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Reconstructive options in the treatment of osteoradionecrosis of the craniomaxillofacial skeleton

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SUMMARY. Osteoradionecrosis (ORN) of the craniomaxillofacial skeleton is a serious and debilitating complication that can occur following radiation therapy in the head and neck. Patients require effective treatment, which eradicates diseased tissue and restores function with minimal additional morbidity in a single stage, a requirement fulfilled in many cases by free tissue transfer. In a 6-year period from 1994 to 1999, 21 patients with ORN were treated by wide resection and free-flap reconstruction. The median interval between radiation therapy and ORN was 4 years (range: 1–33 years). The median radiation dose was 6000 cGy. The affected areas were the mandible (15 patients), the temporal bone (three patients), the maxilla (one patient), the cervical vertebrae (one patient) and the frontal bone (one patient). Clinical symptoms included pain, ulceration, a persistent draining fistula, exposure of bone or hardware, and pathological fracture or non-union of bone. Six patients had had previous unsuccessful attempts at conservative surgical resection. Ten patients had preoperative hyperbaric oxygen (HBO) therapy. A number of different flaps were used for reconstruction in these patients. These included free fibula flaps (13 patients), iliac crest flaps (two patients), scapula flaps (three patients) and rectus abdominis flaps (three patients). All patients achieved relief from their presenting symptoms and primary bone or wound healing. One flap (4.8%) was lost. This was successfully reconstructed in a subsequent procedure. There were three flap re-explorations, two for arterial thrombosis and one for venous thrombosis. Conservative measures, such as limited debridement and HBO therapy, may be effective in preventing the progression of ORN. However, they fail to eradicate established ORN, which requires radical surgical resection followed by functional reconstruction with well-vascularised tissue.

Keywords: osteoradionecrosis, reconstruction, craniomaxillofacial skeleton.

Osteoradionecrosis (ORN) of the craniomaxillofacial skeleton is one of the more serious and debilitating complications that can occur following radiation therapy in patients with head and neck cancer.[1–5] Development of ORN compounds the morbidity already endured by the patient following therapeutic interventions for the primary disease. It is a late complication of radiation[6] and is a complex metabolic and tissue-homeostatic deficiency created by radiation-induced tissue injury with the development of bone necrosis caused by radiation-induced small and large vessel obliteration.[3–9] Marx explains the pathophysiology of ORN using the '3H' principle to describe the effect of radiation on tissue. In his model, radiation leads to progressively hypocellular, hypovascular and hypoxic tissues. This impedes the replacement of connective tissues and cells as part of tissue turnover in normal homeostasis and in wound healing. Breakdown of tissues can ensue, with or without trauma. ORN is, therefore, a problem of impaired and inadequate tissue turnover and wound healing.[7]

Multiple predisposing factors for the development of mandibular ORN have been suggested, including pre-irradiation and post-irradiation dental extractions,[10,11] poor oral hygiene coupled with tobacco and alcohol use, periodontal disease, use of hyperfractionation therapy,[12] radiation doses of more than 5000 cGy, and the location of the primary tumour, especially when it extended onto the mucosa covering the mandible.[13]

The reported incidence of ORN of the mandible ranges from 4 to 30% of patients undergoing radiation therapy for head and neck cancers, depending on the series[1,14] and on the site. Joensuu et al found only one case of ORN following irradiation of 24 cases of squamous cell carcinoma (SCC) of the tongue,[15] and Wong et al found seven cases of ORN in 150 patients following irradiation for SCC of the tonsillar fossa.[16] ORN of the maxilla or skull base is rare and may be seen after combined therapy for malignancies of the maxillary sinus.[17]

ORN presents clinically as persistent pain and chronically exposed bone.[8,18] In addition, ORN of the mandible may result in non-union, pathological fracture and orocutaneous fistulae.[11,19] The main impact on these patients is in relation to the vital functions of food processing, respiration and speech production. ORN of the temporal bone may result in trismus,[17] hearing loss, otalgia,

otorrhoea and even intracranial complications, such as meningitis, temporal lobe or cerebellar abscesses and cranial neuropathies, if not treated properly.[20]

While conservative management, with antibiotics, sequestrectomy or hyperbaric oxygen therapy (HBO), may be sufficient for patients with limited-area ORN,[11] patients with well-established ORN involving large areas of bone and soft tissue and who present with ulcers, fistulae and exposed bone require more radical management.[21] This should eradicate diseased bone and restore function with minimal additional morbidity, preferably in a single stage—a requirement that is fulfilled by free tissue transfer.

We present our experience of managing 21 of these complicated cases with radical resection and free-flap reconstruction over a 6-year period, and discuss the various reconstructive options.

Patients and methods

Between January 1993 and June 2000, 569 free flaps were performed at our institution to repair head and neck defects. Of these, 21 patients with free-flap reconstruction following ORN of the craniomaxillofacial skeleton formed the basis of our clinical review. There were 14 males and seven females, with a mean age of 60.9 ± 9.2 years (range: 47–79 years), all with histologically proven ORN. The majority had smoked at least 15 pack-years, one patient was a betel-nut chewer, and four drank alcohol regularly. A pack-year is defined as the number of packs smoked per day multiplied by the number of years for which the patient has smoked and is a quantitative estimate of prior cigarette exposure.[22]

In 18 patients a primary diagnosis of SCC led to the initial radiation therapy, either as the sole therapy or in conjunction with surgical resection; the most common primary-tumour site was the oral cavity. The remaining three patients had received radiation therapy for sarcoma, melanoma and parotid adenoid cystic carcinoma, respectively. In total, 15 patients had undergone some form of surgical resection in addition to radiation therapy (Table 1).

Eight patients were irradiated at another institution for their primary disease prior to the development of ORN. The median time between initial radiation therapy and the onset of ORN was 4 years (range: 1–33 years). Ten patients developed ORN within 5 years of the start of their radiation therapy, and the remaining 11 patients developed ORN more than 5 years after the start of their radiation therapy. Most patients had a radiation dose of 6000–6600 cGy (range: 5355–16 000 cGy). One patient had adenoid cystic carcinoma of the parotid and was irradiated with a combined estimated cumulative dose of 16 000 cGy (both conventional and neutron-beam therapy) for late recurrence.

In total, 15 patients had ORN of the mandible, three had ORN of the temporal bone and temporomandibular region, one had ORN of the cervical vertebrae, one had ORN of the maxilla and one had ORN of the frontal bone. Most patients with mandibular ORN initially presented with an ulcer and/or fistula, followed by pain and difficulty in chewing. Ulcers and exposed bones were the most common presenting complaints among patients with non-mandibular ORN (Table 2). Six patients had undergone previous unsuccessful attempts at conservative surgical resection, and 10 patients had had preoperative HBO therapy.

The resection margins of the diseased segments were guided by preoperative panoramic radiographs and CT scans. The preoperative imaging was used as a guide, and the adequacy of resection was further assessed clinically during surgery by the presence of healthy bleeding bone at the resection margin. There was a good correlation between the preoperative images and the clinically assessed resection margins. All resected specimens were

Table 1 Patient and primary disease characteristics of the patients with ORN

	Number of cases
sex	
male	14
female	7
age	
< 60 years	10
> 60 years	11
smoking	
non-smoker	6
moderate (10–30 pack years)	8
heavy (>30 pack years)	7
other substance abuse	
alcohol	4
betel nuts	1
Histology	
squamous cell carcinoma	18
adenoid cystic carcinoma	1
sarcoma (malignant fibrous histiocytoma)	1
melanoma	1
site	
oral cavity	10
external (including parotid)	4
tonsil	4
hypopharynx/larynx	2
maxilla	1
treatment of primary disease (including recurrences before ORN)	
radiation alone	6
radiation and surgery	15

Table 2 Symptomatology of patients with ORN

	Number of cases
ORN of the mandible ($n = 15$)	
pain	7
difficult mastication	4
ulcer/fistula	11
exposed bone/plate	8
pathological fracture/non-union of bone	4
ORN at other sites ($n = 6$)	
pain	2
difficult mastication (trismus at temporomandibular joint)	1
ulcer/fistula	4
exposed bone/plate	2

subjected to histopathological examination to confirm the presence of ORN and to exclude any residual or recurrent tumour residing within the diseased segment.

Mandibular defects were classified according to Boyd et al's HCL classification.[23] Surgical resection resulted in two central-segment defects (C), three angle-to-angle defects (LCL), nine body defects (L) and one hemimandible defect (H). The fibular flap was used in 12 patients, the iliac crest flap in two patients and the scapular–parascapular flap in one patient (Table 3). While some of these patients had had a mandibulotomy at the time of their original surgery, there did not seem to be any correlation between the presence of a mandibulotomy and the development of ORN.

For patients with non-mandibular ORN, the scapular flap was used in two patients with forehead and cervical-vertebrae ORN, respectively, and the rectus abdominis flap was used in three patients with temporal-bone ORN and in one patient with ORN of the maxilla.

Table 3 Mandibular defect sites and flap selection (HCL classification after Boyd et al)[23]

Mandibular defect	*Number of cases*	*Flap used*
Cm	2	iliac crest (1), fibula (1)
Hm	1	fibula
LCLm	3	fibula
Lms	1	scapular-parascapular
Lm	5	fibula
Lo	3	fibula (2), iliac crest (1)

Results

Morbidity and perioperative mortality

There were five instances of minor wound-related complications. Partial flap necrosis requiring debridement occurred in two cases, minor wound dehiscence was treated conservatively in one case (case 5; Table 4) and the mandibular reconstruction plate had to be removed owing to plate exposure in two cases (cases 7 and 17; Table 5).

Four patients experienced flap compromise due to vascular thrombosis. Three of these flaps—in two patients with arterial thrombosis and one patient with venous thrombosis (cases 3, 4 and 17)—were salvaged at emergency re-exploration. One of these patients died in the postoperative period of a cerebrovascular event and pneumonia (case 4). One flap was lost 2 weeks postoperatively owing to infection (flap loss rate: 4.8%). This patient had a rectus abdominis flap for reconstruction of maxillary ORN (case 2). She subsequently underwent a successful second reconstruction, again using a free rectus abdominis flap, 6 months later.

Primary bone healing was obtained in all cases with mandibular ORN, and primary soft-tissue coverage was obtained in all but two patients (cases 7 and 17). Primary wound healing was obtained in all but one patient with non-mandibular ORN (case 5).

All the surviving patients were relieved of their symptoms and were satisfied with their reconstruction in terms of restoration of form and function. At the last follow-up 18 patients were alive (mean follow-up: 26.9 months; range: 2–79 months).

Five patients developed and were treated for tumour recurrence prior to the development of ORN. All but one of these patients developed a second recurrence some time after definitive treatment of their ORN, although tumor recurrence was not detected in the resected specimens at the time of ORN treatment. Six patients developed tumour recurrence after wide resection and free-flap reconstruction of their ORN: five developed recurrent SCC of the oral cavity or pharynx and one developed recurrent adenoid cystic carcinoma of the parotid. All but one of these patients were heavy smokers and continued to smoke following their primary resection. Three patients with recurrent tumours went on to have a further resection and free-flap reconstruction. Although all specimens were examined for the presence of tumour at the time of ORN resection, none was found.

Ten patients received HBO therapy prior to wide resection and free-flap reconstruction. One patient experienced a minor wound breakdown at the recipient site, which was treated conservatively; none had any major flap complications. Four patients in this HBO group had tumour recurrence following free-flap reconstruction for ORN. Table 4 summarises the tumour characteristics, the time interval to the development of ORN, the management and the eventual outcome in each patient.

Discussion

Complications of radiation therapy for head and neck cancer can be acute or long-term. Acute complications include mucositis, impairment of wound healing and decreased quality of life.[24] Significant long-term complications include the induction of second malignancies, such as sarcomas,[25,26] and the development of ORN.[5,17,20,27] Measures such as the use of a spacer to shield lingual gingiva during treatment with brachytherapy,[28] the promotion of dental hygiene, and the removal of selected teeth affected by peridontal disease prior to radiation therapy[10] may be effective in preventing ORN. It is interesting to note that ORN can occur in patients who have never had surgery. Surgeons in particular tend to associate ORN with the double insult of surgery and radiation. This is not necessarily the case. We have already stated that breakdown of tissues can occur with or without trauma. This supports the hypocellular, hypovascular and hypoxic (3H) theory of Marx.[7]

The goals of the management of established craniomaxillofacial ORN are two-fold: the treatment of symptoms and possible residual or recurrent tumour, and the restoration of form and function. These goals are similar for both mandibular and non-mandibular ORN.

For patients with mandibular ORN, the particular goals of reconstruction are to restore the function of the mandible, especially with regard to food processing, swallowing and intelligible speech production, and to

Table 4 Summary of patients with craniomaxillofacial ORN managed with free-flap reconstruction

Case number	*Age (years)/ sex*	*Primary diagnosis and stage*	*Primary treatment*	*Interval between RT and ORN (years)*	*Previous treatment of ORN*	*Preoperative HBO therapy*	*Defect site*[a]	*Flap used*	*Complications*	*Eventual outcome*	*Follow-up (months)*	*Status*
1	59/M	forehead SCC; T2N0	excision; recurrence after 1 year treated by RT	1	conservative	–	forehead	Scap + CBG	–	well; flap debulked 1 year later; no recurrence; good result 3 years later	36	A1
2	56/F	SCC of the maxilla; T4N0	excision, RT	2	conservative	–	maxilla	RAM	Flap lost after 14 days (infection)	Second free RAM 9 months later	15	A1
3	53/M	tonsillar SCC; TxNx	RT[b]	>30	conservative	–	neck	Scap	arterial thrombosis (kink) 12 h postoperatively	further release of contracture 3 years later	36	A1
4	85/M	scalp sarcoma	excision, LD FF, RT	1	none	–	temporal bone	RAM	arterial thrombosis (suction drain) 1 day postoperatively; stroke next day; pneumonia 5 days later	died 14 days postoperatively from cardiorespiratory failure		D1
5	53/M	parotid adenoid cystic carcinoma	excision, RT; recurrence after 2 years treated by RT (neutron beam)[b]	6	two local flap reconstructions	20 dives	condyle, maxilla, temporal bone, TMJ	RAMc	recipient site wound breakdown	recurred and resected again with second free rectus 2 years later	36	A1
6	59/M	SCC of the external ear; T2N0	RT	3.5		20 dives	coronoid, temporal bone, TMJ	RAM	–	good release of trismus	32	A1
7	55/M	SCC of the tongue; T4N2cM0	excision, RF FF, RT[a]	1		refused	Man(Cm)	F OC	skin-paddle necrosis, debrided; mandibular plate exposed, removed 4 months postoperatively	recurrence of ORN and tumour 6 years later with second free fibula flap	78	A1
8	72/M	SCC FOM + Man; T2N0	Chemo, RT; recurred 2 years later, treated by excision and pedicled flap[b]	2	F FF reconstruction[b] failed	–	Man(Cms)	IC OC	–	debulking of flap 7 months postoperatively	7	A1
9	71/M	SCC FOM; T4N0	excision, RT	9		30 dives	Man(Hm)	F OC	–		31	A1
10	61/M	melanoma of the skin	excision, RND, RT[a]	13		25 dives	Man(LCLm)	F OC	–	Good cosmetic and functional result; dental rehabilitation at 10 months	13	A1
11	60/M	SCC FOM; T2N0	RT; recurred 2 years later, treated by excision and RND	2	segmental resection	27 dives	Man(LCLm)	F OC	–	second primary resected and RF FF 2 years postoperatively; recurred again 1 year later	24	A2; LR
12	75/F	SCC of the oral cavity; T2N0	RT	18	sequestrectomy	30 dives; 10 dives post-treatment	Man(LCLm)	F OC	–	osseointegrated implants 18 months postoperatively	12	A1

(*continued*)

Table 4 Continued

Case number	*Age (years)/ sex*	*Primary diagnosis and stage*	*Primary treatment*	*Interval between RT and ORN (years)*	*Previous treatment of ORN*	*Preoperative HBO therapy*	*Defect site*[a]	*Flap used*	*Complications*	*Eventual outcome*	*Follow-up (months)*	*Status*
13	62/M	SCC of the tonsils; T2N0	RT	12	partial mandibulectomy	–	Man(Lm)	F OC	–	Good mastication and cosmesis, but oesophageal stricture required dilatation 3 years later	36	A1
14	53/M	SCC of the palate; T1N0	RT	2		25 dives	Man(Lm)	F O	–	bilateral pain in the TMJ; intra-articular inj by anaesthetist 3 years postoperatively	36	A1
15	65/M	SCC of the subglottic larynx; T3N0	RT; recurred 4 years later, treated by excision, FND and RT	7	debrided	7 dives	Man(Lm)	F OC	–	recurrence anterior-neck skin resected 2 years later, repaired with PM flap; no recurrence 6 months after second operation	46	D2; LR
16	48/F	SCC of the tongue; T1N0	excision[b]; recurred and excised[b]; further recurrence treated by excision, RF FF, RND and RT[b]	2		30 dives	Man(Lm)	F OC	–	good function 1 year postoperatively; developed third recurrence 2 years later	24	A2; LR
17	64/F	SCC of the tonsil; T1N0	RT	4		refused	Man(Lms)	Scap-Para OC	venous congestion 1 day postoperatively; exposed plate few months later	non-union of flap on CT scan 2 years later, flap union at exploration so PM flap used for external coverage	30	A1
18	49/F	SCC of the tonsil; T2N1	excision, RND, RT	1	–	–	Man(Lm)	F OC	–	good functional and cosmetic result 3 years postoperatively	36	A1
19	79/M	SCC of the pharynx; T2N0	excision, RT	7	–	–	Man(Lo)	F O	–	recurrent tongue SCC after 1 year; died of aspiration pneumonia 6 months later	12	D2; LR
20	47/M	SCC of the tongue; T4N0	excision, RND, RT	9	–	–	Man(Lo)	IC O	–		2	A1
21	74/F	SCC of the FOM and Man; T4N0	excision, RF OC FF, RT	1.75		30 dives	Man(Lo)	F O	–	no recurrence, good functional and cosmetic result 2 years postoperatively	24	A1

ORN: osteoradionecrosis; HBO: hyperbaric oxygen; SCC: squamous cell carcinoma; FOM: floor of the mouth; Man: mandible; TMJ: temporomandibular joint; FND: functional neck dissection; RND: radical neck dissection; RT: radiation therapy; chemo: chemotherapy; FF: free flap; LD: latissimus dorsi; RF: radial forearm; F: fibula; RAM: rectus abdominis muscular; RAMc: rectus abdominis myocutaneous; CBG: calvarial bone graft; Scap: scapula; Scap-Para: scapula-parascapula; PM: pectoralis major; IC: iliac crest; O: osseous; OC: osteocutaneous; A1: alive without disease; A2: alive with disease; D1: died free of disease; D2: died of recurrent disease; LR: locoregional recurrence.

[a] Mandibular defect LCL classification after Boyd et al.[23]

[b] Procedure performed at another institution.

Table 5 Complications following free-flap reconstruction of ORN

Complication	*Number of cases*	*Management*
minor complications		
minor flap breakdown at recipient site	1	packed
skin-paddle necrosis	2	debridement
Plate loosening/exposure	2	removal of plate
major complications		
venous congestion (<24 h post-operatively)	1	pedicle repositioned
arterial thrombosis (<12 h post-operatively)	2	pedicle revised
flap loss (2 weeks postoperatively)	1	flap removed

restore the appearance of the lower face. Management of these patients includes conservative measures, such as the establishment of good oral and dental hygiene, HBO therapy and antibiotics, and surgical measures ranging from limited resection of sequestra to mandibular replacement with vascularised tissue. HBO therapy may hinder the progression of ORN, but limited resection may not completely clear the ORN, leading to progression of the necrotic process. Placement of a non-viable graft in an irradiated bed is contraindicated as it is associated with significant complications.[29] Pedicled flaps such as the pectoralis major muscle flap,[30–32] though good in other situations in the head and neck, are not optimal for the reconstruction of mandibular ORN as they do not restore the mandibular arch, which is vital for proper function. While it is true that lateral defects of the mandible may be treated with soft-tissue interposition alone, it has been our experience that such treatment occasionally results in contracture, with subsequent rotation of the mandible, which may interfere with occlusion. Our feeling is that this fibrosis is more likely in irradiated patients, and for this reason we have continued to use bone. We have also avoided the use of reconstruction plates alone in lateral defects because many of these patients are long-term survivors and may ultimately fracture the plate.

One of the earliest symptoms of ORN may be pain, and this diagnosis should be considered in patients who are at risk. We have not found the duration of pain to be correlated with the likelihood of a diagnosis of ORN. Progression of the condition may ultimately lead to ulceration and pathological fracture, but neither ulceration nor bone exposure needs to be present in order to make the diagnosis. The goal should be to treat the ORN before it progresses to this advanced stage. None of the patients in this group had progressed to the stage of pathological fracture.

Several of these patients had hardware in place at the time of the development of ORN. While we did see screw loosening in association with ORN, we have also seen this in patients in whom there is no evidence of ORN.

Radical resection followed by free-flap reconstruction has been recommended as the reconstructive method of choice in the surgical management of mandibular ORN.[33–35] The main advantage of free tissue transfer is its ability to import non-irradiated well-vascularised tissue into an irradiated and diseased area.[4,34,36,37]

The goals of management for patients with non-mandibular ORN are similar to those for patients with mandibular ORN. Diseased bone and soft tissue must be removed and replaced with vascularised tissue so as to restore function. Free tissue transfer can produce results that could not be achieved with simpler forms of reconstruction, such as skin grafts or local flaps.

The surgical management of these patients is particularly challenging. Several factors contribute to this complexity. All of the patients have received irradiation, with its attendant wound-healing problems, and some have had previous surgery, resulting in the obliteration of tissue planes. In a study of carotid-artery images in orthopantograms of 122 patients, Friedlander et al concluded that individuals with radiation doses sufficient to cause ORN of the mandible are at a higher risk of developing carotid-artery atherosclerotic lesions than age-matched non-irradiated controls.[38] In addition, because some of the patients have had previous free-flap reconstruction, the choice of recipient vessels may be limited. Meticulous and careful dissection and the use of alternative vessels for anastomoses can overcome some of these difficulties. Alternative vessels include vessels from the opposite neck, and the external carotid artery for arterial anastomosis and the cephalic turnover vein for venous anastomosis if no native neck veins are suitable. In this series, the use of vein grafts was limited to one patient.

The fact that several patients presented with tumour recurrence both before and after definitive treatment for their ORN supports Slaughter et al's field cancerisation theory. This theory assumes that the entire mucosa of the upper aerodigestive tract is at the same risk of developing malignancy because it has been subjected to the same carcinogenic influence,[39] and reflects the biological aggressiveness of these tumours. In the group of patients who developed recurrence after free-flap reconstruction of their ORN, there were no postoperative flap complications. In this group, four patients had their recurrences treated successfully with further resection and free-flap reconstruction.

Harris proposes ultrasound as a non-invasive method of treating ORN and presents data to show that ultrasound stimulates the production of angiogenic factors such as interleukin 8 (IL-8), basic fibroblast growth factor (bFGF) and vascular endothelial growth factor (VEGF). He suggests this as a possible mechanism by which therapeutic ultrasound induces angiogenesis and healing.[40,41] We do not have any experience with the use of therapeutic ultrasound in the treatment of ORN.

HBO therapy has been used in the management of ORN,[42–47] but it has not been conclusively proven to be of benefit.[48,49] HBO therapy has been shown to improve the healing of soft tissue in irradiated wounds.[44,50] It is interesting to note that none of the patients who had received prior HBO therapy developed any major complications, though, because such small numbers are involved, this observation is not statistically significant (Fisher's two-tail exact test: $P = 0.09$). A possible advantage of HBO therapy is that it improves the state of the vessels that lie within the zone of

radiation,[45,51] thereby reducing thrombosis factors. Repeated visits to the HBO chamber for multiple dives add to the logistic inconvenience but should be considered as part of the multidisciplinary approach to treating these patients.

We recommend multimodal therapy in the management of ORN. Essential points in the management include early diagnosis and cessation of smoking, optimisation of oral and dental hygiene, a course of preoperative HBO therapy (if logistically practical) to improve local circulation, and wide resection of necrotic bone with immediate free-flap reconstruction. The recommendation of HBO therapy is not, however, based on any randomised controlled studies, but is based on retrospective data from this unit.[52] The choice of flap depends on the composition of the defect. We rely on workhorse flaps, but are ready to use alternative sites when the standard flaps are either not available or inadequate. Close surveillance and early aggressive surgical management of recurrences offers the patient the best chance of locoregional control, survival and functional rehabilitation.

In conclusion, ORN of the craniomaxillofacial skeleton is a serious complication of radiation therapy in the head and neck. Conservative measures have a limited role in the treatment of ORN. Well-established ORN should be treated aggressively with wide resection of the diseased areas and immediate free-flap reconstruction. Free tissue transfer imports well-vascularised non-irradiated tissue, enabling primary wound healing, optimal symptomatic resolution and functional rehabilitation, in a one-stage procedure. The free fibula flap is the flap of choice for mandibular ORN. Flap selection for non-mandibular ORN depends on the specific defect and the reconstructive requirements.

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