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Gait changes in patients after reconstruction of facial bones with fibula and iliac crest free vascularized flaps

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Purpose: Patients with malignant tumours of the oral cavity require its surgical removal and reconstruction of the bone and soft tissues. The grafts are obtained either from leg (fibula) or pelvis (iliac crest). The removal of grafts from the locomotor apparatus can impair the gait. The aim of this study was to find out how the localization of donor site influences the gait pattern. *Methods:* Results obtained for 30 patients were analyzed (16 fibula graft, 14 iliac crest graft). Patients underwent instrumented gait analyses three times (VICON system): before surgery, 2–4 month after the surgery, and 4–8 months after the surgery. *Results:* In both groups several gait parameters were changed. Two parameters changed in both groups: gait speed and cadence. In patients receiving iliac crest graft the changed gait variables were: pelvic rotation, hip range in sagittal plane (operated side), knee range in sagittal plane (operated side), foot dorsiflexion in swing on both sides. In patients receiving fibula flap the changed gait variables were: tilt, range motion of the tilt, minimum hip flexion (operated side), time to maximum knee flexion (non-operated side), GGI (non-operated side) and step length (non-operated side). *Conclusions:* The primary gait deviations occurring after surgery, and the compensatory mechanisms which subsequently arise depend on the localization of graft donor site. The results indicate that the patients in whom fibula flap was used have less problems with gait pattern after the surgery than the patients receiving iliac crest graft.

Key words: *gait pattern, reconstructive surgery, malignant tumour, oral cavity*

1. Introduction

Patients with malignant tumours of the oral cavity invading maxilla or mandible require surgical removal of the tumour and reconstruction of the bone and soft tissues. The grafts are obtained either from leg (fibula) or pelvis (iliac crest). The type of surgery may not have an influence on the outcome of the treatment [2]. The removal of bone and soft tissues from the locomotor apparatus can impair the gait, and could influence quality of life. To our knowledge this aspect of reconstructive surgery has not been investigated in detail. The aim of this study was to find out how the localization of donor site influences the gait pattern of these patients. When the surgeons have a choice from which place the graft can be taken, results of analysis presented in this paper could guide selection of the flap, and thus, minimize the side effects of the procedure.

Free fibula flap (FFF) [5]

The length of the fibula, consistent blood supply and relative ease of harvesting of this flap make it very useful in mandible reconstruction. The head of the fibula does not take part in the knee joint, but the distal fibula is part of the ankle joint. To avoid ankle disability distal six centimeters of the fibula should be preserved. The skin paddle can be marked on an axis slightly posterior to the axis of the bone. A paddle up to 5 centimeters wide can be closed primarily. Har-

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vesting of this flap involves resection of a fragment of fibula and parts of soleus muscle if perforators to the skin paddle running through the muscle are found. Surgical injury to peroneal muscles and nerve can occur and in patients with insufficient anterior tibial vessels blood supply to the foot can be reduced. These surgical lesions can affect mobility and strength of leg, and adversely influence the gait.

Iliac Crest Flap (ICF)

The ICF provides a large segment of cancellous bone up to 15 centimeters long and 6 centimeters wide. The FFF contains only cortical bone. In addition, when the peroneal artery flow is not adequate or the lower extremities have been injured, the ICF is the best choice when a large bone fragment is necessary. The ICF is harvested without a skin paddle. Harvesting the ICF may include parts of oblique, transversalis and illiacus muscles, part of attachments of gluteal muscles and may cause damage to lateral femoral cutaneous nerve. Because full thickness of abdominal wall without peritoneum is excised, there is a possibility of hernia formation and polypropylene mesh may be used to reinforce the abdominal wall. These surgical lesions do not directly influence mobility of the lower limb.

2. Materials and methods

Patients

40 patients agreed to participate in the study. All patients were diagnosed with malignant tumours of oral cavity and were treated in Head and Neck Cancer Department, Cancer Center M. Sklodowska-Curie Memorial Institute. Four patients eventually could not undergo surgery, 6 did not finish the study due to post-surgical complications or death. Results obtained in 30 patients who completed the whole experimental protocol (19 women, 21 men, aged 21–70) were analysed. In 16 patients – free fibula flap (FFF) was used (FFF group – FFFG) and in 14 it was ilicac crest flap (ICF) (ICF group – ICFG). All patients were undergoing oncological treatment (chemotherapy and radiotherapy) prior to the surgery. Patients were not randomly assigned to the groups, although the patients recruited to the study were as similar in both groups as possible in oncological patients. Patients in whom only one graft site was possible for medical reasons were excluded from the present study. The patients could express their preferences for the graft site.

Methods

Patients three times underwent instrumented gait analyses in Dept. of Paediatric Rehabilitation, The Children's Memorial Health Institute: before surgery, 2 to 4 month after the surgery, and 4 to 8 months after the surgery. All patients started rehabilitation 1 day after surgery and continued for 3 weeks. The rehabilitation program was done in Dept. Physical Therapy, Cancer Center M. Sklodowska-Curie Memorial Institute, Warsaw. The gait analysis was performed at the beginning of the study using 6 camera VICON460 and later using 12 camera VICON MX system. The Plug-In-Gait marker set and models were used in both systems. During each session, at least 6 trials were recorded. Patients were instructed before the collection of data to walk with their natural, preferred speed. All data were averaged using Polygon software. The spatio-temporal and kinematic data were extracted from the Polygon reports. The following gait parameters were analysed: gait velocity and cadence (normalized to a percent of normal reference data [2]), pelvic tilt, range of pelvic tilt, pelvic retraction, pelvic range of motion in transversal plane, pelvic obliquity, hip and knee ranges of motion in sagittal plane, minimum hip flexion, knee flexion at initial contact, ankle dorsiflexion in stance and swing phases, foot progression angle, step length (normalized to percent of normal reference data [6]). From kinematic and spatio-temporal data obtained, Gillettte Gait Index (GGI) was calculated [7]. The GGI is a single number, which quantifies the deviation of patient's gait pattern from normal gait pattern. The calculations and analyses were performed separately for operated (affected – A) and non-operated side (non-affected – NA).

Statistical analysis

As variables were non-normally distributed the nonparametric tests were used for comparisons. Comparisons between FFFG and ICFG were performed using Mann–Whitey U test for independent samples. For changes of gait pattern in time the Friedman ANOVA test for paired groups was used. All calculations were done with MedCalc© software. Statistical significance was set at $p < 0.05$.

3. Results

In both groups several gait parameters were changed in the post-surgery period in respect to pre-surgery gait pattern. Two parameters that changed in both groups were gait speed and cadence (Table 1).

Table 1. Gait speed and cadence (normalized to a percent of sex and age matched reference data)

Variable	ICFG		FFFG	
	median	10–90 percentile	median	10–90 percentile
Gait speed pre-op	80	43–106	88	56–100
Gait speed post-op I	70	51–101	73	39–95
Gait speed post-op II	77	57–107	87	48–99
Cadence pre-op	90	66–100	90	71–100
Cadence post-op I	83	64–97	82	59–93
Cadence post-op II	88	73–96	82	59–93

In ICFG, the gait variables that changed in the post-surgery period (statistically significant) were pelvic rotation, hip range of motion in sagittal plane on the operated side, knee range of motion in sagittal plane on the operated side, foot dorsiflexion in swing phase on both sides (Fig. 1).

In FFFG, the gait variables that changed during post-surgery period were (statistically significant): tilt, range motion of the tilt, minimum hip flexion on the operated side, time to maximum knee flexion on the non-operated side, GGI on the non-operated side and step length on the non-operated side (Fig. 2).

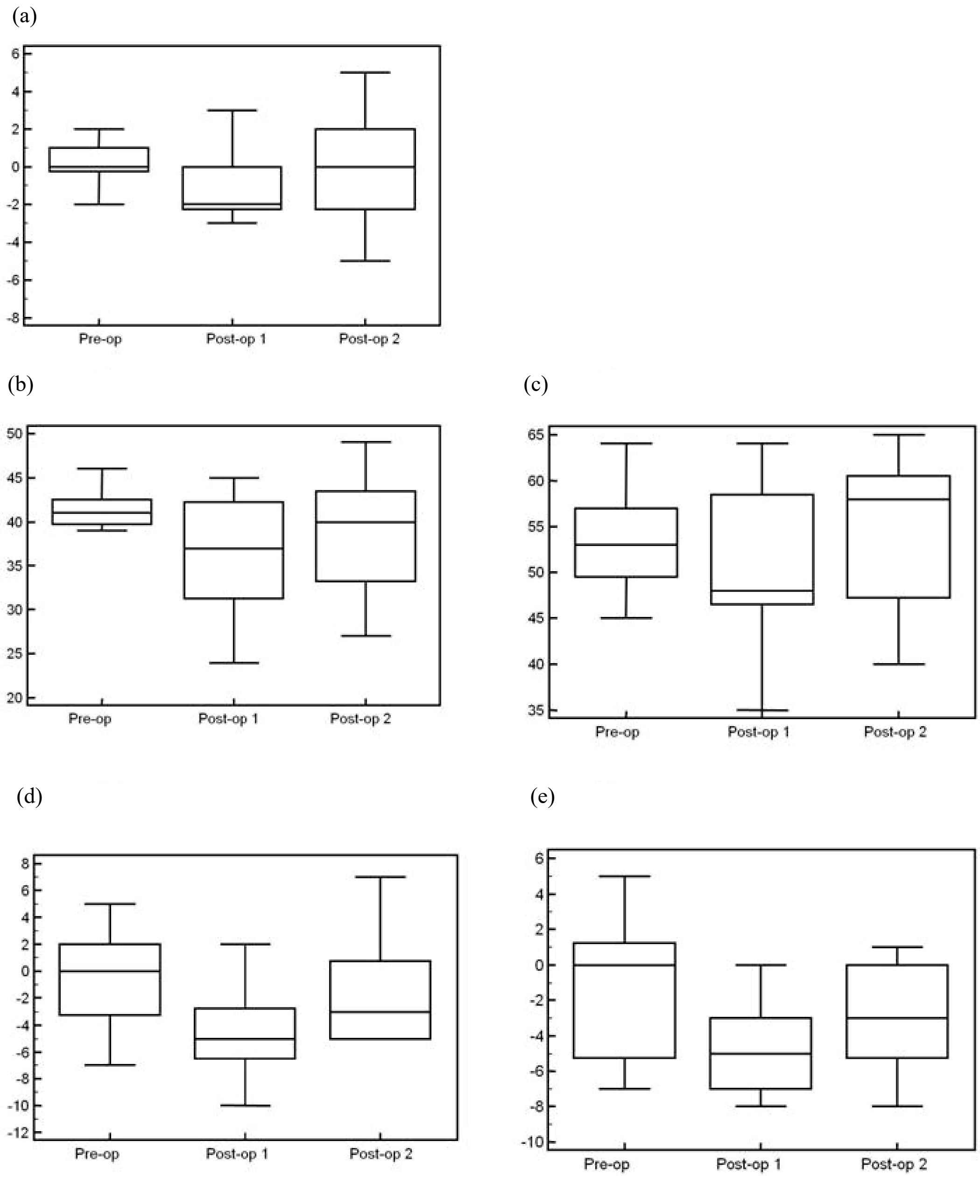

Fig. 1. The gait variables that were changing during post-surgery period in ICFG group: (a) Pelvic rotation [°], (b) Hip range of motion in sagittal plane on the operated side [°], (c) Knee range of motion in sagittal plane on the operated side [°], (d) Foot dorsiflexion in swing phase on the operated side [°], (e) Foot dorsiflexion in swing phase on the non-operated side [°]

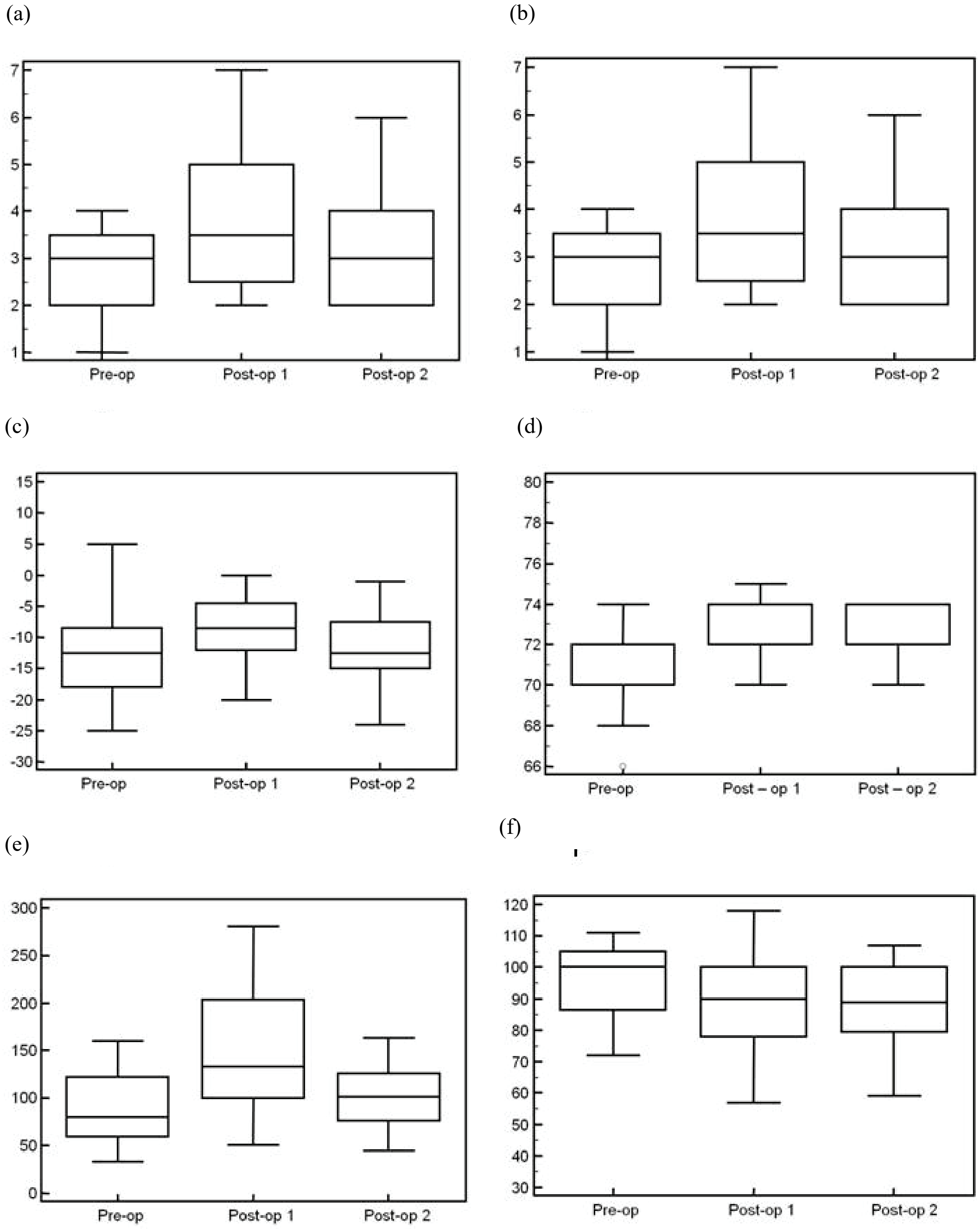

Fig. 2. The gait variables which were changing during post-surgery period in FFFG group: (a) Pelvic tilt [°], (b) Range of pelvic tilt [°], (c) Minimum hip flexion on the operated side [°], (d) Time to maximum knee flexion on the non-operated side [% of the gait cycle], (e) GGI on the non-operated side, (f) Step length on the non-operated side (normalized to % of age and sex matched reference data)

4. Discussion

The results of the instrumented gait analysis show that in both ICFG and FFFG the gait pattern worsens after the surgery, but improves after rehabilitation. The primary gait deviations occurring after surgery and the compensatory mechanisms which subsequently arise depend on the localization of graft donor site.

In both groups both gait velocity and cadence decreased after the surgery and improved in time, as revealed by the third gait analysis (Table 1). The pre-operative gait velocity and cadence were decreased in both groups due to pre-operative oncological treatment (chemo- and radiotherapy). In FFFG the speed at the time of the third analysis reached pre-operative value, while in ICFG it was still reduced.

The following gait parameters changed in ICFG after the surgery (Fig. 1): pelvic rotation (increased range), range of motion of the hip in sagittal on the affected side (decreased), knee range of motion in the sagittal plane on the affected side (decreased), and foot position in swing in both legs (increased plantarflexion). The hip and knee motion ranges improved at the time of the third gait analysis, compared to post-surgical examination (Figs. 1b and 1c), but were still diminished in comparison with the pre-operatives values. The plantarflexion in the swing phase in both legs, which appeared after the surgery, was present during the third gait analysis, although its value was smaller. These results suggest that although the grafts were taken from the iliac crest, the ability to perform proper movement in the sagittal plane was affected not only in the hip, but also in the knee. As the direct mechanical cause of these disturbances could not be established, one could speculate that the amount of the scars and grafts taken negatively influence whole lower limb kinematic chain. The high variability of the pelvic rotation which appeared after the surgery and remained present in the third gait analysis could indicate that the patients tried to use pelvis to compensate for the decreased ranges of motion in hip and knee on the affected side. This is indirectly confirmed by the fact that the step length remained unchanged in time. The plantarflexion which appeared in both legs after the surgery could point out to overall patients' weakness, caused by the coupled effect of surgery and oncological treatment.

The following gait parameters changed in FFFG after the surgery (Fig. 2): pelvic tilt (increased in the post-surgical analysis), range of pelvic tilt (increased), hip extension at the end of the stance phase in the affected leg (decreased), time to maximal knee flexion in the non-affected leg (increased), GGI of the non-affected leg (increased), and step length of the non-affected leg (decreased). In the third gait analysis the pelvic range and hip extension were the same as in pre-operative examination (Figs. 2a and 2c), range of pelvic tilt and GGI improved, compared to the second gait analysis, but were still increased in comparison to pre-operative examination (Figs. 2b and 2e), while time to peak knee flexion and step length of the non-affected side were the same as during the second gait analysis (Figs. 2d and 2f). The decreased hip extension at the end of the stance phase in the affected limb in the second gait analysis could be linked to the post-surgical changes in the lower leg. During hip extension via the movement of the kinematic chain of the whole leg, the elongation of the soft tissue could be painful, hence the patients avoid pain by limiting hip extension. The slightly increased pelvic tilt together with increased tilt range were compensatory mechanisms, which both could influence the step length on the non-affected leg. The increased GGI of the affected leg could suggest that the compensatory mechanisms were arising on this side.

It should be pointed out that the values from all three examinations were within normal limits of the gait lab [8], (upper limit for the normal gait is 150). Therefore, these disturbances and compensations mechanisms had to be subtle ones, and difficult to pinpoint.

There is very limited data available to compare the results of this study with. Lee and co-workers [4] analysed gait pattern of 20 patients after fibula flap surgery. They found that patients had decreased step length, cadence and gait speed postoperatively after 1 month, but these changes disappeared 3 months after surgery. The only change that remained was increased plantarflexion in swing. These results are partly contradictory to our results. For cadence and gait speed our results were similar to the ones reported by Lee, but we did not observe increased plantar flexion in FFFG, and the decrease of step length was present only in non-affected leg. This discrepancy of the results could be attributed to the different time-points in which the gait analysis was done in both studies. Our second examination was done 2 to 4 months post-operatively, and it corresponds to the third examination time of the Lee's study. The lack of planatarflexion in our patients could be attributed to the early rehabilitation program they underwent, which included strength training.

The study by Kramers de Quervain et al. [3] showed that patients who suffered from open injury fracture of the lower limb or ankle and had a soft tissue surgery with muscle-flap more than two years after the accident displayed some asymmetry in gait pattern only during very fast or uphill walking. Archer and co-workers [1] performed clinical study of 24 moths follow-up of 381 patients after lower-limb trauma and reconstruction. They found that the gait abnormalities present in some patients were correlated with their age and balance problems, but not with the past accidents.

5. Conclusions

The shortcoming of this study is limited number of patients. Out of 40 enrolled patients only 29 finished the full protocol (30 % drop-outs). Nevertheless, the results indicate that the patients in whom FFF was used have less problems with gait pattern after the surgery than the patients with ICF. This study is the first to compare gait patterns after two reconstruction techniques. Good results in FFFG are supported by one study that investigated patients with FFF and indirectly by studies showing favourable results in patients after severe trauma. Causes of gait disturbances in ICFG need further investigation.

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