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Risk Factors of Avulsion Fracture after Iliac Crestal Flap for Jaw Reconstruction

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Abstract: The iliac crestal flap is often used in maxillofacial reconstruction surgery because it has a similar bone contour to jaw bone. However, complications occur frequently in this flap, and the avulsion fracture of the anterior superior iliac spine (ASIS) occurs only in rare cases. The purpose of this study is to evaluate the risk factors affecting fractures that may occur after iliac crestal flap harvesting. In this study, we performed preoperative and postoperative CT scans of the iliac bones of 22 patients who underwent iliac crestal flaps between February 2013 and July 2019. Three of these patients had fractures within 1 month after surgery. After converting DICOM files to a three-dimensional model using Mimics software, some reference points were defined for analysis. The patients were classified into fracture and non-fracture groups. The patients' age and sex, harvested bone, residual bone and absolute bed rest (ABR) periods were investigated. The patients' age and sex were not associated with fracture occurrence. There was a statistically significant difference in the width of the anterior–superior part of residual bone. The fracture group showed statistically significantly shorter ABR periods. In the case of the iliac crestal flap, it was found that the factors that can affect the occurrence of fractures are the width of the residual bone and the ABR period. Iliac avulsion fracture can be prevented when the remaining bone is sufficient and the ABR period is prolonged sufficiently.

Keywords: iliac crestal flap; mandible reconstruction; maxilla reconstruction; donor site morbidity; iliac bone fracture

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1. Introduction

Bone grafts are frequently used for reconstruction in maxillofacial surgery, such as in cancer surgery, trauma, and severe bone resorption, and for the correction of congenital deformities [1]. The reconstruction of the jaw can be performed using microvascular composite free flaps with the scapula, iliac crest, and fibula [2,3]. The surgeon chooses the donor site based on several factors such as the size and location of the defect and the condition of the patient [4]. The iliac crest has been a common donor site for mandible and maxilla reconstruction because it provides the highest concentration of osteocompetent cells and available volume [1,5–12]. Furthermore, the iliac crest can be accessed with a reasonable surgical method [7,8,13]. For these reasons, iliac crestal bone has been used for bone grafts for various defects as the gold standard [7,8,14,15], and it is suitable for both free non-vascularized and vascularized bone grafts [16]. In addition, compared to the fibula flap, the iliac crestal flap has benefits in terms of the bone contour for the reconstruction of the jaw, such as adequate bone height and width for dental implantation and optimal soft tissue reconstruction using internal oblique muscle without the need for a skin flap [3]. Another important factor to consider when selecting a donor site is its morbidity after grafting [4]. Urken et al. reported minimal donor-site morbidity after over 1 year of follow-up when using the iliac crestal osseomyocutaneous microvascular free flap [17].

Conventionally, the anterior iliac crestal flap has been harvested as a bicortical form, which can lead to an abnormal hip contour, hernia, severe bleeding tendency, and gait disturbance [3]. The monocortical iliac crestal flap may reduce the donor-site morbidity after harvesting a large amount of bone segment [3]. Recently, computer-assisted surgery has become popular in oral and maxillofacial surgery. Most reconstructive surgeries are performed by preoperative simulation and surgical guide fabrication. Therefore, it is important to determine the optimal bone harvesting site in the anterior iliac crest for successful reconstruction during simulation for preoperative planning. Serious complications related to the iliac crestal flap are rare, but when they do occur, they cause serious problems [14]. Major complications have been reported, such as chronic pain, neurological or vascular injury, infection, hematoma, intestinal prolapse, cosmetic defect, and iliac crest avulsion fracture [5,6,8,11,14,15,18–20]. Among these complications, fractures of the anterior iliac crest following bone graft are very rare [5,21,22]; only a few cases have been reported in the literature [21,23–27]. The stress fracture of the anterior iliac crest after the harvesting of the iliac crestal flap has been reported in a few works, which may cause significant problems and increase morbidity [18]. Although the avulsion fracture of the anterior superior iliac spine (ASIS) after bone grafting is not common, the fracture could occur more commonly in older patients than reported in the literature [21]. The treatment of fractures usually focuses on walking assistance after a short break until the fracture heals, but sometimes additional surgical treatment is required to remove avulsed bone or open reduction and internal fixation [21]. Previous studies have reported that the iliac crestal flap in elderly patients with osteoporosis may increase the risk of iliac crest fractures [21,23,28]. Some authors have reported that harvesting sites and surgery methods also could affect the fracture risk [18,29–32]. An understanding of the bone harvesting techniques and management of the risk factors for fracture could help prevent iliac crest fractures after bone grafting.

The aim of this study was to evaluate the risk factors associated with avulsion fracture after iliac crestal flap harvesting for jaw reconstructions.

2. Patients and Methods

2.1. Patients

This study was conducted with 22 patients who underwent iliac crestal flap surgery for jaw reconstruction from February 2013 to July 2019. The patient's medical records and pre- and post-operative CT scan data of iliac bones were evaluated. Within one month after surgery, fracture of the iliac bone occurred in three patients, of which two patients required surgical reduction and one patient was treated with conservative treatment by maintaining bed rest for six weeks.

Patient 1 was a 70-year-old male who underwent reconstruction surgery using the iliac crestal flap for mandibular reconstruction. The patient had absolute bed rest for 6 days, then conducted a wheelchair ambulation after the 7th postoperative day (POD) and was discharged on the 18th POD. About a month after the operation, he was complaining of pain in the donor site while walking downhill. An x-ray of the pelvis was taken and he was diagnosed with an anterior superior iliac spine (ASIS) avulsion fracture (Figure 1a). He underwent open reduction and internal fixation. There was no gait disturbance after surgery during 18 months follow-up.

Patient 2 was a 78-year-old female who had a partial maxillectomy with verrucous carcinoma and reconstructive surgery with a DCIA flap. She complained of pain in the donor site on the 16th POD when moving out of bed. There was a fracture of the ASIS on the donor side (Figure 1b). She needed ABR for about a month or more and was treated using symptomatic treatment and gait training with physical therapy in the department of rehabilitation medicine. At 32 days after the fracture, callus formation was observed on x-ray and CT images. Due to her old age and the decrease of muscle, she had 4 weeks of walking practice. She was on follow-up for more than 2 years and she did not have difficulties in walking at her final check-up.

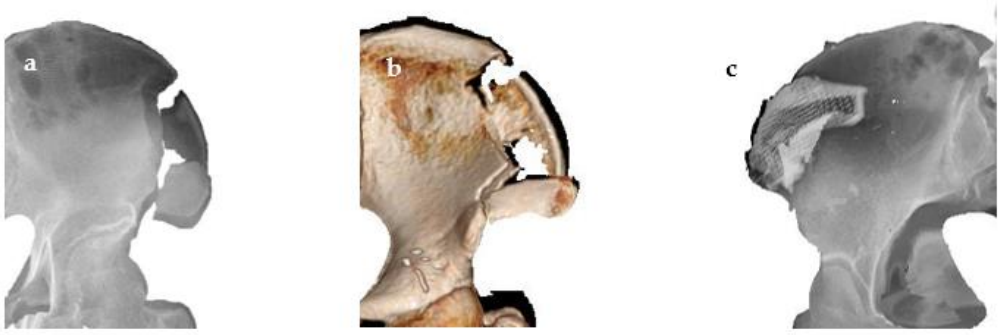

Figure 1. Three-dimensional modeling of fractured patients; (**a**) the fractured iliac bone images of patient 1. The patient had to undergo open reduction and internal fixation; (**b**) fractured pelvis of patient 2. Conservative treatment led to the recovery of the fracture site; (**c**) 3D reconstruction model of patient 3, showing the reduced fracture segment after reduction with a 3D titanium implant.

Patient 3 was a 53-year-old male with reconstruction surgery using an iliac crestal flap after segmental mandibulectomy. After the third POD, he was allowed to move using a wheelchair, and after the fifth POD, gait practice was performed with support from the nursing staff. He complained about the sound from the donor-side pelvis bone at the 24th POD. An avulsion fracture of the ASIS was founded in pelvis x-ray and CT scan images (Figure 1c). A reductive operation was performed with a titanium mesh. He was discharged after hospitalization for about one month, and no gait disturbance was observed in follow-up checks for more than 3 years.

2.2. Operation and Postoperative Care

All surgeries were performed by a surgeon of the oral and maxillofacial surgery. The anterior approach was used for the harvesting of iliac crest grafts. Prophylactic antibiotics were given intravenously after the induction of general anesthesia. The iliac bone and internal oblique muscle flap were harvested from the iliac crestal area with deep circumflex iliac vessels. A vacuum drain was used in the all cases to prevent unnecessary hematoma.

The patients were instructed to stabilize for a certain period of time after surgery, and the range of activities was gradually increased, including the period of movement using assistive devices such as wheelchairs, depending on the patient's condition.

2.3. Measurement

Iliac CT scan data of patients were organized into DICOM files. After converting DICOM files to a three-dimensional model and photomapping the postoperative pelvic radiographs using Mimics software, we defined some reference points for analysis.

Point A was defined as the contact point by drawing a vertical line on the boundary of the harvested bone segment from the ASIS. Point B was defined as the contact point by drawing a vertical line on the boundary of the harvested bone segment from point C. Point C was defined as the most concave point between the ASIS and anterior inferior iliac spine. Then, we measured the distance between the ASIS and Point A (DA), between Point B and Point C (DB) and the width at Point A (WA) and Point B (WB) using Mimics software. We also measured the midpoint width of the superior and inferior part (SW, IW), height and length of the harvested bone segment (Figure 2). The age and sex of the patients and the ABR period were investigated. We set up the fracture group and the non-fracture group to statistically analyze the difference between groups.

2.4. Statistical Methods

The Mann–Whitney test and the independent *t*-test were used to compare the samples according to the age, sex, ABR period and characteristics of the donor site and harvested bone. Statistical computation was performed with SPSS 20.0 (IBM, New York, NY, USA) using of Windows 10 Pro (Microsoft, Redmond, WA, USA).

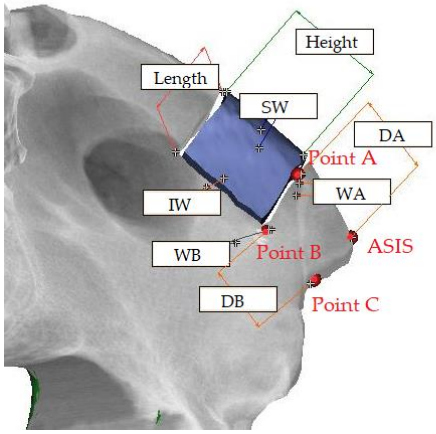

Figure 2. Reference points and the distance between reference points of a non-fracture patient. Point A was defined as the contact point by drawing a vertical line on the boundary of the harvested bone segment from the ASIS. Point B was defined as the contact point by drawing a vertical line on the boundary of the harvested bone segment from point C. Point C was defined as the most concave point between the ASIS and anterior inferior iliac spine. (DA: distance between the ASIS and Point A; DB: distance between Point B and C; WA: width at point A; WB: width at point B; SW: midpoint width on the superior part of harvested bone; IW: midpoint width on the inferior part of harvested bone).

3. Results

3.1. Patient Characteristics

The gender makeup of the patients was 11 males and 11 females, and this factor was not associated with fracture incidence (p = 0.557, Pearson's correlation analysis) (Table 1).

Table 1. Classification of patients by sex.

	Non-Fracture	Fracture	Total
Male	9	2	11
Female	10	1	11
Total	19	3	22
p-value		0.295	

The mean (S.D) age of the patients at the time of operation was 55.9 (19.30) (range 15–80, median 62). There was no correlation between fracture incidence and age (p = 0.295, Pearson's correlation analysis) (Table 2).

Table 2. Classification of patients by age.

Age	Non-Fracture	Fracture	Total
10–19	2	0	2
20–29	1	0	1
30–39	1	0	1
40–49	2	0	2
50–59	4	1	5
60–69	7	0	7
70–79	6	2	8
<80	1	0	1
p-value		0.557	

3.2. Anatomical Characteristics

The average length of DA was 16.88 ± 4.54 mm in the non-fracture group; it was 22.28 ± 9.80 mm in the fracture group, and there was no statistically significant difference.

WA was 13.63 ± 1.58 mm on average in the non-fracture group and 17.05 ± 3.71 mm in fracture group, and there was a statistically significant difference ($p = 0.032$, independent t-test). DB averaged 17.29 ± 4.44 mm in the non-fracture group and 20.95 ± 7.66 mm in the fracture group, and WB was 10.74 ± 1.63 mm in the non-fracture group and 13.38 ± 5.52 mm in the fracture group. Each result showed no statistically significant difference (Tables 3–6).

Table 3. Distance measurement on fractured patients.

(Mean ± S.D.)				
(mm)	**DA**	**DB**	**WA**	**WB**
1	33.36	29.12	14.84	11.15
2	14.78	13.92	14.98	9.32
3	18.69	19.80	21.34	19.67
Mean	22.28 ± 9.80	20.95 ± 7.66	17.05 ± 3.71	13.38 ± 5.52

Table 4. Harvested bone segment on fractured patient.

(Mean ± S.D.)				
(mm)	**Height**	**Length**	**SW**	**IW**
1	33.36	29.12	14.84	11.15
2	14.78	13.92	14.98	9.32
3	18.69	19.80	21.34	19.67
Mean	22.28 ± 9.80	20.95 ± 7.66	17.05 ± 3.71	13.38 ± 5.52

Table 5. Comparisons of non-fracture and fracture groups.

(Mean ± S.D.)				
(mm)	**DA**	**DB**	**WA**	**WB**
Non-fracture	16.88 ± 4.54	17.29 ± 4.44	13.63 ± 1.58	10.74 ± 1.63
Fracture	22.28 ± 9.80	20.95 ± 7.66	17.05 ± 3.71	13.38 ± 5.52
p-value	0.237	0.586	0.032 *	0.705

* There is a statistically significant difference ($p < 0.05$) (independent t-test).

Table 6. Comparisons of measurement on harvested bone segment.

(Mean ± S.D.)				
(mm)	**Height**	**Length**	**SW**	**IW**
Non-fracture	22.00 ± 5.37	11.86 ± 2.04	16.75 ± 2.01	11.86 ± 2.04
Fracture	22.85 ± 5.83	10.07 ± 4.31	13.65 ± 2.77	10.07 ± 4.31
p-value	0.953	0.441	0.110	0.441

There is no statistically significant difference ($p < 0.05$) (independent t-test).

3.3. Postoperative Care

When the ABR period was investigated, ambulation was performed after an average of 10.50 ± 3.61 days in the non-fracture group and 5.67 ± 2.31 days in the fracture group. This period showed a statistically significant difference (Table 7).

Table 7. Comparisons of ABR period.

(Mean ± S.D.)	
	ABR Period
Non-fracture	10.50 ± 3.61
Fracture	5.67 ± 2.31
p-value	0.045 *

* There is a statistically significant difference ($p < 0.05$) (independent t-test).

4. Discussion

Harvesting autogenous bone from the iliac crest has been a reliable and well-established technique in oral and maxillofacial surgery in recent decades [33–35]. However, complications at the donor site are common [19]. The incidence of minor complications following autogenous iliac crest bone graft harvest has been reported to be from 0% to 48% [8,36–41] and the rate of major complications is up to 11.9% [42]. Deep infections, hemorrhages, hernias, ilium fractures and pelvic instability, as well as vascular and nervous lesions, are reported as major complications [11,14].

Fracture is caused by the contraction of the sartorius muscle and other immediate causes [43]. The harvesting of anterior iliac crest bone grafts can occur too close to the ASIS, thereby causing the fracture of the ASIS from the iliac wing in a few studies [25,44]. Therefore, most of the literature suggested that iliac grafts 3–4 cm posterior to the ASIS provide maximum support for the sartorius and tensor fascia latae muscles. Barone et al. placed the anterior osteotomy 2 cm distal to the ASIS to avoid any weakening of the pelvic ring [35]. Additionally, Hu et al. showed that the removal of bone 30 mm posterior to the ASIS preserves 2.4 times more strength of the iliac crest compared with the harvesting of a bone graft 15 mm posterior to the ASIS [23]. The downward pulling of the sartorius muscle and tensor fascia latae muscle can lead to a late stress fracture after harvesting the anterior iliac crest, so the base of ASIS must be wide enough to reduce the risk of stress fracture due to the downward pulling of the sartorius muscle [5].

In this study, there was no statistically significant difference in the distance from the ASIS to the harvesting margin between the fracture group and non-fracture group. This is because the operation was performed maintaining a sufficient distance from the ASIS of at least 2 cm to prevent the avulsion fracture of the ASIS.

In order to reduce the complications of the pelvis, Jones et al. reported that an osteotome-harvested graft had an increased incidence of propagations of fracture compared with saw-harvested bone grafts on fresh frozen cadavers [29]. Burstein et al. evaluated the morbidity of grafts by comparing traditional iliac bone grafts with minimally invasive techniques [45]. They reported that a minimally invasive technique was statistically superior for pain control, operation time and mean incision length. Eufinger et al. reported that the short-term morbidity (pain and scar at the donor site) in the traditional open osteotomy group was slightly greater than the closed harvesting group [46]. Conversely, long-term morbidity showed a negligible difference in both groups. Sandor et al. reported a minimally invasive trephine method [33] which is a safe method and minimizes morbidity. Brawley et al. reported that there no patients experienced morbidity at the harvesting site when using a small acetabular reamer [47].

Most of the iliac crest fractures reported in the literature occurred within 2 weeks after the harvesting procedure [1,21,25,26,44,48]. Since a forceful activity with contraction of the sartorius muscle should cause the avulsion of the weakened bone part, a sufficient ABR period is needed to stabilize the donor site. In this study, there was a statistically significant difference in ABR periods between the fracture group and non-fracture group.

Clinical studies suggest that old age, obesity, osteoporosis, co-morbidities and improper harvesting techniques are the risk factors for the fracture of the iliac crest after bone grafting [5,21,23].

The treatment of iliac crest fracture is usually symptomatic and involves a short rest period with assisted ambulation and the usage of analgesics until the fracture has healed [23,49]. However, for a displacement of the fragment by more than 3 cm inferolaterally, non-union and patients that need a short rest period such as athletes, comorbidities are indications of the open reduction and internal fixation for the iliac avulsion fracture [5].

In summary, the location of the harvesting bone (distance from the ASIS), harvesting method (bi-cortical and mono-cortical) and a short ABR period can increase the risk of avulsion fracture at the anterior iliac crest.

The measurement reference point may vary depending on the person who measures it, and there is a problem that the bone density test or investigation is insufficient. There is

also a limited number of cases, which makes the measurement statistically more prone to errors. This should be addressed in future research.

5. Conclusions

Although an iliac bone graft has many advantages, it may result in donor site complications. Fracture of the iliac crest is a rare complication, but while rare, the surgeon should be fully aware of the risk that the patient may suffer from a fracture of the donor site after bone grafting. When harvesting the iliac crestal flap, a sufficient distance posteriorly from the ASIS of at least 2 cm should be maintained; however, if 2 cm of residual bone cannot be preserved, the patient should maintain a sufficient ABR period to minimize avulsion fracture.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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