Home-based Exercise on Functional Outcome of the Donor Lower Extremity in Oral Cancer Patients after Fibula Flap Harvest

Ting-Yuan Liu[1], Yu-Chi Huang[1], Chau-Peng Leong[1], Chiung-Yi Tseng[1], Yur-Ren Kuo[2]

Background: After harvesting the fibula flap, pain, sensory disturbance, weakness of donor leg, reduced walking endurance, ankle instability, and lower walking speed had been reported. The aim of this study was to quantitatively assess functional outcome of regular home-based exercise on donor ankle strength, endurance, and walking ability after free fibula flap for mandibular reconstruction.

Methods: Fourteen patients were recruited. Objective isokinetic testing and a 6-min walk test (6MWT) were used to evaluate ankle strength/endurance and walking ability, respectively.

Results: There was a significant increase in the peak torque of ankle dorsiflexion/foot inversion of the healthy leg and ankle dorsiflexion/foot eversion of the donor leg after exercise ($p < 0.05$). After home-based exercise, there was reduced asymmetry in the peak torques of ankle dorsiflexion and foot eversion and the total work of foot eversion between the donor and healthy legs. In 6MWT, no significant difference was found between the walking distances before and after exercise.

Conclusion: Regular home-based exercise could improve the strength of ankle dorsiflexion and foot eversion of the donor leg, and get more symmetric ankle motor function between the donor and healthy legs.

(Biomed J 2013;36:90-95)

Key words: donor-site morbidity, fibula flap, home-based exercise, mandibular reconstruction

At a Glance Commentary

Scientific background of the subject

After harvesting the fibula flap, weakness of donor leg, reduced walking endurance and speed, and ankle instability had been reported. Regular home-based exercise could improve the strength of ankle dorsiflexion and foot eversion of the donor leg, and get more symmetric ankle motor function.

What this study adds to the field

The results of present study encourage the regular home-based exercise in oral cancer patient after fibula flap harvest.

The osteocutaneous free flap, which provides bone reconstruction and soft tissue coverage, has been widely used in reconstruction of mandibular defect after oral cancer ablation.[1-3] Many donor options have been described for osteocutaneous free flaps, including fibular, scapular, the iliac crest, and the radial forearm.[4-7] One of the most popular methods for mandibular reconstruction is the vascularized autogenous fibular graft, which was first reported by Taylor, *et al*., in 1975.[8] Advantages of the free fibula flap include longer bone length for harvesting, adequate length and dimension of the transfer vessel, and ample segmental blood supply.

Although concerns regarding donor-site morbidities often arise after the harvest of the free fibula flap, several studies have assessed donor-site morbidities after free fibula flap and the overall morbidity was considered low.[9-17] However, pain, sensory disturbance, muscle spasm, donor leg weakness, reduced ambulatory endurance, ankle stiffness, ankle joint instability, and lower preferred walking speed have been reported.[9-17] Farhadi, *et al.,*[16] described muscle torque deficit of foot eversion, peroneus longus muscle weakness, and the sequel of medial ankle osteoarthritis after harvest of the free fibula flap. Although Babovic, *et al.*,[13] showed that immediate postoperative rehabilitation programs were beneficial in early mobilization and achievement

From the [1]Department of Physical Medicine and Rehabilitation, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan, [2]Department of Plastic and Reconstructive Surgery, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University College of Medicine, Kaohsiung, Taiwan
Received: Mar. 1, 2012; Accepted: Jul. 10, 2012
Correspondence to: Dr. Yur-Ren Kuo, Department of Plastic and Reconstructive Surgery, Kaohsiung Chang Gung Memorial Hospital. 123, Dapi Rd., Niaosong, Kaohsiung 833, Taiwan (R.O.C.). Tel: 886-7-7317123 ext. 8002; Fax: 886-7-7354309;
E-mail: kuoyr@adm.cgmh.org.tw
DOI: 10.4103/2319-4170.110370

of preoperative ambulation ability, several patients with the free fibula flap still exhibited foot numbness, limited ambulatory distance, and difficulty walking stairs.

However, no studies have reported objective and quantitative evaluations of the effects of regular long-term exercise on donor-site morbidities after harvesting the free fibula flap. We hypothesized that a regular long-term exercise program would decrease donor-site morbidity. Therefore, the aim of this study was to investigate functional outcome of regular long-term exercise on ankle strength and endurance and walking ability in oral cancer patients after the free fibula flap for mandibular reconstruction.

METHODS

Twenty-four patients with oral cancer, who underwent free fibula osteocutaneous flap surgery after cancer ablation, were referred by surgeons to assess ankle muscle strength, the endurance of both normal healthy and donor legs, and performance in the 6-min walk test (6MWT) before a home-based exercise program. Patients were excluded if they had a history of surgery or trauma of the lower limbs, serious osteoarthritis of the knees or ankles, previous musculoskeletal impairment of the lower limbs, a history of neuropathy or myopathy, or usage of specific medications resulting in muscle weakness. A physiatrist at a rehabilitation clinic provided instructions for a 3-month home-based exercise program and encouraged the patients to regularly perform the exercises by themselves. We compared the ankle strength and endurance between both donor and normal healthy limbs before and after home-based exercise. The 6MWT was also analyzed before and after home-based exercises. The study was approved by the Medical Ethics Committee of the hospital and informed consent was obtained from each patient.

Objective measures of ankle muscle strength and endurance

Isokinetic testing, including ankle peak torques and the total works of both normal and donor legs, was performed using a Cybex II dynamometer (Cybex International, Inc. NY) before and after home-based exercises. The isokinetic testing was performed by an independent physical therapist. Before testing, the participants received instructions for all procedures and were allowed adequate time for practice. The examination was stopped to prevent further musculoskeletal injury or fatigue if the patient complained of any subjective pain or discomfort during testing. The isokinetic testing objectively assessed both ankle peak torques and the total works of ankle dorsiflexion (DF)/plantarflexion (PF) and foot inversion/eversion for the bilateral lower extremities. While performing these ankle motions, the participants were seated on a reclining chair with their knees flexed at 90 and their ankles in a neutral position with a thigh stabilizer pad. The patients were required to push their feet away from their ankles and then pull them toward their ankles or turn their feet inward and outward with maximum force against a resistant force for five repeats with an angular velocity of 30/sec. Testing for the peak torques of four ankle motions was carried out for three trials with a 3-min rest between each trial. The peak torques of ankle DF/PF and foot inversion/eversion were determined from the average of three trials. The total work was assessed by measuring the total work of 10 repeated ankle DF/PF or foot inversion/eversion movements with an angular velocity of 120°/sec. We used total work of ankle motions during the isokinetic evaluation as the indicator of the endurance of the ankle motion.[18]

The 6MWT

The 6MWT was used to evaluate walking ability on level ground. The patients were asked to walk to and fro on a 15-m walkway at a fast and comfortable speed for 6 min. All obstacles were removed from the walking route. The total walking distance in 6 min was recorded by a physical therapist and the time was measured by a stopwatch and was called every minute. The 6MWT was performed before and after home-based exercise to investigate changes in level-walking ability after regular exercise.

Home-based exercise program and questionnaire

A home-based exercise program that included climbing stairs or walking for at least 20 min (once daily, 3-5 days per week) at a comfortable speed was instructed by a physiatrist following the baseline isokinetic evaluation. The 24 patients were encouraged to perform the exercises as tolerated for at least 3 months. A self-report questionnaire was provided for all patients, in which they described the duration, frequency, type, and location of the home-based exercises. A regular exercise program was defined as exercise at least three times per week of at least 20 min duration for at least 3 months. All participating patients were asked to fill out the questionnaire before the final evaluation. Fourteen patients completed the regular home-based exercise program and underwent isokinetic testing and the 6MWT after exercise.

Statistical analysis

All collected data were analyzed by SPSS 12.0 software. The ankle peak torque, total work, and the 6MWT distance before and after home-based exercise were compared by the Wilcoxon signed-rank test. The significance level was set at $p < 0.05$.

RESULTS

Twenty-four patients with free fibula osteocutaneous flap surgery were referred to the rehabilitation clinic to assess ankle muscle strength, the endurance of legs, and 6MWT before a home-based exercise program. During the second evaluation after completing home-based exercise program, 4 of the 24 patients could not meet regular exercise criteria. Three patients were lost to follow-up. Two were diagnosed with recurrent oral cancer before the second evaluation. One suffered from foot pain due to gout arthritis. Finally, 14 men with oral cancer after mandibular reconstruction were enrolled in this study. The mean age of these patients was 54.1 years (range, 38-70 years), the mean duration from surgery to the baseline evaluation was 12.2 months (range, 5.1-27.6 months), and the mean area of skin paddle of fibula flap was 113.7 cm^2 (range, 48-160 cm^2) [Table 1]. In Table 2 it is observed that the peak torques of ankle PF, DF, inversion, and eversion in the healthy leg before exercise were 46.7, 22.2, 20.7, and 19.7 N m, respectively. After exercise, the peak torques of these four ankle movements in the healthy leg were 53.4, 29.9, 29.3, and 25.8 N m, respectively. There were significantly improved peak torques of ankle DF ($p = 0.03$) and foot inversion ($p = 0.03$) of the healthy leg after exercise. Total works of the ankle PF, DF, inversion, and eversion in the healthy leg were 125.9, 39.5, 99.9, and 81.2 J, respectively, before exercise and 144.7, 55.6, 104.5, and 96.4 J, respectively, after exercise. No significant differences were noted between total works of the healthy leg before and after exercise while performing these four ankle motions. For the donor leg [Table 3], we found that the peak torques of the ankle motions before exercise were 35.0, 18.1, 17.5, and 12.1 N m, respectively. After exercise, the peak torques of all ankle movements were increased to 38.7, 27.0, 19.4, and 18.1 N m, respectively. There were significantly increased peak torques of ankle dorsiflexion ($p = 0.02$) and eversion ($p = 0.01$) in the donor leg after exercise. Total works of these ankle movements in the donor leg were 76.1, 34.3, 64.6, and 60.3 J, respectively, before exercise and 79.0, 47.4, 74.0, and 83.0 J, respectively, after exercise. No significant differences were noted between total works of the donor leg before and after exercise while performing these four ankle motions.

Before home-based exercise, significantly decreased ankle peak torques in PF ($p = 0.004$), ankle DF ($p = 0.02$), and foot eversion ($p = 0.001$) were observed in the donor legs compared to that of the healthy legs. The total works of PF ($p = 0.001$), inversion ($p = 0.006$), and eversion ($p = 0.03$) were significantly impaired in the donor legs compared with that of the healthy legs before home-based exercise. No significant differences were found in the peak torque of foot inversion and the total work of the ankle DF between the donor and normal healthy legs before exercise [Figure 1]. After home-based exercise, there were significant differences only in the peak torques of the ankle PF ($p = 0.004$) and inversion ($p = 0.03$), and the total work of the ankle PF ($p = 0.002$) and foot inversion ($p = 0.03$) between the donor and healthy legs [Figure 2]. Therefore, similar peak torques of ankle dorsiflexion and foot eversion and similar total works of ankle dorsiflexion and foot eversion between the healthy and donor legs were found after exercise. The mean walking distance of the 6MWT was 401.7 m before exercise and 422.4 m after exercise [Table 4], which was

Table 1: Clinical parameters in oral cancer patients

Patients (*n*=14)	Characteristics
Age (mean±SE, years)	54.1±2.5
Men: Women	14:0
Body height (mean±SE, cm)	166.0±1.1
Body weight (mean±SE, kg)	59.0±3.0
Duration since surgery (mean±SE, months)	12.2±2.1
Skin paddle of fibula flap (mean±SE, cm^2)	113.7±8.9

Table 2: Comparison of muscle peak torque and endurance of the healthy leg between before and after exercise (*n*=14, mean±SE)

Variables	Before exercise	After exercise	*p*
Peak torque (30°/sec)			
Plantarflexion, Nm	46.7±3.2	53.4±4.5	0.05
Dorsiflexion, Nm	22.2±4.8	29.9±5.2	0.03*
Inversion, Nm	20.7±1.7	29.3±6.1	0.03*
Eversion, Nm	19.7±2.7	25.8±5.0	0.66
Total work (120°/sec)			
Plantarflexion, J	125.9±13.7	144.7±21.4	0.41
Dorsiflexion, J	39.5±14.6	55.6±15.2	0.31
Inversion, J	99.9±2.6	104.5±14.3	0.93
Eversion, J	81.2±8.7	96.4±8.8	0.20

*: Significant difference (p<0.05) by Wilcoxon signed-rank test

Table 3: Comparison of muscle peak torque and endurance of the donor leg between before and after exercise (*n*=14, mean±SE)

Variables	Before exercise	After exercise	*p*
Peak torque (30°/sec)			
Plantarflexion, Nm	35.0±2.7	38.7±3.6	0.64
Dorsiflexion, Nm	18.1±3.6	27.0±5.1	0.02*
Inversion, Nm	17.5±1.6	19.4±2.7	0.78
Eversion, Nm	12.1±2.0	18.1±3.0	0.01*
Total work (120°/sec)			
Plantarflexion, J	76.1±10.2	79.0±12.5	0.85
Dorsiflexion, J	34.3±10.7	47.4±12.7	0.40
Inversion, J	64.6±6.1	74.0±7.7	0.35
Eversion, J	60.3±9.0	83.0±15.3	0.15

*: Significant difference ($p < 0.05$) by Wilcoxon sign-rank test

Table 4: The 6-min walk test results before and after home-based exercise (*n*=14)

Variable	Before exercise (mean±SE)	After exercise (mean±SE)	p
6-min walk test (m)	401.7±18.5	422.4±18.7	0.30

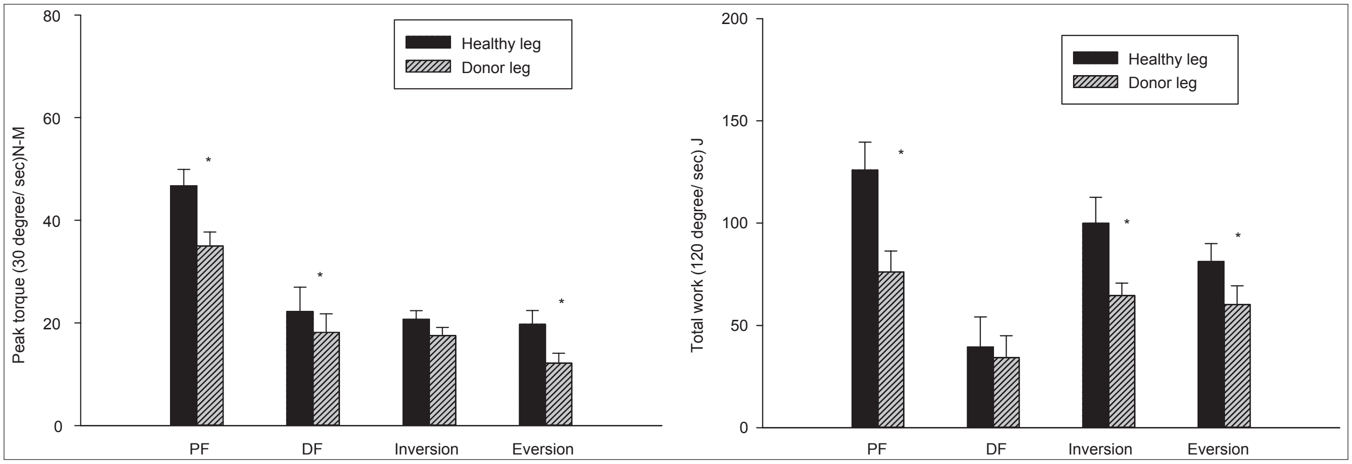

Figure 1: The peak torque and total work between donor and healthy legs before exercise. Before home-based exercise, there were significantly decreased ($p < 0.05$) ankle peak torques in ankle dorsiflexion, ankle plantarflexion, and foot eversion of donor legs, while comparing with contralateral healthy leg. The total works of PF, inversion, and eversion in the donor legs were significantly impaired ($p < 0.05$) while comparing with healthy leg. *Significant difference ($p < 0.05$) by Wilcoxon signed-rank test

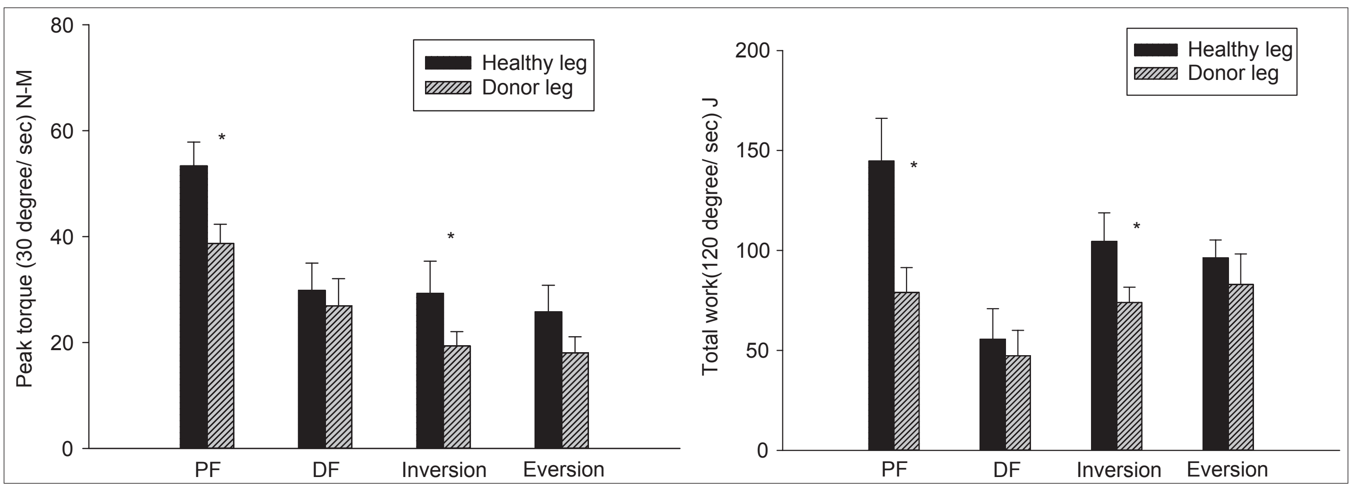

Figure 2: The peak torque and total work between donor and healthy legs after exercise. After home-based exercise, there were significant decreases in the peak torque of the ankle plantarflexion ($p = 0.004$) and foot inversion ($p = 0.03$), and the total work of the ankle plantarflexion ($p = 0.002$) and foot inversion ($p = 0.03$) between the donor and healthy legs. *Significant difference ($p < 0.05$) by Wilcoxon signed-rank test

not significant ($p = 0.30$).

DISCUSSION

After harvesting a free fibula flap, Anthony, *et al.*,[9] observed a significant decrease in the strength of the knee and ankle in the donor leg compared with the normal healthy leg. Furthermore, Farhadi, *et al.*,[16] reported decreased strength of the anterior tibial muscle, the posterior tibial muscle, and the peroneus longus muscle, and an eversion torque deficit on the donor side. The isokinetic findings of donor-site morbidities in our study were consistent with previous studies. This included decreased peak torques of the ankle DF, PF, and foot eversion, and total works of ankle PF, foot inversion, and eversion in the donor legs compared with normal healthy legs after a free fibula flap at least 6 months after surgery.

Anatomically, the extensor digitorum longus, extensor hallucis longus, flexor hallucis longus, tibialis posterior, peroneus brevis and longus, and several parts of the soleus muscle have bony attachments on the fibula. When harvesting a free fibula flap, the sacrifice of the partial fibula leads to bony detachments of several leg muscles. The loss of the bony attachments of the flexor, extensor, and evertor muscles of the leg lowers the strength and endurance of the ankle DF, PF, and foot eversion of the donor legs. Moreover, immobilization or partial weight bearing associated with donor-site pain, prolonged wound healing, or fibrotic changes of the exploring tissues of the donor legs after surgery may contribute to further attenuation of the overall motor functions of the ankle and lower extremity.

Functionally, the ankle PF and DF play important roles in daily activities, including generation of required torques during walking and stair climbing.[19-22] Moreover, patients with a fibula flap exhibited decreased ankle strength of the donor leg and asymmetric motor functions between the normal healthy and donor legs. Decreased muscle strength of the lower leg was linked to ankle instability, poor dynamic balance, lower walking speed, functional limitation, and falling risk in older people.[22-25] The asymmetric strength and endurance of the bilateral lower extremities would result in unequal weight bearing while standing or an abnormal gait pattern while walking, and induce further complications such as tendinopathy or degenerative change of the knee or ankle. In our study, we prescribed a general and simple home-based exercise program that included walking or stair climbing exercises for patients. We considered that simple exercises and a convenient environment for exercises would result in better compliance for completing exercise program. Therefore, the ankle motor function and walking ability could get improved by simpler and more compliable exercises. The results revealed that home-based exercise reduced the asymmetry in ankle dorsiflexion, foot eversion strength, and foot eversion endurance between the donor and normal healthy legs. The increased ankle motor function after exercise may decrease functional instability and potential long-term morbidity of the lower extremities after the harvest of a free fibula flap for mandibular reconstruction. After exercise, there were still significant differences in the peak torques of ankle PF and foot inversion, and the total works of the ankle PF and foot inversion between the donor and healthy legs. The findings may be associated with lack of a specific exercise prescription based upon these motor deficits in the donor leg.

The 6MWT is an objective measure of walking ability and cardiopulmonary function. Fulk, *et al.,*[25] reported that the 6MWT is a strong predictor of community walking activity in high-functioning stroke patients and showed that there was no significant difference in steps taken per day during a 7-day period between healthy participants and stroke patients who were able to walk at least 367 m in the 6MWT. Shumway-Cook, *et al.,*[26] also found that the non-disabled elderly could walk 366.7 m per trip in the community. Therefore, we consider that the enrolled patients walked less than 367 m in the 6MWT, which may indicate limited community walking ability, which could impact their instrumental activities of daily living. In our study, no significant difference was observed between the mean walking distances of the 6MWT before and after exercise training. However, 5 (35.7%) of 14 patients walked less than 367 m in the 6MWT before exercise. Two of these five patients showed greater walking ability (330-420 m and 345-480 m, respectively), which may lead to better community participation after regular home-based exercise.

In our study, the asymmetry of both strength and endurance of ankle PF and endurance of foot inversion between the normal and donor legs did not show a statistically significant improvement after exercise. Therefore, we suggest that strengthening or endurance exercises should be specifically designed for the muscle groups associated with the strength and endurance of ankle PF and foot inversion instead of general home-based exercise for patients after a free fibula flap. The limitations of this study include: (1) a possible self-report bias in the exercise questionnaire, (2) lack of a control group without exercise, (3) the small sample size, and (4) lack of an individualized exercise prescription based upon the results of motor deficits in the donor leg.

In summary, regular home-based exercise could improve the strength of ankle dorsiflexion and foot eversion and the endurance of foot eversion in the donor leg to get more symmetric ankle function between bilateral lower legs. These findings suggest that a general home-based exercise program could be recommended to improve ankle dorsiflexion and foot eversion strength of the donor leg and get more symmetric ankle motor function between donor and healthy legs in oral cancer patients after the harvest of a fibula flap.

Acknowledgments

We thank the co-workers in Chang Gung Memorial Hospital–Kaohsiung Medical Center. This study was supported by grants CMRPG880041 and CMRPG880042 provided by the Chang Gung Medical Research Fund.

REFERENCES

1. Wei FC, Seah CS, Tsai YC, Liu SJ, Tsai MS. Fibula osteoseptocutaneous flap for reconstruction of composite mandibular defects. Plast Reconstr Surg 1994;93:294-304.
2. Shpitzer T, Neligan PC, Gullane PJ, Freeman JE, Boyd BJ, Rotstein LE, *et al*. Oromandibular reconstruction with the fibular free flap. Analysis of 50 consecutive flaps. Arch Otolaryngol Head Neck Surg 1997;123:939-44.
3. Hidalgo DA, Pusic AL. Free-flap mandibular reconstruction: A 10-year follow-up study. Plast Reconstr Surg 2002;110:438-49.
4. Wei FC, Chen HC, Chuang CC, Noordhoff MS. Fibular osteoseptocutaneous flap: Anatomic study and clinical application. Plast Reconstr Surg 1986;78:191-200.
5. Urken ML, Bridger AG, Zur KB, Genden EM. The scapular osteofasciocutaneous flap: A 12-year experience. Arch Otolaryngol Head Neck Surg 2001;127:862-9.
6. Puxeddu R, Ledda GP, Siotto P, Pirri S, Salis G, Pelagatti CL, *et al*. Free-flap iliac crest in mandibular reconstruction following segmental mandibulectomy for squamous cell carcinoma of the oral cavity. Eur Arch Otorhinolaryngol 2004;261:202-7.
7. Militsakh ON, Wallace DI, Kriet JD, Tsue TT, Girod DA. The role of the osteocutaneous radial forearm free flap in the treatment of mandibular osteoradionecrosis. Otolaryngol Head Neck Surg

2005;133:80-3.

8. Taylor GI, Miller GD, Ham FJ. The free vascularized bone graft. A clinical extension of microvascular techniques. Plast Reconstr Surg 1975;55:533-44.

9. Anthony JP, Rawnsley JD, Benhaim P, Ritter EF, Sadowsky SH, Singer MI. Donor leg morbidity and function after fibula free flap mandible reconstruction. Plast Reconstr Surg 1995;96:146-52.

10. Vail TP, Urbaniak JR. Donor-site morbidity with use of vascularized autogenous fibular grafts. J Bone Joint Surg Am 1996;78:204-11.

11. Shpitzer T, Neligan P, Boyd B, Gullane P, Gur E, Freeman J. Leg morbidity and function following fibular free flap harvest. Ann Plast Surg 1997;38:460-4.

12. Tang CL, Mahoney JL, McKee MD, Richards RR, Waddell JP, Louie B. Donor site morbidity following vascularized fibular grafting. Microsurgery 1998;18:383-6.

13. Babovic S, Johnson CH, Finical SJ. Free fibula donor-site morbidity: The Mayo experience with 100 consecutive harvests. J Reconstr Microsurg 2000;16:107-10.

14. Zimmermann CE, Borner BI, Hasse A, Sieg P. Donor site morbidity after microvascular fibula transfer. Clin Oral Investig 2001;5:214-9.

15. Bodde EW, de Visser E, Duysens JE, Hartman EH. Donor-site morbidity after free vascularized autogenous fibular transfer: Subjective and quantitative analyses. Plast Reconstr Surg 2003;111:2237-42.

16. Farhadi J, Valderrabano V, Kunz C, Kern R, Hinterman B, Pierer G. Free fibula donor-site morbidity: Clinical and biomechanical analysis. Ann Plast Surg 2007;58:405-10.

17. Momoh AO, Yu P, Skoracki RJ, Liu S, Feng L, Hanasono MM. A prospective cohort study of fibula free flap donor-site morbidity in 157 consecutive patients. Plast Reconstr Surg 2011;128:714-20.

18. Huang YC, Leong CP, Pong YP, Liu TY, Kuo YR. Functional assessment of donor-site morbidity after harvest of a fibula chimeric flap with a sheet of soleus muscle for mandibular composite defect reconstruction. Microsurgery 2012;32:20-5.

19. Gross MM, Stevenson PJ, Charette SL, Pyka G, Marcus R. Effect of muscle strength and movement speed on the biomechanics of rising from a chair in healthy elderly and young women. Gait Posture 1998;8:175-85.

20. Judge JO, Ounpuu S, Davis RB, 3rd. Effects of age on the biomechanics and physiology of gait. Clin Geriatr Med 1996;12:659-78.

21. Bendall MJ, Bassey EJ, Pearson MB. Factors affecting walking speed of elderly people. Age Ageing 1989;18:327-32.

22. Suzuki T, Bean JF, Fielding RA. Muscle power of the ankle flexors predicts functional performance in community-dwelling older women. J Am Geriatr Soc 2001;49:1161-7.

23. Whipple RH, Wolfson LI, Amerman PM. The relationship of knee and ankle weakness to falls in nursing home residents: An isokinetic study. J Am Geriatr Soc 1987;35:13-20.

24. Sieri T, Beretta G. Fall risk assessment in very old males and females living in nursing homes. Disabil Rehabil 2004;26:718-23.

25. Fulk GD, Reynolds C, Mondal S, Deutsch JE. Predicting home and community walking activity in people with stroke. Arch Phys Med Rehabil 2010;91:1582-6.

26. Shumway-Cook A, Patla AE, Stewart A, Ferrucci L, Ciol MA, Guralnik JM. Environmental demands associated with community mobility in older adults with and without mobility disabilities. Phys Ther 2002;82:670-81.