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Original Article

Assessment of inter and intra-observer variation of Leonetti and Tigani CT bases classification of tibial pilon fractures

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Abstract: Introduction: tibial pilon fracture constitutes 5-7% of all tibial fractures. The treatment of choice is an open reduction with anatomical articular reconstruction and stable fixation. A relievable fracture classification is needed for the preoperative planning the surgical management of these fractures. Hence, we assessed the inter- and intra-observer variation of Leonetti and Tigani CT bases classification of tibial pilon fractures. Materials and methods: In this prospective study, 37 patients aged between 18-65 years with an ankle fracture were included. All these patients underwent a CT scan for the ankle fracture, and the CT scan was further evaluated by 5 independent observers (Orthopaedic surgeon). A kappa value was determined for inter and intra-observer variation. Results: Leonetti and Tigani's CT-based classification of the kappa values was 0.657 to 0.751, with a mean value of 0.700. The range of values for the intra-observer variation using Leonetti and Tigani CT-based classification on the kappa values was 0.658 to 0.875 with a mean value of 0.755. The *P*-value < 0.001 states that there was a significant agreement between the inter-observer and intra-observer classification. Conclusion: Leonetti and Tigani Classification have shown substantial inter- and intra-observer agreement, and the "4B" subclass of Leonetti and Tigani CT-based classification showed a predominance in the present study.

Keywords: Pilon fractures, ankle fracture, CT-based classification, inter and intra-observer variation

Introduction

Tibial pilon fractures are ankle fractures that involve the weight-bearing articular surface of the distal tibial [1-3], and these constitute 5-7% of all tibial fractures [4]. A robust classification system is required for these fractures to define the fracture pattern, guide prognosis, and assist in pre-operative planning and post-operative outcome [5]. The classification system should have high inter and intra-observer reliability [5].

The most common classification used for tibial pilon fractures is Ruedi and Allgower [2, 6-8] system and the OTA/AO [2, 6, 8, 9] fracture classification system. However, these classification systems are based on plain radiographic evaluation of the ankle and have moderate agreement and reproducibility [1, 2, 8, 10]; these classifications lacking in providing sufficient information for proper preoperative surgical planning, and they also have a high quotient of inter and intra-observer variability [1, 2, 8, 10].

CT scan is routinely used for radiographic assessment and surgical planning of tibial pilon fractures. It has significantly improved the ability to assess the injury pattern and further formulate surgical plans for definitive strategic fixation with minimization of soft tissue dissection [10-12]. In 2005, Topliss et al. proposed a classification for tibial pilon fractures which was based on the fracture configuration in axial CT images [2, 6, 8, 10]. It was divided into coronal, sagittal, and comminuted families.

Recently, Leonetti and Tigani have proposed a new CT-based classification of Pilon fractures [1, 2, 6].

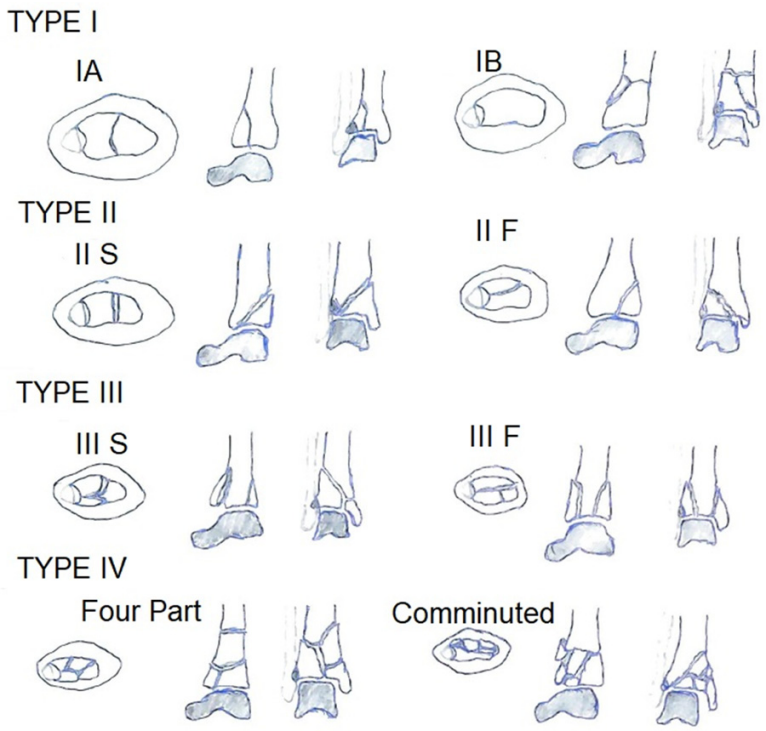

Figure 1. Types of tibial pilon fractures based on Leonetti and Tigani Classification.

The advantages of Leonetti and Tigani's [1] CT-based classification are: (a) A better evaluation of tibial pilon fracture in the 3-dimension, which helps in improving the pre-operative planning and subsequent surgical management [1]. (b) An easy way to classify pilon fractures [1, 2, 6]. (c) Adequately correlate long-term outcomes.

There is scanty literature about a reliable and reproducible classification for tibial pilon fracture. Thus, there is a need to propose a reliable classification.

Inclusion criteria: 1. Adults aged more than 18 years of age of either sex. 2. Closed fracture of distal tibia less than 3 weeks old involving weight-bearing articular surfaces.

Exclusion criteria: 1. Pathological fractures. 2. Open fracture with loss of a bone fragment. 3. Prior surgery around the distal leg and ankle. 4. Patients not willing to participate in the study. 5. Segmental fracture of the ipsilateral tibia.

Material and methods

After taking clearance from the Institutional ethical committee *(IECHR/2020/PG/47/30).* Thirty-seven patients aged 18-65 years of either sex with tibial pilon fracture were recruited for this prospective study in the department of orthopaedics of a tertiary care center after taking informed consent. All demographic data of the included patients were recorded in a predesigned proforma. All the patients were subjected to an axial 2D CT scan of the leg with the ankle joint. The CT scan was analyzed by 5 different observers (Orthopaedic surgeons) on two different occasions, eight weeks apart. All observers were informed about the Leonetti & Tigani patient's CT-based classification [1, 2, 6] and received printouts with proper illustrations to be able to check the classification as necessary. The fractures were divided into four labeling factors: (1) Articular surface involvement, (2) Articular fragments number, (3) Major fracture line direction, and (4) Areas of comminution, shown in **Figure 1**.

Tibial pilon fractures were therefore divided into the following groups and subgroups:

- Type I - Non-Displaced fractures or extra-articular fractures.
  - IA-Undisplaced2 part fracture.
  - IB-Extraarticular Distal Tibia Fracture.
- Type II - Displaced 2-Part fractures.
  - IIS-2 Part fracture with major fracture line in Sagittal plane.
  - IIF-2 Part fracture with major fracture line in Frontal plane.
- Type III - Displaced 3 Part fractures.
  - IIIS-3 Part fracture with major fracture line in Sagittal plane.
  - IIIF-2 Part fracture with major fracture line in Sagittal plane.

Figure 2. Pre-operative X-Ray of tibial pilon fractures.

● Type IV - Displaced 4 Part or Highly Comminuted fractures.

○ Intraarticular Fracture with 4 major fracture fragments.

○ Intraarticular Fracture with high comminution. It further divides as:

▪ Die punch fracture.

▪ Depending on the location of comminution (Anterior/Medial/Lateral/Posterior).

Illustrative figures of preoperative X-rays, CT-scans, and postoperative X-rays are shown in **Figures 2**-**4**, respectively. Five different observers evaluated CT scan to minimize observer bias and improve the precision. Any discrepancy was resolved by mutual agreement between 5 observers. Every observer classified the fractures based on Leonetti & Tigani CT-based classification [1, 2, 6]. They all were made blind to patients' demographic data, radiologist reports, and the fracture classifications done by the other participating Orthopaedic surgeons. All the observers have given adequate time as required to study a particular CT scan accurately. The classification responses made at the first viewing were not available to the observers during the second viewing. The observer was not provided with any feedback after the first viewing, and a CT scan was not available to any of the observers between the first and second viewing. The evaluation criteria for the study are based on the statistical analysis, which has been described underneath.

Statistical analysis

The observer's responses on each occasion were documented in a predesigned proforma and entered into a Microsoft Excel Sheet. The inter-observer variation was determined based on the result of the first reading, and the intra-observer variation was determined based on a particular observer's reading and the second reading. The level of agreement was determined using Kappa's test as defined by Cohen. Kappa is a coefficient of agreement that varies from +1 (perfect agreement) to '0' (agreement no better than chance) [13]. A *P*-value of < 0.05 was considered statistically significant.

Results

Demography

Thirty-seven patients aged between 18-65 years with closed tibial pilon fractures of less than 3 weeks old were included in the study. The mean age of patients in the current study was 38 years (range 19-64).

The majority of the subjects in the study were male (29 out of 37). There was a difference in frequency between various fracture patterns. The observations were recorded by 5 different Orthopaedic surgeons (**Table 1**). It shows a majority of "4B" that defines the comminuted type of tibial pilon fracture in 12 out of 37 patients.

Observations

The inter and intra-observer variation for tibial pilon fracture as classified on CT radiographs based on Leonetti and Tigani CT-based classifi-

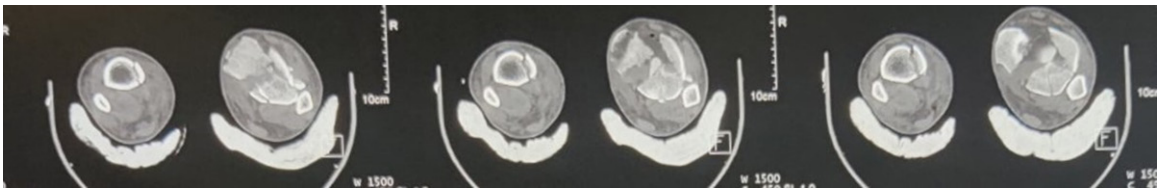

Figure 3. Preoperative CT scan of tibial pilon fracture.

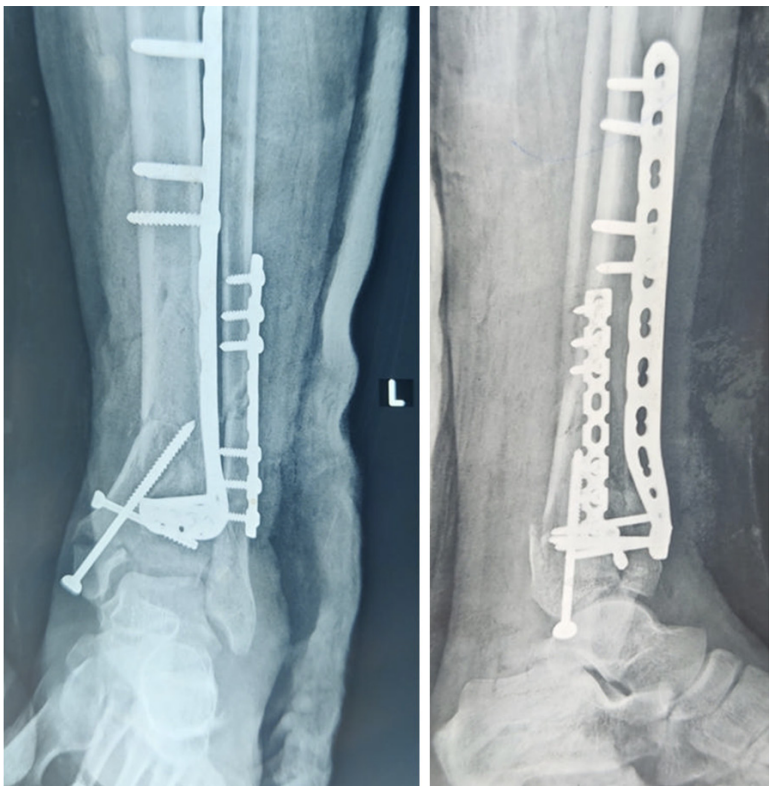

Figure 4. Post-operative X-ray of tibial pilon fracture.

cation had a range of values for the inter-observer variation using Leonetti and Tigani CT-based classification on the kappa values was 0.657 to 0.751 with a mean value of 0.700. The range of values for the intra-observer variation using Leonetti and Tigani CT-based classification on the kappa values was 0.658 to 0.875 with a mean value of 0.755 (**Table 2**).

The mean kappa values for interobserver variation using Leonetti and Tigani CT-based classification, as documented for all observers, was 0.700, showing a substantial agreement. Moreover, as documented for all observers, the mean kappa values for intra-observer variation using Leonetti and Tigani CT-based classification was 0.755, which also shows a substantial agreement. The *P*-value < 0.001 states that there was a significant agreement between inter-observer and intra-observer classification of CT-based classification of tibial pilon fracture by Leonetti and Tigani.

Discussion

Ruedi Allgower and AO Classification system is the most commonly used tool for classifying tibial pilon fractures. The basic purpose of any fracture classification system is to define fracture patterns, formulate a strategic plan for further management (for both operative and nonoperative treatment) and evaluate prognosis or outcomes corresponding to fracture patterns [14]. However, there is minimal literature on its inter and intra-observer variation as compared to other classifications [1, 2, 6, 8, 15-17].

In the current study, five Orthopaedic surgeons analysed the CT scan for 37 patients, and inter and intra-observer-based agreement for Leonetti and Tigani CT-based classification was deduced. The data analysis showed substantial agreement for inter and intra-observer-based variation for Leonetti and Tigani CT-based classification.

Leonetti and Tigani [1] conducted a study on 71 patients with tibial pilon fractures using the new foresaid classification based on a CT scan. The intra-observer agreement was taken at an interval of at least two weeks. The inter-observer variation was based on observation by 6 orthopaedic surgeons. The classification showed the average K-weighted value for inter-observer agreement to be 0.88, while the aver-

Table 1. Shows the patient's data and observed classification based on the CT scan

Case No	AGE	SEX	Leonetti & Tigani CT-Based Classification										Consensus	1A	1B	2S	2F	3S	3F	4A	4B
			A1	A2	B1	B2	C1	C2	D1	D2	E1	E2									
1	22	M	4B	4B	3F	3F	4B	2F	4A	4A	3S	3F	4B	0	0	0	0	0	0	0	1
2	40	M	1A	1A	2S	1A	1A	1A	1A	1A	1A	1A	1A	1	0	0	0	0	0	0	0
3	24	M	3F	3S	3S	2S	3S	3F	2S	2S	3F	2S	2S	0	0	1	0	0	0	0	0
4	20	M	1B	1B	2F	2F	1B	1B	2F	2S	1B	1B	1B	0	1	0	0	0	0	0	0
5	32	M	4B	4B	4A	4A	4B	4B	3S	4B	3F	4B	4B	0	0	0	0	0	0	0	1
6	30	F	3S	3S	3S	3S	3S	2S	3S	3S	3S	3S	3S	0	0	0	0	1	0	0	0
7	40	M	3S	3F	4B	4B	4B	4B	4B	4B	4B	4B	4B	0	0	0	0	0	0	0	1
8	58	F	4B	3S	2F	2F	3S	1A	4A	3F	3F	3F	3F	0	0	0	0	0	1	0	0
9	24	M	2S	1A	3F	3F	4B	4A	1A	1A	3F	2F	3F	0	0	0	0	0	1	0	0
10	55	M	4B	2F	3S	3F	3F	3F	4B	3F	4A	3F	3F	0	0	0	0	0	1	0	0
11	65	F	2S	2S	2S	2S	4A	2S	2F	3S	3S	3S	2S	0	0	1	0	0	0	0	0
12	19	F	4B	4B	4B	4B	4B	3F	2F	4B	4B	3F	4B	0	0	0	0	0	0	0	1
13	35	M	4B	3S	3S	3S	4B	4B	3F	3S	3S	3S	3S	0	0	0	0	1	0	0	0
14	54	M	4B	4B	3F	3F	4B	4B	4A	4B	4B	4B	4B	0	0	0	0	0	0	0	1
15	40	M	3F	2S	2F	4A	4B	3F	3F	3F	3F	3F	3F	0	0	0	0	0	1	0	0
16	48	M	1A	1A	1A	2F	1A	1A	1B	1A	1A	1A	1A	1	0	0	0	0	0	0	0
17	36	M	2S	3F	1A	1A	3S	1A	3F	3F	3F	2S	3F	0	0	0	0	0	1	0	0
18	40	M	2F	2F	2F	2F	2F	2F	2S	2S	3F	2F	2F	0	0	0	1	0	0	0	0
19	46	M	3F	3F	2F	3F	4B	3F	3S	3F	4B	3F	3F	0	0	0	0	0	1	0	0
20	48	F	4B	4S	4B	3F	4B	3F	4B	4B	4B	4B	4B	0	0	0	0	0	0	0	1
21	50	M	4B	4B	4B	4B	4B	4B	4B	4B	4B	4B	4B	0	0	0	0	0	0	0	1
22	42	M	4B	4B	3F	3F	4A	3F	3F	3F	3S	3F	3F	0	0	0	0	0	1	0	0
23	33	M	2F	3F	2F	3F	3F	3F	3S	3F	3F	3F	3F	0	0	0	0	0	1	0	0
24	16	F	4B	4B	3F	3F	4B	2F	4B	4B	4B	4B	4B	0	0	0	0	0	0	0	1
25	52	M	3S	3S	3S	3S	3S	2S	4A	3S	4A	2S	3S	0	0	0	0	1	0	0	0
26	64	F	1A	1A	2S	2S	1B	1A	3S	3S	1A	2S	1A	1	0	0	0	0	0	0	0
27	28	M	2S	2F	1B	3F	1B	2F	1A	1A	1B	1B	1B	0	1	0	0	0	0	0	0
28	45	M	3S	3S	2F	3F	4B	2F	4B	3S	3S	4B	3S	0	0	0	0	1	0	0	0
29	29	M	4B	4B	4B	4B	4B	4B	4B	4B	4B	4B	4B	0	0	0	0	0	0	0	1
30	45	M	4B	4B	4B	4B	4B	3F	4B	4B	4B	4B	4B	0	0	0	0	0	0	0	1
31	58	M	4A	4A	3F	2F	4A	3F	4A	4A	2F	3F	4A	0	0	0	0	0	0	1	0
32	27	M	2S	2S	4B	3S	4B	4B	2S	3S	2S	2S	2S	0	0	1	0	0	0	0	0
33	35	M	4B	4B	4B	4B	4B	4B	4B	4B	4B	3F	4B	0	0	0	0	0	0	0	1
34	23	M	4B	4A	4B	4B	3S	4B	3F	4B	3F	3F	4B	0	0	0	0	0	0	0	1
35	34	M	1A	2S	1A	1A	2F	1B	2S	1B	1A	1A	1A	1	0	0	0	0	0	0	0
36	42	M	3F	3F	2F	3F	4A	3F	2F	4B	3F	3F	3F	0	0	0	0	0	1	0	0
37	24	F	1B	2F	1B	1B	2S	2S	1B	1B	2F	2F	1B	0	1	0	0	0	0	0	0
														4	3	3	1	4	9	1	12

age K-weighted value was recorded to be 0.90, which denotes an excellent or perfect agreement [1].

In a study conducted by Palma et al. in 2019 on 71 patients with tibial pilon fracture, it was classified by Leonetti and Tigani based classification on CT. The intra-observer agreement was taken at an interval of 6 weeks. The inter-observer variation was based on observation by 6 orthopaedic surgeons. The inter-observer agreement was with a kappa value of 0.61 which is a substantial agreement, and the intra-observer agreement was with a kappa

Table 2. Inter and intra observer agreement

Observers	Inter Observer					Intra-Observer
	A	B	C	D	E	
A	1	.643	.692	.632	.767	.875
B	.512	1	.558	.445	.586	.754
C	.460	.738	1	.504	.746	.700
D	.759	.662	.530	1	.658	.658
E	.717	.595	.506	.809	1	.789
Mean kappa values for each observer	.689	.727	.657	.678	.751	
Mean kappa values for all observers			.700			.755

Table 3. Comparison between the current study and previous study for variation in responses for Leonetti and Tigani CT-based classification

Study	Inter-Observer Agreement	Intra-Observer Agreement
Leonetti and Tigani (2017)	Perfect (0.88)	Perfect (0.90)
Palma et al. (2019)	Substantial (0.61)	Substantial (0.78)
Xu-Sheng Qiu et al. (2019)	Substantial (0.55)	Substantial (0.77)
Current Study (2020)	Substantial (0.70)	Substantial (0.75)

Table 4. Comparison of inter and intra-observer agreement for various classifications of tibial pilon fractures [1, 2, 6, 8, 15-17]

Classification	Inter Observer Agreement	Intra Observer Agreement
Leonetti and Tigani	0.55-0.88	0.78-0.90
Topliss CT based	0.47-0.54	0.58-0.77
AO/OTA	0.47-0.80	0.56-0.72
Ruedi Allgower	0.50-0.61	0.53-0.85

value of 0.78 which shows substantial agreement [2].

In another study conducted by Xu-Sheng Qiu et al. (2019) [6] on 68 patients (70 legs), tibial pilon fractures were classified by Leonetti and Tigani based classification on CT. The intra-observer agreement was taken at an interval of 3-4 weeks. The inter-observer variation was based on observation by 4 orthopaedic surgeons. The inter-observer agreement was with a kappa value of 0.55 which is a moderate agreement, and the intra-observer agreement was with a kappa value of 0.77 which shows substantial agreement.

The current study also shows substantial agreement in inter and intra-observer variation among 37 subjects. The comparison of the current study with various previous studies done for inter and intra-observer agreement is mentioned below and shows a substantial agreement (**Tables 3** and **4**). The current study derives its strength from being a prospective study. However, the limitation of the study is a small sample size due to the limited time frame of the study.

Conclusion

The CT scan-based Leonetti and Tigani Classification of tibial pilon fractures has shown substantial inter and intra-observer agreement with kappa values (k) of 0.70 and 0.75, respectively, which is substantial. The “4B” subclass of Leonetti and Tigani CT-based classification showed a predominance amongst 37 subjects in the present study.

Clinical implication

Tibial pilon fractures are intraarticular fractures where as seen in cases of fracture of distal radius an articular incongruence of more than 2 mm can lead to early osteoarthritis [18]. It is therefore an essential aspect to assess the

intraarticular congruity by the use of a CT scan. It is also known that various approaches are defined for the fixation of tibial pilon fractures based on the major fragment pattern. Leonetti and Tigani CT Based Classification holds importance in defining the fracture pattern hence assisting further surgical planning.

Disclosure of conflict of interest

None.

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