular fracture through an endosseous implant. Int J Oral Maxillofac Implants 1992;7:401–4.
32. Kan JY, Lozada JL, Boyne PJ, Goodacre CJ, Rungcharassaeng K. Mandibular fracture after endosseous implant placement in conjunction with inferior alveolar nerve transposition: a patient treatment report. Int J Oral Maxillofac Implants 1997;12:655–9.
33. Raghoebar GM, Stellingsma K, Batenburg RH, Vissink A. Etiology and management of mandibular fractures associated with endosteal implants in the atrophic mandible. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000;89:553–9.
34. Karlis V, Bae RD, Glickman RS. Mandibular fracture as a complication of inferior alveolar nerve transposition and placement of endosseous implants: a case report. Implant Dent 2003;12:211–6.
35. Meijer HJ, Raghoebar GM, Visser A. Mandibular fracture caused by peri-implant bone loss: report of a case. J Periodontol 2003;74:1067–70.
36. Laskin DM. Nonsurgical management of bilateral mandibular fractures associated with dental implants: report of a case. Int J Oral Maxillofac Implants 2003;18:739–44.
37. Luna AH, Passeri LA, de Moraes M, Moreira RW. Endosseous implant placement in conjunction with inferior alveolar nerve transposition: a report of an unusual complication and surgical management. Int J Oral Maxillofac Implants 2008;23:133–6.
38. Romanos GE. Nonsurgical prosthetic management of mandibular fracture associated with dental implant therapy: a case report. Int J Oral Maxillofac Implants 2009;24:143–6.
39. Oh WS, Roumanas ED, Beumer J III. Mandibular fracture in conjunction with bicortical penetration, using wide-diameter endosseous dental implants. J Prosthodont 2010;19:625–9.
40. Goodacre CJ, Kan JY, Rungcharassaeng K. Clinical complications of osseointegrated implants. J Prosthet Dent 1999;81:537–52.
41. Lamas Pelayo J, Peñarrocha Diago M, Martí Bowen E, Peñarrocha Diago M. Intraoperative complications during oral implantology. Med Oral Patol Oral Cir Bucal 2008;13:E239–43.
42. Soehardi A, Meijer GJ, Manders R, Stoelnga PJ. An inventory of mandibular fractures associated with implants in atrophic edentulous mandibles: a survey of Dutch oral and maxillofacial surgeons. Int J Oral Maxillofac Implants 2011;26:1087–93.
43. Ezsiás A, Sugar AW. Pathological fractures of the mandible: a diagnostic and treatment dilemma. Br J Oral Maxillofac Surg 1994;32:303–6.
44. Kalantar Motamedi MH. Aneurysmal bone cysts of the jaws: clinicopathological features, radiographic evaluation and treatment analysis of 17 cases. J Craniomaxillofac Surg 1998;26:56–62.
45. Goddard R, Patel N. Aneurysmal bone cyst masquerading as unknown mandibular metastatic deposit causing pathological fracture. Dent Update 2007;34:230–2.
46. Karr RA, Best CG, Salem PA, Toth BB. Synovial sarcoma metastatic to the mandible: report of two cases. J Oral Maxillofac Surg 1991;49:1341–6.
47. Bhaskar PB, White CS, Baughman RA. Eosinophilic granuloma of the mandibular condyle. A case report and management discussion. Oral Surg Oral Med Oral Pathol 1993;76:557–60.
48. Stavropoulos MF, Ord RA. Lobular adenocarcinoma of breast metastatic to the mandibular condyle. Report of a case and review of the literature. Oral Surg Oral Med Oral Pathol 1993;75:575–8.
49. Johal AS, Davies SJ, Franklin CD. Condylar metastasis: a review and case report. Br J Oral Maxillofac Surg 1994;32:180–2.
50. Furutani M, Ohnishi M, Tanaka Y. Mandibular involvement in patients with multiple myeloma. J Oral Maxillofac Surg 1994;52:23–5.
51. Takinami S, Yahata H, Kanoshima A, Yamasaki M, Funaoka K, Nakamura E et al. Hepatocellular carcinoma metastatic to the mandible. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1995;79:649–54.
52. Plath T, Marks C. Pathologic fracture of the mandible caused by intraosseous metastasis of oesophageal squamous cell carcinoma: a case report. Int J Oral Maxillofac Surg 1996;25:282–4.
53. Wright GW, Wiesenfeld D, Seymour JF. Bilateral fracture of the mandible in chronic lymphocytic leukaemia. Case report. Aust Dent J 1997;42:20–4.
54. Ong AH, Siar CH. Cemento-ossifying fibroma with mandibular fracture. Case report in a young patient. Aust Dent J 1998;43:229–33.
55. Rosenberg A, Mokhtari H, Slootweg PJ. The natural course of an ossifying fibroma. A case report. Int J Oral Maxillofac Surg 1999;28:454–6.
56. Gibson S, Strutt R, Chye R. Managing a malignant orocutaneous fistula: stem the tide with octreotide? Intern Med J 2002;32:191–2.
57. Zachariades N, Koumoura F, Sklavounou-Andrikopoulou A, Papadakis D. Small cell carcinoma metastatic to the mandible. Report of a case. Int J Oral Maxillofac Surg 2004;33:307–9.
58. Kobayashi K, Murakami R, Fujii T, Hirano A. Malignant transformation of ameloblastic fibroma to ameloblastic fibrosarcoma: case report and review of the literature. J Craniomaxillofac Surg 2005;33:352–5.
59. Khodayari A, Khojasteh A. Mandibular pathologic fracture as a first sign of disseminated angiosarcoma: a case report and review of literatures. Oral Oncol Extra 2005;41:178–82.
60. Jia J, Zhang WF, Liu B, Zhao YF. Pathological fracture of condyle from metastatic breast adenocarcinoma. Oral Oncol Extra 2006;42:98–100.
61. Li R, Walvekar RR, Nalesnik MA, Gamblin TC. Unresectable hepatocellular carcinoma with a solitary metastasis to the mandible. Am Surg 2008;74:346–9.

62. Hansen T, Kunkel M, Katenkamp D, Eletr S, Wagner W. Hemangioma of the mandible: case report with special emphasis on bone degradation. Oral Maxillofac Surg 2009;13:239–42.
63. Garas G, Stacey-Clear A, Whitaker S, Collyer J. An atypical presentation of breast cancer metastasis. BMJ Case Rep 2009;2009:pii: bcr10.2008.1061.
64. Pandey M, Rao LP, Das SR. Predictors of mandibular involvement in cancers of the oromandibular region. J Oral Maxillofac Surg 2009;67:1069–73.
65. Esen A, Dolanmaz D, Kalayci A, Günhan O, Avunduk MC. Treatment of localized Langerhans' cell histiocytosis of the mandible with intralesional steroid injection: report of a case. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;109:e53–8.
66. Moore FR, Bergman S, Geisinger KR. Metastatic hepatocellular carcinoma mimicking acinic cell carcinoma of the parotid gland: a case report. Acta Cytol 2010;54:889–92.
67. Boffano P, Viterbo S, Barreca A, Berrone S. Pathologic mandibular fracture as the presenting manifestation of multiple myeloma. J Craniofac Surg 2011;22:1312–5.
68. Schmitz JP, Gassmann CJ, Bauer AM, Smith BR. Mandibular reconstruction in a patient with pyknodysostosis. J Oral Maxillofac Surg 1996;54:513–7.
69. Alibhai ZA, Matee MI, Chindia ML, Moshy J. Presentation and management of chronic osteomyelitis in an African patient with pycnodysostosis. Oral Dis 1999;5:87–9.
70. de Jong B, Vander Poorten V, Smet M, Hermans R, Proesmans M, De Boeck K. A 1-year old girl with fever and a unilateral swelling of the jaw. Eur J Pediatr 2004;163:179–80.
71. Kato H, Matsuoka K, Kato N, Ohkubo T. Mandibular osteomyelitis and fracture successfully treated with vascularised iliac bone graft in a patient with pycnodysostosis. Br J Plast Surg 2005;58:263–6.
72. Scolozzi P, Lombardi T, Edney T, Jaques B. Enteric bacteria mandibular osteomyelitis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2005;99:e42–6.
73. Jain MK, Manjunath KS, Jagadish SN. Unusual oral complications of herpes zoster infection: report of a case and review of literature. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;110:e37–41.
74. Frota R, Linard RA, de Oliveirae Silva ED, Antunes AA, Carvalho RW, Santos Tde S. Mandibular osteomyelitis and fracture in a patient with pyknodysostosis. J Craniofac Surg 2010;21:787–9.
75. Rajkumar GC, Hemalatha M, Shashikala R, Kumar DV. Recurrent chronic suppurative osteomyelitis of the mandible. Indian J Dent Res 2010;21:606–8.
76. van Merkesteyn JP, Balm AJ, Bakker DJ, Borgmeyer-Hoelen AM. Hyperbaric oxygen treatment of osteoradionecrosis of the mandible with repeated pathologic fracture. Report of a case. Oral Surg Oral Med Oral Pathol 1994;77:461–4.
77. Ioannides C, Fossion E, Boeckx W, Hermans B, Jacobs D. Surgical management of the osteoradionecrotic mandible with free vascularised composite flaps. J Craniomaxillofac Surg 1994;22:330–4.
78. Hermans R, Fossion E, Ioannides C, Van den Bogaert W, Ghekiere J, Baert AL. CT findings in osteoradionecrosis of the mandible. Skeletal Radiol 1996;25:31–6.
79. Jisander S, Grenthe B, Salemark L. Treatment of mandibular osteoradionecrosis by cancellous bone grafting. J Oral Maxillofac Surg 1999;57:936–42.
80. Chang DW, Oh HK, Robb GL, Miller MJ. Management of advanced mandibular osteoradionecrosis with free flap reconstruction. Head Neck 2001;23:830–5.
81. Ang E, Black C, Irish J, Brown DH, Gullane P, O'Sullivan B et al. Reconstructive options in the treatment of osteoradionecrosis of the craniomaxillofacial skeleton. Br J Plast Surg 2003;56:92–9.
82. Maurer P, Meyer L. Osteoradionecrosis of the mandible–resection aided by measurement of partial pressure of oxygen (pO2): a technical report. J Oral Maxillofac Surg 2006;64:560–2.
83. Alam DS, Nuara M, Christian J. Analysis of outcomes of vascularized flap reconstruction in patients with advanced mandibular osteoradionecrosis. Otolaryngol Head Neck Surg 2009;141:196–201.
84. Oh HK, Chambers MS, Martin JW, Lim HJ, Park HJ. Osteoradionecrosis of the mandible: treatment outcomes and factors influencing the progress of osteoradionecrosis. J Oral Maxillofac Surg 2009;67:1378–86.
85. Hao SP, Chen HC, Wei FC, Chen CY, Yeh AR, Su JL. Systemic management of osteoradionecrosis in the head and neck. Laryngoscope 1999;109:1324–7.
86. Mounsey RA, Brown DH, O'Dwyer TP, Gullane PJ, Koch GH. Role of hyperbaric oxygen therapy in the management of mandibular osteoradionecrosis. Laryngoscope 1993;103:605–8.
87. Epstein J, van der Meij E, McKenzie M, Wong F, Lepawsky M, Steven-Moore P. Postradiation osteonecrosis of the mandible: a long-term follow-up study. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1997;83:657–62.
88. Koka VN, Deo R, Lusinchi A, Roland J, Schwaab G. Osteoradionecrosis of the mandible: study of 104 cases treated by hemimandibulectomy. J Laryngol Otol 1990;104:305–7.
89. Buchbinder D, St Hilaire H. The use of free tissue transfer in advanced osteoradionecrosis of the mandible. J Oral Maxillofac Surg 2006;64:961–4.
90. Hirsch DL, Bell RB, Dierks EJ, Potter JK, Potter BE. Analysis of microvascular free flaps for reconstruction of advanced mandibular osteoradionecrosis: a retrospective cohort study. J Oral Maxillofac Surg 2008;66:2545–56.
91. Gal TJ, Yueh BY, Futran ND. Influence of prior hyperbaric oxygen therapy in complication following microvascular reconstruction for advanced osteoradionecrosis. Arch Otolaryngol Head Neck Surg 2003;129:72–6.
92. Chen YB, Chen HC, Hahn LH. Major mandibular reconstruction with vascularized bone grafts: indications and selection of donor tissue. Microsurgery 1994;15:227–37.
93. Shaha AR, Cordeiro PG, Hidalgo DA, Spiro RH, Strong EW, Zlotolow I et al. Resection and immediate microvascular reconstruction in the management of osteoradionecrosis of the mandible. Head Neck 1997;19:406–11.
94. Santamaria E, Wei FC, Chen HC. Fibula osteoseptocutaneous flap for reconstruction of osteoradionecrosis of the mandible. Plast Reconstr Surg 1998;101:921–9.
95. Teng MS, Futran ND. Osteoradionecrosis of the mandible. Curr Opin Otolaryngol Head Neck Surg 2005;13:217–21.
96. Seth R, Futran ND, Alam DS, Knott PD. Outcomes of vascularized bone graft reconstruction of the mandible in bisphosphonate-related osteonecrosis of the jaws. Laryngoscope 2010;120:2165–71.
97. Ruggiero SL, Dodson TB, Assael LA, Landesberg R, Marx RE. American Association of Oral and Maxillofacial Surgeons. American Association of Oral and Maxillofacial Surgeons position paper on bisphosphonate-related osteonecrosis of the jaws – 2009 update. J Oral Maxillofac Surg 2009;67:2–12.
98. Marx RE. Reconstruction of defects caused by bisphosphonate-induced osteonecrosis of the jaws. J Oral Maxillofac Surg 2009;67:107–19.
99. Ruggiero SL, Fantasia J, Carlson E. Bisphosphonate-related osteonecrosis of the jaw: background and guidelines for diagnosis, staging and management. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2006;102:433–41.
100. Aarabi S, Draper L, Grayson B, Gurtner GC. Bisphosphonate-associated osteonecrosis of the jaw: successful treatment at 2-year follow-up. Plast Reconstr Surg 2008;122:57e–9e.

101. Arribas-Garcia I, Alcalá-Galiano A, García AF, Moreno JJ. Fracture of the anterior iliac crest following monocortical bone graft harvest in bisphosphonate-related mandibular pathological fracture: a case report. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;107:e12–4.
102. Fisher KL, Pogrel MA. Gorham's syndrome (massive osteolysis): a case report. J Oral Maxillofac Surg 1990;48: 1222–5.
103. Hirayama T, Sabokbar A, Itonaga I, Watt-Smith S, Athanasou NA. Cellular and humoral mechanisms of osteoclast formation and bone resorption in Gorham-Stout disease. J Pathol 2001;195:624–30.
104. Ricalde P, Ord RA, Sun CC. Vanishing bone disease in a five year old: report of a case and review of the literature. Int J Oral Maxillofac Surg 2003;32:222–6.
105. Tsang WM, Tong AC, Chow LT, Ng IO. Massive osteolysis (Gorham disease) of the maxillofacial skeleton: report of 2 cases. J Oral Maxillofac Surg 2004;62:225–30.
106. Raghuveer HP, Jayalekshmy R. Gorham's massive osteolysis of the mandible - a progressive radiographic presentation. Dentomaxillofac Radiol 2009;38:292–5.
107. Pedroletti F, Rangarajan S, McCain JP, Velez I. Conservative treatment of a pathologic fracture in a patient with Gorham-Stout disease. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;109:e49–52.
108. Tong AC, Leung TM, Cheung PT. Management of massive osteolysis of the mandible: a case report. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;109:238–41.
109. Kiran DN, Anupama A. Vanishing bone disease: a review. J Oral Maxillofac Surg 2011;69:199–203.
110. Boffano P, Gallesio C. Kissing molars. J Craniofac Surg 2009;20:1269–70.
111. Boffano P, Roccia F. Bilateral mandibular angle fractures: clinical considerations. J Craniofac Surg 2010;21:328–31.
112. Gallesio C, Berrone M, Ruga E, Boffano P. Surgical extraction of impacted inferior third molars at risk for inferior alveolar nerve injury. J Craniofac Surg 2010;21:2003–7.
113. Boffano P, Roccia F, Gallesio C. Lingual nerve deficit following mandibular third molar removal: review of the literature and medicolegal considerations. Oral Surg Oral Med Oral Pathol Oral Radiol 2012;113:e10–8.
114. Boffano P, Roccia F, Pittoni D, Di Dio D, Forni P, Gallesio C. Management of 112 hospitalized patients with spreading odontogenic infections: correlation with DMFT and oral health impact profile 14 indexes. Oral Surg Oral Med Oral Pathol Oral Radiol 2012;113:207–13.