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Three-phase bone scintigraphy and viability of vascularized bone grafts for mandibular reconstruction

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Abstract. Three-phase bone scintigraphy was undertaken to check the anastomotic patency and monitor the viability of vascularized bone grafts. Ten consecutive patients who underwent vascularized bone grafting of the mandible were reviewed. A successful clinical outcome was achieved in 8 patients. The graft failed in 2 patients. In this series, 3-phase bone scintigraphy of radiolabeled ^{99m}Tc-methylene-diphosphonate was performed at 7 days, and at 1, 3, 6, and 12 months after reconstruction. Assessments made using 3-phase bone images were compared with the clinical findings. The clinical outcome of the cases presented in our series correlated extremely well with 3-phase bone images. Three-phase bone scintigraphy is a useful method for the assessment of patency and viability of vascularized bone grafts. The use of this method can be very helpful in assessing the anastomotic patency and viability of a graft which for clinical reasons is suspected of being non-viable.

Key words: three-phase bone scintigraphy; vascularized bone graft; mandibular reconstruction; sequential evaluation.

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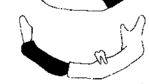
Bone scintigraphy using ^{99m}Tc-methylene-diphosphonate (MDP) has been utilized frequently to monitor the viability of vascularized bone. The sensitivity and reliability of bone imaging have been previously discussed[1–4,7,10–12,15,16]. NUTTON et al.[10] have reported the dynamic bone imaging technique for the study of blood flow and other factors affecting bone scan uptake in healing bone. They pointed out that clinical bone scanning can be empirically divided into three phases. In phase 1, an angiographic image can be obtained while the isotope is still in the large vessels. This phase occurs immediately after injection. In phase 2, a blood pool image records an isotope angiogram, which is thought to represent the tracer in the capillary bed. This indicates relative vascularity. In phase 3, a standard delayed bone image is used to demonstrate the distribution of the tracer in the bone. Recently, three-phase bone scintigraphy for vascularized bone grafts has been shown to be a reliable method for assessing graft patency and viability in postoperative stages[6,8,9,14]. However, there have been few reports on the sequential evaluation utilizing this method. We have used 3-phase bone scintigraphy for the postoperative monitoring of revascularized bone grafts and have carried out sequential long-term evaluation. We present a comparative analysis between the assessments made using 3-phase bone scan and the clinical findings.

Material and methods

Ten consecutive patients (8 men and 2 women, aged 45 to 74 years) who underwent vascularized bone grafting of the mandible in the period from May 1996 to November 1997 were included in the present study. The primary site of the carcinoma was the oropharynx (n=4), the floor of the mouth and the lower gum (n=2 each), and the tongue and the hard palate (n=1 each). The histopathological diagnosis was squamous cell carcinoma (n=9) and mucoepidermoid carcinoma of the hard palate (n=1). Four patients underwent secondary mandibular reconstruction after radical ablation of an oral carcinoma (Table 1). Three patients underwent primary reconstruction for osteoradionecrosis of the mandible which had not responded to conservative treatment. Three patients underwent secondary reconstruction

Table 1. Patient characteristics

Patient No.	Age/Sex	Diagnosis	Mandibular reconstruction	Location of mandible defect	Grafted bone	Flap	Clinical outcome
No. 1	74/F	Lower gum Ca.	Secondary		Scapular	LDMC	Successful
No. 2	54/F	Floor of mouth Ca.	Secondary		Scapular	LDMC	Successful
No. 3	53/M	ORN	Immediate		Iliac	Forearm	Successful
No. 4	52/M	Oropharynx Ca.	Secondary		Iliac	Not done	Successful
No. 5	74/M	ORN	Secondary		Scapular	LDMC	Successful
No. 6	61/M	ORN	Secondary		Scapular	LDMC	Successful
No. 7	45/M	ORN	Secondary		Fibular	Peroneal	Successful
No. 8	65/M	ORN	Immediate		Iliac	Forearm	Partial Necrosis
No. 9	52/M	ORN	Immediate		Fibular	Peroneal	Total Necrosis
No. 10	64/M	Lower gum Ca.	Secondary		Fibular	Peroneal	Successful

ORN: osteoradionecrosis, LDMC: Latissimus dorsi myocutaneous flap.

for osteoradionecrosis of the mandible, where prior attempts at plate reconstruction had failed because of infection and/or plate exposure. In the 6 patients treated for osteoradionecrosis, the total dose of radiotherapy ranged from 65 to 80 Gy.

In the 10 cases, scapular bone was applied in 4 grafts, and iliac and fibular bone in 3 grafts each. Nine grafts were transferred with overlying skin, and, in one case involving iliac reconstruction, the graft was transferred without overlying skin. Clinical follow-up was obtained in all cases (follow-up period, 27 to 46 months; mean, 35.1 months).

To allow assessment of the time course of revascularization, the timing of the bone scan after surgery was varied. Eight patients underwent bone scans at 7 days (mean, 7.8 days; range, 6–13), 1 month (mean, 27.7 days; range, 26–29), 3 months (mean, 95.4 days; range, 88–119), 6 months (mean, 206.7 days; range, 176–264), and 1 year (mean, 373.9 days; range, 278–537) after reconstruction. One patient, in whom the graft was a total failure, underwent scans at 7 days and 1 month after reconstruction. Another patient, who developed partial necrosis, had scans performed at 7 days, and at 1 and 3 months after the reconstruction.

In order to monitor the patency of anastomosis and the viability of the graft, all patients underwent a ^{99m}Tc-methylene-diphosphonate (MDP) "three-phase" bone scan. Each patient received 555 MBq of ^{99m}Tc-MDP intravenously, lying supine on the board of a γ-camera device (SNC-5100R Shimadzu gamma camera system, Japan). Phase 1 images were stored by computer in a 64$\times$64 matrix, and phase 2 images were stored in a 128$\times$128 matrix. For dynamic study, 60 phase 1 images were acquired at 1 spot/2 sec, followed by 30 phase 2 blood pool images acquired at 1 spot/20 sec. During the dynamic imaging, manually drawn circular regions of interest (ROIs) were set up on the implanted bone sites and on the contralateral sites to obtain time activity curves (TACs). The activity ratios between the implant and the contralateral site were calculated after generation of TACs for both ROIs. In phase 3, a static image was taken 3 hours after the injection of ^{99m}Tc-MDP and the activity ratio was calculated. In the 8 cases in which the graft was successful, quantitative results are given as mean$\pm$standard deviation. In all cases, the contralateral sites of the mandible did not show uptake caused by inflammation.

Results

A successful clinical outcome was achieved in 8 vascularized bone grafts (Table 1), and the success rate of surgical reconstruction was 80% (8/10). Case 8 developed an orocutaneous fistula which did not respond to conservative treatment. The distal connecting portion of the graft revealed a fibrous union, and thus this area was removed 5 months postoperatively. Case 9 developed postoperative infection and an anastomosed artery ruptured 8 days after reconstruction. This artery was immediately ligated and the transplanted bone was removed 1 month postoperatively.

The findings of 3-phase bone imaging are shown in Fig. 1. Phase 1 imaging revealed a constant patency over the 12-month period in the successful cases. In case 9, however, the activity ratio diminished significantly after the anastomosed artery was ligated.

Phase 2 imaging showed a decrease in the slope of the TACs for successful cases after 1 month. This indicates that remodeling activity in the implanted bone gradually decreased over time. In contrast, the activity ratio in case 8 increased beyond 1 S.D. 3 months after surgery, indicating inflammation in the transplanted bone.

Phase 3 imaging showed that the activity ratio decreased gradually over time in successful cases. Scintigrams at 1 week postoperatively showed the most intense uptake (Fig. 2). After 4 weeks, the uptake was limited to the contours of the grafted bone itself. Foci of in-

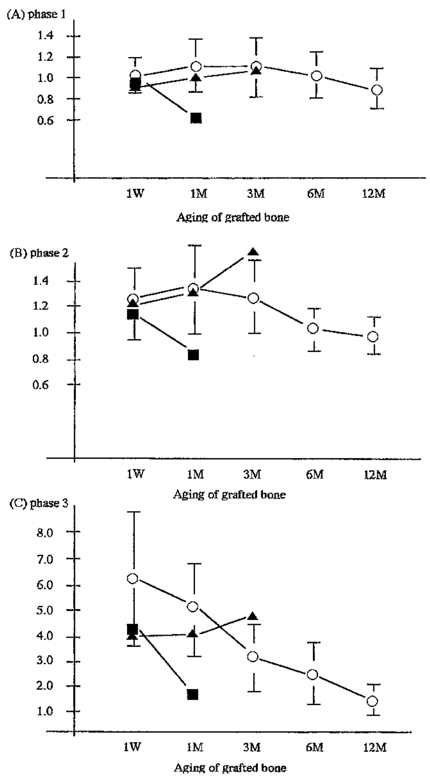


Fig. 1. Activity ratio of scintigraphic follow-up after mandibular reconstruction. (A) phase 1. (B) phase 2. (C) phase 3. ○=successful vascularized bone graft; ▲=vascularized bone graft with partial necrosis; ■=vascularized bone graft with total necrosis.

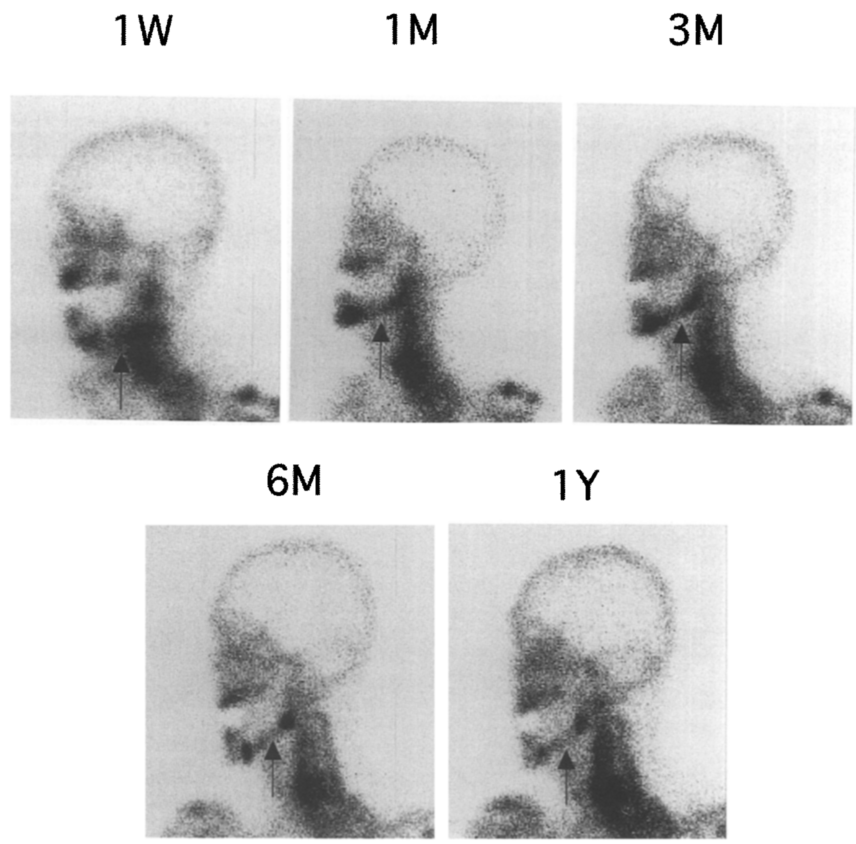


Fig. 2. Sequential static bone images in a patient who had a successful clinical outcome (case 10). Scintigrams at 1 week postoperatively showed the most intense uptake. After 1 month, uptake decreased and was first limited to the contour of the grafted bone itself, and then gradually to osteotomy sites alone (arrow).

creased tracer activity are normally seen at the osteotomy site. Images of case 8 taken 1 month postoperatively, after the anastomosed artery was ligated, showed a cold defect (Fig. 3).

Discussion

Monitoring of bone grafts used in reconstructive surgery can be a major problem. Radiographs are unreliable during the first few months because a 30–40% alteration in bone mineral content is necessary before changes are visible[3]. Angiography is a very definitive technique, but the contrast agent is injurious to the endothelium of the intima of the anastomosed vessels. Therefore, early monitoring of the status of the blood vessels using this technique is not recommended. Furthermore, angiograms only show the state of the feeding vessels and not the metabolic function of the bone graft. The laser doppler flowmetry is a valuable modality for monitoring free flaps. YUEN & FENG[17] demonstrated that the laser doppler flowmeter detected vascular compromise in 13 of 232 cases with no false positives or negatives. Although this method may be reliable even if overlying skin is not present, it is not able to show the viability of the grafted bone. Recently, positron emission tomography (PET) has been shown to have high sensitivity in detection of graft viability[5,13]. However, PET has a high cost, and it would take some time to become a conventional modality to assess graft viability. Most researchers agree that bone imaging is a non-invasive, simple, and sensitive tool for the assessment of the viability of vascularized bone grafts[4,6,9,12,14–16]. In the present study, we used 3-phase bone scintigraphy to monitor the anastomotic patency and viability of vascularized bone grafts. However, the sequential long-term evaluation utilizing this method has seldom been reported.

In the cases in which grafting was successful, phase 1 scanning revealed that the anastomotic patency was constant throughout the 12-month period. Phase 2 scanning revealed that the activity ratio decreased after 1 month, indicating that remodeling activity in the implanted bone gradually decreased over time. Phase 3 scanning showed that uptake was most intense at 1 week postoperatively, and that it extended beyond the limits of the grafted bone in every case. After 4 weeks, the uptake had apparently decreased and was limited to the contour of the grafted bone itself, and then gradually to the osteotomy sites only.

In the patient who developed partial necrosis (case 8), phase 1 scanning revealed constant patency for the first 3 months postoperatively. Phase 2 and 3 scanning showed that the activity ratio increased between 1 and 3 months postoperatively, indicating inflammation in the transplanted bone. Although uptake of tracer generally correlates with graft viability, a gradual increase in uptake 3 months after surgery might be predictive of subsequent graft failure. We suggest that sequential study for at least 3 months postoperatively might be

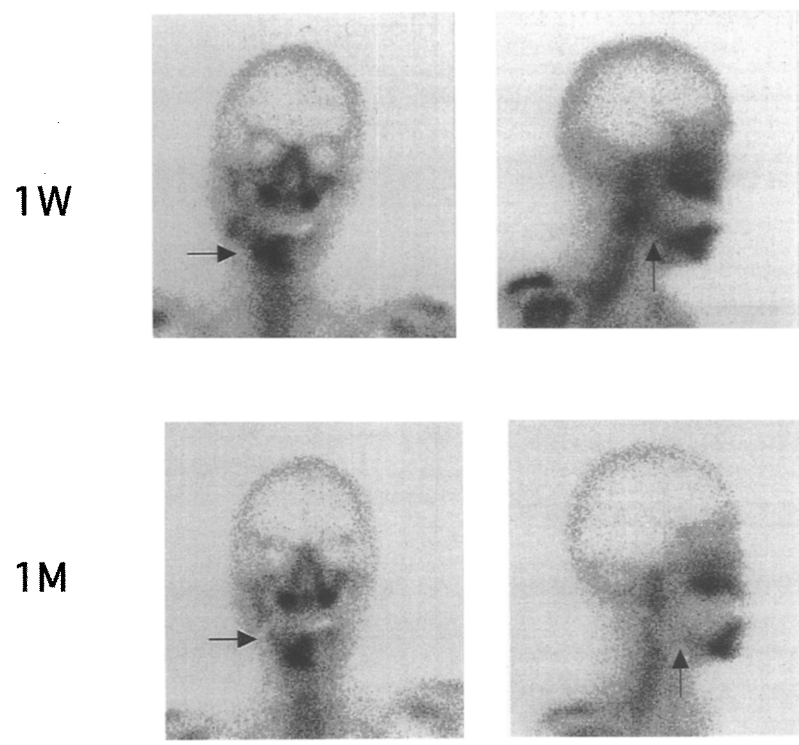


Fig. 3. Static bone images in the anterior and right lateral in a patient in whom an anastomosed artery was ligated 8 days after reconstruction (case 9). Tracer uptake was seen throughout the lateral mandibular graft 7 days after surgery. Scintigrams showed a cold defect 1 month postoperatively (arrow).

a reliable method to detect graft failure in cases developing persistent infection.

In the patient in whom the graft was a total failure (case 9), phase 1 and 2 scanning showed a significant decrease in the activity ratio at 1 month postoperatively, and the static bone image showed a cold defect. BERGGEN et al.[2] have warned of the unreliability of static bone imaging as a diagnostic tool to assess the viability of bone grafts when it is performed at more than one week postoperatively. They pointed out that even if the major portion of the graft is not viable, static bone imaging could provide a positive result. This is reportedly due to the presence of new bone formed by creeping substitution on the surface of dead bone after more than one week postoperatively. However, TAKATO et al.[16] insisted that those results from experimental studies using dogs cannot be applied to clinical cases, because the bone models were small and the recipient sites were very different from those in clinical cases. They performed sequential scintiscans on reconstructed mandibles with revascularized iliac crest and fibular grafts until 6 weeks postoperatively. They found no false positive scans and concluded that scintigraphy is reliable for at least 4–6 weeks after surgery. In our series, the fact that a static bone image taken at one month postoperatively, and after the ligation of the anastomosed artery, showed a cold defect supports the view of TAKATO et al. that scintigraphy is reliable for assessing the viability of vascularized bone grafts from immediately after surgery to at least 1 month postoperatively. However, dynamic bone imaging could provide extra information to monitor the anastomotic patency. We consider that 3-phase scintigraphy does facilitate the assessment of mechanical vascular accidents such as thrombosis and kinking.

The clinical outcome of the cases presented in our sequential evaluation correlated extremely well with the 3-phase bone imaging. The use of this method can be very helpful in assessing the anastomotic patency and the viability of a graft which for clinical reasons is suspected of being non-viable. However, five bone images a year involves too many scans and gives too little information, especially in uneventful graft healing. It would be most appropriate to perform bone imaging once early after surgery and immediately upon suspicion of a clinical event which may result from a failing vascularized bone graft. In addition, sequential study for at least 3 months postoperatively might be a reliable method to detect graft failure in cases developing persistent infection.

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