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Natural History of Diabetic Foot and Ankle Fractures: A Retrospective Review of 40 Patients

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Background: *Ankle fractures in diabetics with secondary complications are more prone to postoperative complications than ankle fractures in diabetics without secondary complications. This study retrospectively compared the post injury complications of foot and ankle fractures in diabetics with and without secondary complications. Secondary complications of diabetes mellitus include peripheral arterial disease, nephropathy, and/or peripheral neuropathy. Uncomplicated diabetics did not have any of these end organ diseases associated with diabetes. Our hypothesis was that foot and ankle fractures in complicated diabetics would incur more post injury complications than uncomplicated diabetics.*

Materials and Methods: *We contrasted the post injury complications of foot and ankle fractures in 25 complicated diabetics with15 uncomplicated diabetics.*

Results: *At an average follow-up of 33.8 weeks we established that foot fractures in complicated diabetics had a non significant trend of a 2.8 times increase in overall post injury complications versus foot fractures in uncomplicated diabetics. Furthermore, with an average follow up of 28.8 weeks we demonstrated a non significant tendency of a 1.4 times increase in overall post injury complications of ankle fractures in complicated diabetics compared to ankle fractures in uncomplicated diabetics. Lastly, with a mean follow up of 33.7 weeks we found insignificant trends of a 1.7 times increase in overall post injury complications and a 2.8 times increase in noninfectious complications (malunion, delayed union, nonunion or Charcot neuroarthropathy) in complicated diabetic foot and ankle fractures contrasted to uncomplicated diabetic foot and ankle fractures.*

Conclusion: *Foot and ankle fractures in complicated diabetics are presumably at an increased risk of developing a post injury complication compared to uncomplicated diabetics. Specifically, foot fractures should be treated similar to ankle fractures in complicated diabetics with an extended period of non-weight-bearing in a total contact cast. Mandatory post injury clinical evaluation for peripheral arterial disease, peripheral neuropathy and nephropathy should be implemented. This analysis will be used as a template for a future prospective comparative study evaluating foot and ankle fractures in complicated and uncomplicated diabetics with a power analysis to achieve statistical significance.*

Key words: Diabetes mellitus, ankle fracture, Charcot arthropathy

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In 2010 it was projected that 25.8 million people in the United States had diabetes mellitus representing 8.3% of the population with another 7 million undiagnosed.[1]

The first report of diabetes mellitus affecting bone healing was an animal study in 1968 by Herbsman, et al.[2] They found that rats with uncontrolled diabetes mellitus had reduced fracture healing compared to the healthy controls.

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Other animal studies have confirmed these results and have found that fractures in diabetic rats treated with insulin improved bone healing.[3-6] In the earliest human case report, Cozen reviewed 9 diabetics with lower extremity fractures and contrasted them with 9 matched controls. He verified a delayed time to union in the diabetic patients.[7]

Several studies have demonstrated increased complications in diabetic ankle fractures compared to the healthy controls.[8-12] However, several recent studies have shown that ankle fractures in diabetics without comorbidities (uncomplicated diabetics) had complication rates similar to the controls. Conversely, complicated diabetics (peripheral neuropathy, nephropathy and peripheral arterial disease) had significantly increased complications.[13-15] However, to the best of our knowledge, in the English literature, there have been no studies examining the natural history of diabetic foot and ankle fractures concomitantly. Thus, a retrospective review of 40 patients with diabetes mellitus who sustained a foot and/or ankle fracture was performed.

Methods and Patients

On July 26, 2012, the Western Pennsylvania Allegheny Health System Institutional Review Board accepted this as an exempt study. A retrospective review of patient charts, radiographs, and operative reports with diagnosis codes for "diabetes mellitus" and "fracture" to the foot and/or ankle was assembled. Complicated diabetics were diagnosed with peripheral neuropathy (PN), peripheral arterial disease (PAD) and/or nephropathy. Uncomplicated diabetics did not have any of these end organ diseases.[16,17] PN was diagnosed when the patient could not detect the 5.07 Semmes Weinstein monofilament. PAD was diagnosed if the patient had been revascularized in the past or when the patient had non palpable dorsalis pedis or posterior tibial pulses.

Nephropathy was diagnosed when the patient had a serum creatinine of $\geq$ 1.5.[11] Charcot neuroarthropathy was defined as bone fragmentation, bone absorption and boney consolidation.[18]

Superficial infections were categorized based on the need for only oral antibiotics and local wound care. Deep infections were delineated when the wound required intravenous antibiotics and surgical debridment.[11]

A nonunion was defined when a minimum of 9 months has passed and there are no interval changes consistent with a union on serial radiographs. A delayed union had decreased bone healing on serial radiographs.

Data was collected for patients treated between 1/1/2002 – 7/1/2012. Patients less than 18 years old and with incomplete medical records were excluded. The information gathered included age, sex, body mass index (BMI), fracture type, fracture location, fracture treatment, time to union, malunion, nonunion, infection, ulceration, Charcot neuroarthropathy, amputation, PN, nephropathy, and PAD.

The type of treatment was at the judgment of the attending foot and ankle surgeon. All patients with an ankle fracture underwent open reduction and internal fixation (ORIF) with plates and screw fixation of the fibula. Also, the medial malleolar fixation was accomplished with screws or tension banding. Syndesmotic fixation was accomplished with tri-cortical or quad-cortical screws when appropriate. All ankle fractures received preoperative antibiotics with continuation of antibiotics through the hospital course for open fractures. Non-weight-bearing (NWB) was generally instituted for a minimum of 7 weeks in a total contact cast (TCC) with transitioning to weight-bearing (WB) for a minimum of 4 weeks in a fracture walker for postoperative ankle fractures.

Forefoot fractures (toe and metatarsal) were commonly allowed WB in a surgical shoe or fracture walker for at least 2 weeks before transitioning to a sneaker. Patients were usually followed up at 2 week and subsequently 1 month intervals until fracture union. At most visits, medial oblique, anteroposterior and lateral radiographs were obtained to assess fracture healing.

Table 1: Frequency by diabetic group (complicated vs. uncomplicated).

Diabetes Type	Complicated		Uncomplicated		Fisher's Exact
Age	Mean 62.32		Mean 61.93		p = .91
BMI	Mean 32.64		Mean 36.65		p = .25
Sex	Male 12 (48%)	Female 13 (52%)	Male 6 (40%)	Female 9 (60%)	p = .75
BMI.	Open 1 (4 %)	Closed 24 (96%)	Open 2(13%)	Closed 13 (87%)	p = .25
***Treatment**	ORIF 9 (38%)	Non-op 15 (62%)	ORIF 11 (73%)	Non-op 4 (27%)	p = .43[19]

*Excludes one case of percutaneous pinning procedure. All percentages represent percent within that diabetic group.
[19] Holm-Bonferroni correction applied to all p-values. Correction was applied to Treatment test, with original p-value = .048. As this was non-significant, no subsequent corrections were required.

Table 2: Time-based measures in weeks (complicated vs. uncomplicated).*

Diabetes Type	Complicated	Uncomplicated	Fisher's Exact
Weight Bearing	8.56±5.64	7.40±6.70	p = .56
****NWB**	7.93±4.17	7.75±3.25	p = .90
Clinical Union	10.12±6.35	9.27±3.44	p = .64
X-Ray Union	14.76±7.20	12.87±5.87	p = .40[19]

*Independent samples t-tests conducted, two-tailed. Values express mean±standard deviation.
**Non-weight bearing weeks – only 27 cases were NWB.
All percentages represent percent within that diabetic group.
[19] Holm-Bonferroni[1] correction applied to all p-values. Correction was applied to Treatment test, with original p-value = .048. As this was non-significant, no subsequent corrections were required.

Results

There were a total of 40 diabetic foot and ankle fractures with an average follow up of 31.7 (4-137) weeks. Patient ages ranged from 43 to 85, with a mean of 62.00±10.34 (standard deviation). There were a total of 22 females (55%) and 18 males (45%). Patient BMI ranged from 21.81 to 56.35 with a mean of 34.11±5.91. Thirty seven (93%) experienced closed injuries while three (7%) experienced open injuries. Nineteen patients (48%) were treated non-operatively (toe, metatarsal and cuboid fractures) and 21 (52%) were treated operatively (ankle and a calcaneal avulsion fracture).

Twenty five patients possessed a previous diagnosis of complicated diabetes (63%) while fifteen patients had uncomplicated diabetes (37%).

Regarding type of injury, 17 patients experienced an ankle fracture (43%), 12 patients a metatarsal fracture (30%), nine patients a phalanx (toe) fracture (22%), one patient a calcaneal avulsion fracture (2.5%), and one patient a cuboid fracture (2.5%).

When evaluating BMI there was no difference between complicated diabetics (mean=32.64±5.10) and uncomplicated diabetics (mean=36.55±6.51), t (38) = 2.12, p = .25. There was no difference in age between complicated diabetics (mean = 62.32±10.65) and uncomplicated diabetics (mean=61.93±10.15), t (38) = .11, p = .91.

Table 3: Complications among foot fractures.

	Injury Complication Outcome			
Diabetes	**Complications**	**No Complications**	**Total**	**Fisher's Exact**
Complicated	10 (56%)	8 (44%)	**18**	
Uncomplicated	1 (20%)	4 (80%)	**5**	
Total	**11**	**12**	**23**	p = .32

*Percentages represent percentage within diabetes category.

Table 4: Complications among ankle fractures.

	Injury Complication Outcome			
Diabetes	Complications	No Complications	**Total**	Fisher's Exact
Complicated	4 (57%)	3 (43%)	**7**	
Uncomplicated	4 (40%)	6 (60%)	**10**	
Total	**8**	**9**	**17**	p = .64

*Percentages represent percentage within diabetes category.

Table 5: Diabetes complications by post injury complications.

	Number of Injury Complications				
Diabetes Comps.	0	1	2+	**Total**	Chi-square
One	10 (56%)	4 (22%)	4 (22%)	**18**	
Two+	1 (14%)	4 (57%)	2 (29%)	**7**	
Total	**11**	**8**	**6**	**25**	p = .14

*Percentages represent percent within diabetes category.

Also, there was no statistical difference between uncomplicated and complicated diabetes with regards to the frequency of sex and treatment (Table 1).

There was no statistical difference between complicated and uncomplicated diabetics regarding the number of weeks WB (8.56±5.64, 7.40±6.70, p = .56) and non-weight-bearing (7.93±4.17, 7.75±3.25, p = .90). Along with no statistical significance among complicated and uncomplicated diabetics (table 2) in weeks to clinical union (10.12±6.35, 9.27±3.44, p=.64) and radiographic union (14.76±7.20, 12.87±5.87, p = .40).

Twenty three foot fractures were included in the retrospective review with an average follow up of 33.8 weeks. (Table 3). Eighteen (78%) were complicated diabetics while five (22%) were uncomplicated diabetics. Ten (56%) of the complicated diabetics experienced a post injury complication. Conversely, only 1 (20%) uncomplicated diabetic experienced a post injury complication. A two sided Fisher's Exact test indicated no significant difference in proportion of patients experiencing post injury complications between complicated and uncomplicated diabetic groups (p = .32).

Moreover, there were a total of seventeen ankle fractures with a mean follow up of 28.8 weeks. (Table 4). Seven (41%) had complicated diabetes while 10 (59%) had uncomplicated diabetes. Among complicated diabetics, 4 (57%) experienced a post injury complication, whereas 4 (40%) of uncomplicated diabetics experienced a post injury complication. A two sided Fisher's Exact test indicated no significant difference in proportion of patients who experienced a post injury complication between complicated and uncomplicated diabetic groups (p = .64).

Table 6: Complications among diabetes type.

	Injury Complication Outcome			
Diabetes	**Complications**	**No Complications**	**Total**	**Fisher's Exact**
Complicated	14 (56%)	11(44%)	**25**	
Uncomplicated	5 (33%)	10 (67%)	**15**	
Total	**19**	**21**	**40**	p = .20

*Percentages represent percentage within diabetes category.

Table 7: Complications among foot and ankle fractures.

	Injury Complication Outcome	
Diabetes	**Complications**	**Description of Complications**
Complicated	14/25 (56%)	
Phalanx Fx		Superficial Infection
Phalanx Fx		Ulceration
Phalanx Fx		Charcot neuroarthropathy MTP
Phalanx Fx		Superficial Infection, Ulceration
Metatarsal Fx		Stress Fracture, Stress Fracture
Metatarsal Fx		Delayed Union
Metatarsal Fx		Stress Fracture
Metatarsal Fx		Ulceration
Metatarsal Fx		Nonunion
Calcaneal Fx		Superficial Infection, Delayed Union, Malunion
Fibular Fx		Dehiscence, Dehiscence
Medial Malleolar Fx		Malunion
Bi-Malleolar Fx		Ulceration, Fracture of Hardware
Tri-Malleolar Fx		Malunion, DJD
Uncomplicated	5/15 (33%)	
Metatarsal Fx		Delayed Union
Fibular Fx		CRPS
Bi-Malleolar Fx		Hematoma
Bi-Malleolar Fx		Superficial Infection, Malunion
Tri-Malleolar Fx		Malunion

*Percentages represent percent within diabetes category.

Further analyses evaluated the relationship between severity of complicated diabetes (PN+ PAD + nephropathy) and the number of post injury complications sustained by each patient. Eighteen diabetics (72%) were diagnosed with one complicating factor, six (24%) were diagnosed with two complicating factors, and one (4%) was diagnosed with all three complicating factors.

Among all complicated diabetics, 11 (44%) patients experienced no post injury complications, 8 (32%) patients experienced one complication, five (20%) patients experienced two complications, and one (4%) patient experienced three complications (Table 5). A Pearson's Chi-squared test was conducted indicating no relationship between number of diabetes complicating factors and number of post injury complications, χ^2 (2, N = 25) = 3.96, p = .14.

Table 8: Non-infectious complications by diabetes type and total fractures.

Diabetes Type:	Foot & Ankle Complicated	Uncomplicated	Chi-square
Total # of Comps.			
1	6 (31%)	4 (19%)	
2	3 (15%)	0	
Total	9 (47%)	4 (19%)	p = .38

*All percentages relative to specific diabetes-type and fracture category subgroup.

The relationship between diabetes type and the presence of a post injury complication when collapsing across all types of injuries was conducted (Table 6).Fourteen (56%) complicated diabetics experienced one or more post injury complications. Among uncomplicated diabetics, 5 (33%) experienced one or more post injury complications. A two-sided Fisher's Exact test indicated no relationship between diabetics type and the presence of injury complications (p = .20). All diabetic foot and ankle fracture complications are described in Table 7. There were no amputations performed in any of the complicated or uncomplicated diabetic foot or ankle fractures.

A non-infectious complication includes any complication involving a malunion, delayed union, nonunion or Charcot neuroarthropathy.[13] A total of 9 (47%) complicated diabetic foot and ankle fractures experienced a non-infectious complication and 4 (19%) uncomplicated diabetics experienced a non-infectious complication (Table 8.) A series of Chi-Square analyses were conducted and found no statistical significant relationship between diabetes-type and number of non-infectious complications for foot fractures [χ^2 (2, N = 23) = .66, p = .72.], ankle fractures [χ^2 (2, N = 17) = 1.54, p = .46] and overall fractures [χ^2 (2, N = 40) = 1.95, p = .38].

Discussion

This retrospective review of the natural history of 40 diabetic fractures is the first to evaluate foot and ankle fractures together. In regards to foot fractures (Figure 1), 56% (10/18) of foot fractures in the complicated group experienced a post injury complication while only 20% (1/5) of the uncomplicated group sustained a post injury complication (p = .32). Although not statistically significant, there was a 36% (2.8 times) increase in complications with complicated diabetics who sustained a foot fracture (Table 3). Kristiansen described a diabetic second metatarsal shaft fracture that was allowed to weight bear immediately with a bandage. Three months later the metatarsal fracture developed Charcot neuroarthropathy. He concluded that even metatarsal fractures should be immobilized and weight-bearing must be deferred until fracture healing is complete.[20] The foot fractures (metatarsal, phalanx, and cuboid) in this study were allowed to WB immediately in a surgical shoe or fracture walker. The authors hypothesize that a more aggressive immobilization regimen such as non-weight-bearing or total contact casting should be considered to decrease adverse outcomes in the complicated diabetic group.

Figure 1: Radiographs demonstrating a distal phalanx fracture in a complicated diabetic.

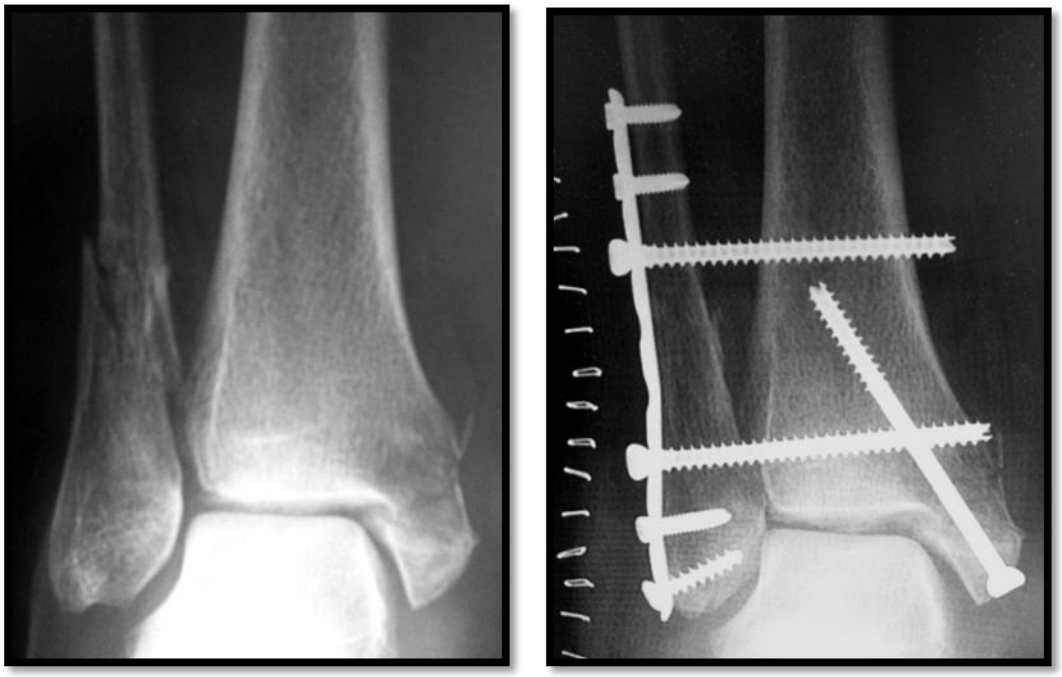

Figure 2: Initial and 12 week radiographs of a bimalleolar ankle fracture in a complicated diabetic.

In evaluating 17 operatively treated ankle fractures (Figure 2), the complicated diabetic group had a 57% (4/7) post injury complication rate while the uncomplicated diabetic group had 40% (4/10) post injury complication rate (p = .64). Many studies, including a meta-analysis of 356 ankle fractures, have established an overall increase in complications in diabetic ankle fractures compared to non diabetics.[21-27] Additionally, Wukich, et al., retrospectively confirmed that complicated diabetics had a 3.8 (p = .003) times amplified risk of a post injury complication.[11] In our study, there was a non significant trend of a 17% (1.4 times) increased complication rate for ankle fractures in the complicated diabetic group compared to the uncomplicated diabetic group. However, in the Wukich, et al., study there was total of 59 uncomplicated diabetics and 46 complicated diabetics which achieved statistical significance.[11] To attain statistical significance in our study, approximately 90 additional ankle fractures would need to be evaluated.

Compiling all diabetic foot and ankle fractures there were a total of 25 complicated and 15 uncomplicated fractures. Post injury complications occurred in 56% (14/25) of the complicated diabetics and in 33% (5/15) of the uncomplicated diabetics (p = .20). Also, 47% (9/19) of the complicated diabetics experienced a non-infectious complication compared to only 19% (4/21) of the uncomplicated diabetics (p = .38). Thus, there was a non significant tendency of a 23% (1.7 times) elevated risk of developing a post injury complication in the complicated diabetics with a 28% (2.4 times) increased risk of having a non-infectious complication. This increase is on par with Wukich, et al., who found a 3.4 times increased risk of developing a non-infectious complication ankle fractures in complicated diabetics. Also, the complicated diabetic group took almost 2 weeks longer for radiographic union compared to the uncomplicated diabetic group (14.76±7.20, 12.87±5.87, p = .40). While there was no statistical difference between the groups, the overall increase in healing time for all diabetic fractures is consistent with other studies.[2-7,12,22]

On the other hand, in our study no diabetic fractures resulted in an amputation. The literature has demonstrated amputation rates of diabetic ankle fractures ranging from 4 -17%.[9,23,28] Our 0% amputation rate is most likely due to the fact that we are not located at a level 1 trauma center and only had 3 (7%) open ankle fractures with no open foot fractures. Open diabetic ankle fractures traditionally have very poor outcomes with a 38% amputation rate in a case study by White, et al., in 2003.

A novel analysis evaluated the relationship between the severity of complicated diabetes and the number of post injury complications sustained by each patient. Eighteen diabetics (72%) were diagnosed with one complicating factor and seven (28%) were diagnosed with two or more complicating factors. Six (78%) of the diabetics with 2 or more complicating factors experienced at least one post injury complication compared to 8 (44%) of the diabetics with only 1 complicating factor (p = .14). This also showed a non significant propensity as the number of diabetic complicating factors increases, the amount of complications increases as well (1.7 times higher).

The most obvious weakness of our evaluation was the study being underpowered. This was because of the relatively small number of diabetic patients reviewed. Over 30 patients had to be excluded from the study due incomplete medical records including no height or weight being recorded, complications described too broad for interpretation, and radiographs/charts missing. These patients may have helped influence the data to become significant.

The other main weakness was the retrospective nature of the study. Retrospective studies are based on the correctness of patient charts/radiographs and thus information collected is only as accurate as the medical information documented. Also, this study also did not evaluate other complications such as deep vein thrombosis, thromboembolism, stroke, or myocardial infarction.

Furthermore, there could have been measurement bias as there was not a standard protocol initiated. However, all diabetic ankle fractures did receive ORIF with treatment based on standard fixation principles. Also, all diabetic foot fractures except one calcaneal avulsion fracture, were treated non-operatively in a surgical shoe or fracture walker.

Non-responder bias is also a part of this study since some patients were followed longer than others. If some patients were observed longer more complications could have been discovered. Most foot fractures were followed until fracture union and were not followed up thereafter. Moreover, there also could have been interview bias as the treating foot and ankle surgeon determined if there was a complication and recorded this in the patient's clinical chart.

Conclusion

Although not statistically significant, the trend of increased complication rate for foot fractures in complicated diabetics leads us to believe that foot fractures should be treated in the same manner as ankle fractures in complicated diabetics. Post injury clinical evaluation for PAD, PN and nephropathy should be considered. This analysis will be used as a template for a future prospective study comparing complicated and uncomplicated diabetic foot and ankle fractures.

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