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Original Article

The clinical diagnosis and risk factors of posterior malleolar fracture in tibial spiral fractures

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Abstract: The tibial spiral fracture is a common fracture associated with occult posterior malleolar fractures (PMFs). Although several previous studies had described the high rates of PMFs, the ignorance of PMF in clinic was still common. The diagnosis of the spiral fracture may affect the treatment strategy and prognosis. The research aims to figure out the differences in spiral fracture with or without PMF, and find risk factors which may help to identify the occurrence of PMF in spiral fractures. Data were collected and compared in terms of sex, age, BMI, mechanism of injury, injured time and season of injury, comorbidities which may increase the risk for fracture such as diabetes, smoking, chronic alcoholism. Binary logistic regression analysis was used to determine risk factors for PMF in the spiral fractures. 71 (47.3%) of the patients tibial spiral fractures were associated with PMF, and other 79 were spiral fractures without PMF. Sex and BMI were identified as risk factors for the PMF, and age and night-time were identified as protective factors. Shorter people were easier to get injured with PMF in spiral fracture. There was not statistical difference in terms of body weight. We concluded young female patients with obesity (high BMI) are more inclined to have PMF in spiral fractures. Patients injured in day time should be checked carefully to detect PMF in spiral fractures. Shorter people who get the spiral fracture should be more alert to have PMF.

Keywords: PMF, comparative study, observational study

Introduction

The tibial shaft fracture was a common type of fracture occurred in people of all ages which requires surgical interventions [1, 2]. The treatment effect of tibial fractures was usually satisfactory with high union rate of over 90% [3]. However, the postoperative complications such as mechanical failure and wound infection were still observed frequently [4]. The mechanical complications are frequently attributed to inadequate fixation provided by internal plate and wrongly identified fracture patterns of tibial fractures. For example, the tibial spiral fracture may occur with or without posterior malleolar fractures (PMFs), and the occurrence rate of PMF varied in different researches [5-7]. The mechanical failures might happen if we did not notice the existence of PMF [8].

The PMF is a fracture involving the posterior aspect of the articular surface of the distal tibia. Hou et al. suggested there was a "communication line" which connected the distal spiral tibial shaft fractures with associated occult posterior malleolar fractures (PMF), and reported that there were high occurrence rates of PMF [9]. So, the appropriate treatment for PMF is essential to sustain the stability of the ankle and improve clinical outcomes after surgery. However, concurrent ankle injuries may be ignored if there is no complaint about the ankle pain at the time of injury. In general, the treatment was still under debate, and we noticed that many patients with PMF in spiral fracture were not diagnosed clearly. It was suggested that clear diagnosis be the primary task to make sure an appropriate treatment was selected.

Currently, few studies have noticed the risk factors of PMF in tibial spiral fracture. What are the factors that may contribute to the occurrence of the PMF in spiral fractures? In this study, we

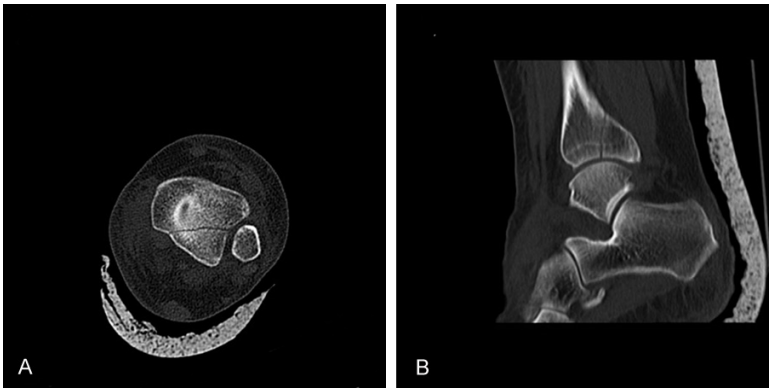

Figure 1. A CT scan demonstrated that a 44-years-old female has a spiral fracture combined with PMF. A. The transverse view of the posterior fracture. B. The sagittal view of the posterior fracture.

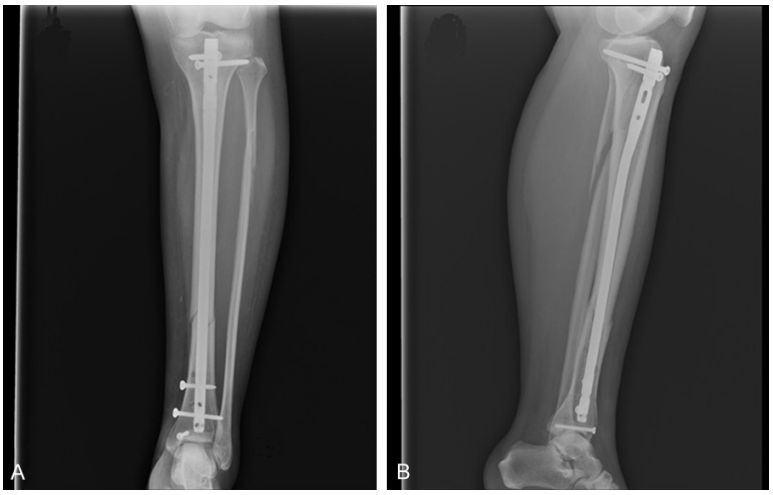

Figure 2. Radiograghy illustrated the female patient with PMF at 1 month after operation. A. The AP views demonstrated that the posterior fracture was fixed by lag screws. B. The lateral views illustrated the screws were placed rightly and have not violated the ankle joint.

collected medical records to analyze the risk factors for the PMF in spiral fracture and aimed to find out the factors which may influence the occurrence of the PMF in spiral fracture.

Materials and methods

Subjects

This study was approved by the ethical committee of the Third Hospital of Hebei Medical University and accordant with the ethical principles of the 1975 Declaration of Helsinki. The patients' data were collected and analyzed anonymously, and verbal consent to publish their data was obtained from all patients through follow up. All patients diagnosed as tibial or fibular fractures such as tibial spiral fractures, tibial shaft fracture, fracture of distal tibial, fracture of ankle, trimalleolar fractures, bimalleolar fractures, tibial fracture or fibular fracture were all judged again to identify the actual fracture patterns.

The retrospective study was performed in the record room of hospital. From December 2013 to July 2015, 150 patients (96 males and 54 females) with tibial spiral fractures combined with or without PMFs were admitted and treated successfully. We reviewed their medical records and collected relevant data including sex, age, BMI, season of injury, mechanism of injury, time of injury (sun rise or fall) and comorbidities which may affect the bone density from the Sybase (a software which can be used to check all medical records about patients). All data about patients diagnosed as tibial spiral fracture with or without PMF were recorded. If the diagnosis and examination in the medical records were too unclear to clarify whether or not it was a tibial spiral fracture, the Ris-report system recording radiological images such as X photography and CT was utilized in advance. For example, many tibial spiral fractures were recorded as the fracture of tibial and fibular, and it was too general to clarify the actual type of fracture. The precious data of the tibial spiral fracture were obtained and collected for analysis about risk factors of PMF. Besides, the correlations between PMF with the height or weight of patients were analyzed respectively.

Statistical analysis

The continuous variables were illustrated as the mean values plus or deduct standard deviation (SD). Frequencies are used to express cat-

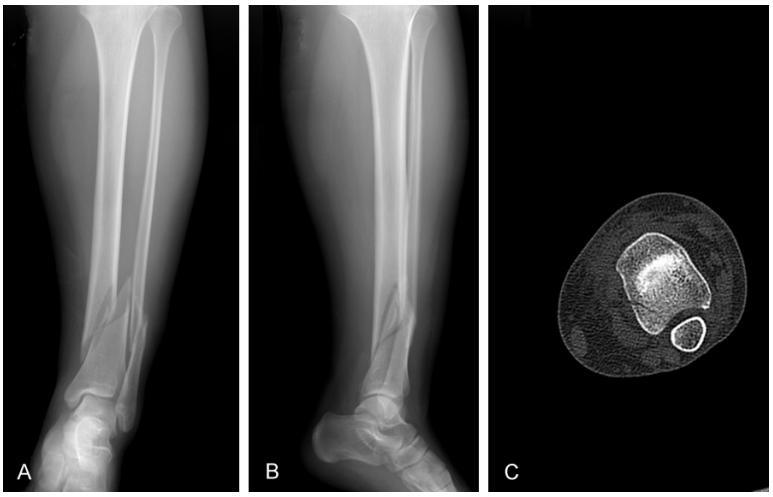

Figure 3. The radiograghy and CT illustrated that a 28-years-old female has a spiral fracture combined with PMF. A, B. The AP and lateral views of the fracture. C. CT scans of the patients demonstrated a PMF which was not displaced.

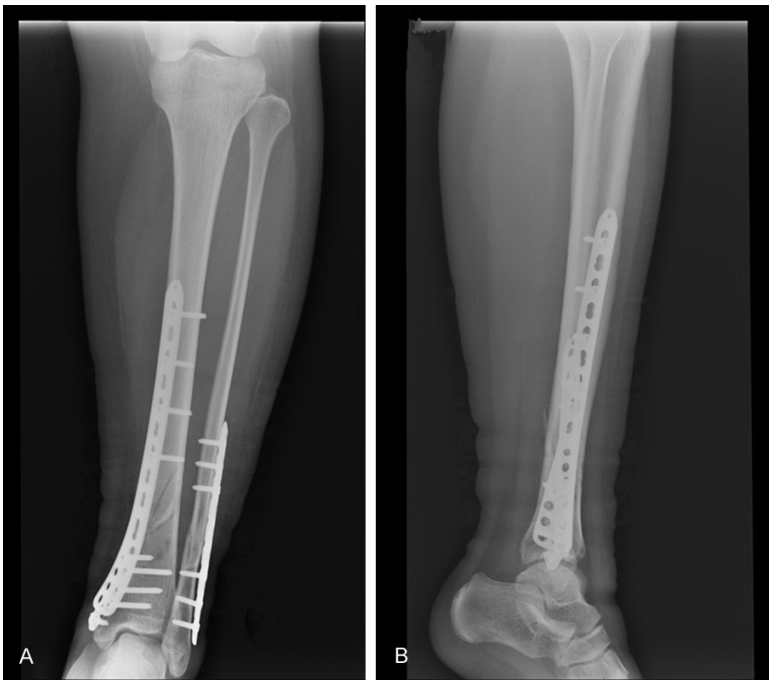

Figure 4. A, B. The spiral fracture was fixed by plate; the undisplaced PMF was not treated.

egorical data. SPSS (PASW statistic 21.0) were used to take statistical analysis, and the significant level was set at $P<0.05$. Binary logistic regression analysis was utilized to identify risk factors for the spiral fracture. T-test or Whitney U test and Chi-square test were utilized to analyze the differences in demographic data between the spiral fracture combined with or without PMF.

Results

The average age of patients when the spiral fracture happened was 41.4±14.2 years (40.1±13.5 years-old for man, and 43.7±15.2 years-old for woman). Among 150 patients, most of them were treated with fixation, but the indication for fixation to PMF (<25%) was inconsistent (**Figures 1**-**4**). Two were treated conservatively, and the other one was treated through the external fixation due to weakness and senility. The patients were categorized into 6 groups according to age and most patients with spiral fractures were 36-45 years old (**Figure 5**). As the time of injury, 100 patients were injured in day time and 50 others happened at night.

The mechanism of injury included traffic accidents, crushing by falling objects such as trees or telegraph poles, falling on flat ground (sprain and push by others) and falling from height (>2 m and skiing). There were 104 patients injured by falling on flat ground, 29 and 17 patients were injured due to traffic accidents and falling from high place respectively. The patients were divided into three groups according to BMI (22.5±3.3): slim = 3 (<18.5), normal = 53 (18.5≤N <24), and obesity = 94 (≥24).

There were significant decrease in age and injury at night time inpatients combined with PMF (**Table 1**). The comorbidities which might impair the bone density illustrated no effect on the PMF. There were statistical decreases in patients' height in PMF group ($P = 0.04$), which mean that the shorter patients have a higher incidence of PMF. However, no significant differences exhibited in weight compared with patients without PMF. The logistic equation was demonstrated as follows:

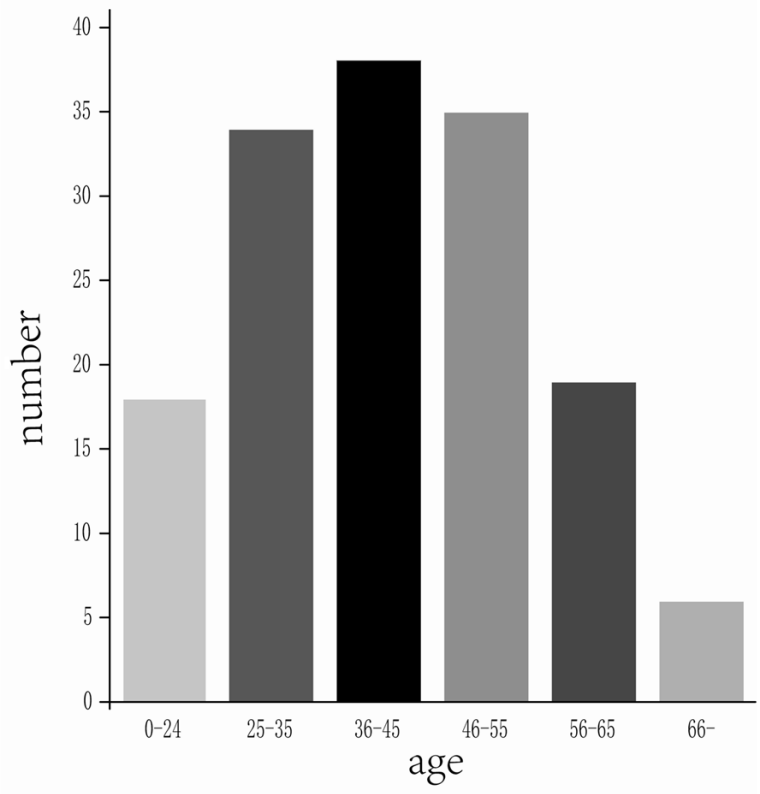

Figure 5. Age composition of patients with spiral fractures. The most frequent spiral fractures were distributed in the 36-45 years-old category; the minimum patients were distributed in the group of 66 years-old and above.

logitP = -1.169+1.031*X1-0.332*X2-1.012*X3+0.78*X4. (**Table 2**; X1 = sex, P = 0.01, OR = 2.81, 95% CI = 1.32-5.96; X2 = age, P = 0.02, OR = 0.72, 95% CI = 0.55-0.94; X3 = injured time, P = 0.01, OR = 0.36, 95% CI = 0.17-0.78; X4 = BMI, P = 0.03, OR = 2.182, 95% CI = 1.09-4.38). The results exhibited that a young female patient with obesity was more prone to get the PMF fractures in spiral fractures. Although it was prone to get injured at night because of the darkness, most of the injury combined with PMF occurred at day time in our research.

Discussion

The purpose of this study was to compare the differences between patients with PMF and those without, and identified the risk factors that may remind surgeons the occurrence of PMF together with spiral fractures. The result revealed that female patients are more susceptible to get a spiral fracture without PMF. The exact reason is still unclear. We suspected that larger volume of bone mass and stronger anti-rotation ability in males may have an influence. As we known, low-velocity rotational injuries were the main mechanism for PMF with spiral fractures [10]. The spiral fracture happens after a close contact between the posterior talus surface and the malleolar surface under applying external force. If the force is higher enough to get the posterior malleolus and the talus surface touching together, PMF would occur after spiral fracture. So no distinguished difference was observed in terms of the incidence between male and female patients in PMF group. Conversely, if the force is not strong enough, the incidence of PMF may be low due to excellent micro architectures and larger volume of bone mass in male patients. But the same level of external force may result in PMF in female patients with low mechanical competence of bone compared to man. The data of injury time identified that patients injured in day time should be paid more attention to inspect the posterior malleolus.

This is the first research to analyze the risk factors for PMF with tibial spiral fractures. We found that sex (female) and obesity were highly associated with PMF in spiral fractures through binary logistic regression analysis. Compared with male patients, female ones have a high incidence of PMF because they have a relative low bone mass resulting from light labor activity and different intrinsic physique. Obese patients have high bearing burden imposed on their lower limb, and they are more likely to have PMF with spiral fracture under the condition of applying the same mechanical force with normal people. In addition, patients with lower height appeared to exhibit a higher incidence of PMF with spiral fracture, but no significant difference was observed in terms of weight. Although the exact reason for this result is still unclear, it could be used for the guidance

Table 1. Thedemographics of the spiral fracture patients with or without PMF (%)

	PMF	NO PMF	Statistical value	*P* value
Patients	71 (47.33)	79 (52.67)		
Sex			4.814	0.03*
Male	39 (40.63)	57 (59.38)		
Female	32 (59.26)	22 (40.74)		
Age (year)	39.1±12.3	43.4±15.5	-1.978	0.043*
BMI	25.6±3.1	24.9±3.2	-2.208	0.032*
Height (m)	1.67±0.07	1.69±0.07	-2.123	0.035*
Weight (kg)	71.5±10.4	71.7±11.8	-0.116	0.908
Mechanism			1.364	0.51
Traffic	11 (37.93)	18 (62.07)		
Fall	51 (49.04)	53 (50.96)		
High fall	9 (52.94)	8 (47.06)		
Injured time			7.073	0.01*
Day time	55 (55)	45 (45)		
Night	16 (32)	34 (68)		
Injured season			7.586	0.06
Spring	21 (41.18)	30 (58.82)		
Summer	11 (52.38)	10 (47.62)		
Autumn	22 (66.67)	11 (33.33)		
Winter	17 (37.78)	28 (62.22)		
Comorbidities				
Diabetes	3 (33.33)	6 (66.67)	0.753	0.39
Smoke	18 (46.15)	21 (53.85)	0.029	0.86
Alcoholism	8 (33.33)	16 (66.67)	2.246	0.13

Note: *means that there is significant difference in Sex, Age, Height and Injured time.

in the examination of the PMF with spiral fractures. The analysis about sex and obesity in our study were consistent with other researches about risk factors of lower limb [2, 3, 11]. Ensrud KE analyzed the risk factors of fracture in aging population, proposing that obesity was a protective factor for the fractures occurred in the wrist, spine, hip and pelvis, but a risk factor of ankle fractures [11]. Based on above information, we concluded that the obese female patients with short stature should be paid more attention to examine the PMF when a spiral fracture happened.

After analyzing the risk factors base on 477 ankle fractures, Varenne reported that the risk of postoperative complications of surgical treatment increased with age and other factors such as comorbidities [12]. However, age was identified to be a protective factor for PMF in our study. It seemed to contradict with the common sense that older people with fragile skeleton, lower bone mineral density, transformation of trabecular geometry, poor micro architecture of bone were more easily to get injured. Fractures occurred in ankle joints are indeed mainly due to micro architectural changes in the metaphysis of tibia, and most of them are trimalleolar or isolated lateral malleolar fracture. The results from other researches also supported this situation. Daly PJ completed an epidemiology study of ankle fractures from 1979 to 1981, found an increased trend in middle-aged women with ankle fractures [13]. Hasselman enrolled 9704 elderly people to determine the incidence and risk factors for foot and ankle fractures, and they concluded the incidence was 3.0 per 1000 people each year and the most common ankle fracture was isolated fibular fracture [14]. Scholes S et al. analyzed a total of 24,725 adults with age greater than 55 years and reported that the incidence of tibial/fibular fracture was 10.6 and 9.9 for men and women respectively. They concluded that as people getting older, structural changes of bone promoted the occurrences of fractures [15]. However, the tibial spiral fracture with PMF is different from ankle fracture, and not suitable to be classified as osteoporotic fracture. It is mainly caused by external mechanical force which is observed frequently in young people. Young people who take daily work by transport vehicles are more inclined to have an accident or take drastic exercises, which make them to get injured more easily. The more frequently young people take sports, the higher incidence of injury they may suffer. In addition, people have more time to take activity in day time, thus there are more chances to get injured or injured seriously with high level of trauma forces during this period. The analysis of comorbilities exhibited that there was no differences between two groups. Although there was a risk for people with complications such as diabetes have a higher incidence of fracture, our research demonstrat-

Table 2. Binary logistic regression analysis for PMF

	B	S.E	Wals	OR	95% CI	*P* value
Sex						
Male	-	-	-	1	-	-
Female	1.031	0.384	7.208	2.805	1.321, 5.955	0.007
Age	-0.332	0.140	5.625	0.718	0.546, 0.944	0.018
0-24	-	-	-	1	-	-
25-35	1.628	1.24	1.724	5.092	0.448, 57.815	0.189
36-45	2.418	1.195	4.094	11.228	1.079, 116.878	0.043
46-55	2.264	1.177	3.702	9.620	0.959, 96.548	0.054
56-65	1.845	1.191	2.399	6.325	0.613, 65.285	0.121
>66	0.900	1.230	0.535	2.460	0.221, 27.427	0.465
Injured time						
Day time	-	-	-	1	-	-
Night	-1.012	0.388	6.804	0.364	0.170, 0.778	0.009
BMI	0.780	0.355	4.827	2.182	1.088, 4.357	0.028
<18.5	-	-	-	1	-	-
18.5-24	-1.290	1.375	0.880	0.275	0.019, 4.077	0.348
≥24	-0.676	0.401	2.841	0.809	0.232, 1.116	0.032

Note: Age, Sex, BMI and Injured time were dependent variable.

ed that young people had more probability to have PMF with spiral fractures. We concluded that the results about comorbidities which were less observed in young people were consistent with our analysis about PMF. Osteoporosis as a skeletal disorder predisposed individuals to have an increased risk of fracture. However, the occurrence of PMF is not an individual pattern and it is usually accompanied with spiral fracture when the external force succeeded the bearing capacity of the bone. We considered that the external force but not the bone density was the essential factor for the occurrence of PMF with spiral fractures.

If the treatment of PMF is needed, its importance to the ankle and the mechanism should be emphasized firstly. Posterior malleolar plays an essential role in sustaining the stability of ankle joint. The PMF always happens combined with other fractures such as bimalleolar fracture and tibial spiral fracture. The individual occurrence of PMF is observed in patients who injured by parachute landings. The mechanism is as follows: axial load to the lower limb may lead to PMF when the foot is at the position of plantar flexion. When it occurs with other types of fracture such as trimalleolar fracture, the integrity of the articular surface is more essential to sustain the rotational stability of the talus. If the limb suffers from external force, the talus' head rotates inversely and externally to a position which is the most common condition in clinic. After an oblique fibular fracture happens, the aggressive external rotation of talus may lead the failure of posterior malleolar. Currently, the involvement area of the articular surface were considered as main factor to choose the operative or nonoperative treatment for PMF along with other factors such as morphology, combined injury and mechanism [16-19]. If PMF involved 25%-30% of the plafond, the displacement of talus might be observed, and the fixation to PMF should be needed [16]. However, Rassch thought that the fibula and anterior tibiofibular ligaments were more essential to stabilize the talus [18]. In biomechanical studies, the stress in intact area of the tibiotalar joint surface increases along with the size of PMF [18, 19]. Fitzpatrick reported that the fractures involving 50% of the tibiotalar joint' surface could lead to a redistribution of stress which pointed to the direction of anterior and medial portion of the ankle joint [20]. The most common classification of posterior malleolus fractures was proposed by Haraguchi [21], and modified by Mangnus and Bartonicek [22, 23]. Mangnus divided Haraguchi Type II with the medial extension into two patterns (posterior-lateral and posterior medial) [22]. Bartoníček classified 137 patients into four types in terms of their anatomic characters [23]. AP lag screws and posterolateral plate are the most commonly used treatment currently, and no posterolateral plate fixation was applied to the 71 patients combined with PMF in our research.

The spiral tibial shaft fractures were tightly associated with PMF in previous studies. In a prospective study performed in our hospital in 2007, 3 cases of PMF were detected by plain film out of 34 spiral fractures. Other PMF cases could not be identified through X photography; however, 27 PMF cases were identified through CT or MRI. So, we strongly recommended that CT scan should be routinely used to evaluate

the fracture in clinical practice [7]. Ferries et al. evaluated twenty-five patients with trimalleolar ankle fractures through conventional radiography and CT to determine the size of the posterior fragment, showing that the plain radiograph has very poor inter- and intrareliability [24]. However, due to the financial problems, CT and MRI are not routinely accepted by patients or as the choice for surgeons especially in less developed cities of China. 3 patients with intact fibular were found to have no PMFs in our research and we supposed that the intact fibular prompt lower or definite few chances to have a PMF by analyzing Lauge-Hansen mechanism classification in spiral fracture patients. If there is a spiral fracture, a wholly illustrated image of fibular combined with the communication line should be obtained which may contribute to the detection of PMF in the premise of not adding other examinations such as CT and MRI. However, the definite result cannot be concluded due to restricted small sample in this research. In our research, there was only one patient injured during skiing, which was consistent with former research about the injury mechanism of skiing in adolescents and adults [25]. With the improvement of the ski-shoes system, few people will be injured by skiing. However, the danger of skiing should not be ignored.

Despite of the reported high rates, the diagnosis of PMF always be neglected in clinical, then a considerable portion of these cases which need surgical intervention result in the occurrence of displacement of PMF postoperatively. The result helped to guide the diagnosis and treatment of PMF in spiral fracture. However, PMF which is not detectable in radiography and CT sometimes may not affect the prognosis when it is small in size with limited displacement. But, in a society with tense doctor-patient relationship, the research may help our colleague to examine similar pattern of fracture more carefully without increasing the cost of treatment obviously. If the diagnosis is adequate and clear, posttraumatic arthritis caused by ignorance of PMF can be prevented. A posterior fragment in ankle fracture frequently result in unsatisfactory outcomes, but the pattern of PMF in spiral fracture is simple. Impacted fracture margins or osteochondral fragment was not observed, so the reduction was easy to conduct. If we assess the impact of PMF on patients' rehabilitation with the AAOS questionnaires, VAS-pain score, range of motion and osteoarthritis, there may be a different results compared with PMF in other fracture.

There are still some limitations in this study. The concomitant ankle injuries were inspected by plain films and CT. The MRI was not routinely utilized to detect the PMF. Health behaviors and other comorbidities that could influence bone union such as kidney failure, chemotherapy and corticotherapy cannot be analyzed due to the comparatively small of subjects. Bone mineral density was not measured due to deficiency of relevant facilities such as QCT (Quantitative CT). However, the research could still guide surgeons to improve the treatment of spiral fractures due to appropriate design of this study.

Conclusion

Young female patients diagnosed as obesity are more inclined to have PMF with spiral fractures. Clinical surgeons should be aware of the patients who are injured in day time to find the combined fracture of posterior malleolus. The diagnosis about the spiral fracture should be checked in detail and make sure not to miss the combined PMF.

Disclosure of conflict of interest

None.

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