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Comparison between standard radiography and spiral CT with 3D reconstruction in the evaluation, classification and management of tibial plateau fractures

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Abstract
Background: Proximal tibia is one of the most critical weights bearing part of the human body. Fractures of the plateau affect knee alignment, stability, and motion. The present study was conducted to decide whether pre-operative CT scan significantly changes the line of action and plan of surgery, against simple digital radiographs, in managing fractures of the upper tibial condyles and hence should it be an essential investigation for treatment in proximal tibial fractures.
Materials & Methods: The present cross-sectional, prospective study was conducted on 42 cases (males- 37, females-5) of traumatic fractures of the proximal tibia. First opinion was taken on the basis of the X-ray alone and second opinion was taken after showing the CT scans.
Results: There were 16 (38.09%) patients in age group of < / = 30 years, 17 (40.48%) patients in age group of 30-45 years, 8 (19.05%) patients in age group of 45-60 years and only 1 (2.38%) patient is the age group of 60-75 years. There were 02 (04.76%) patients diagnosed to have no fracture based on X-ray, 14 (33.33%) patients diagnosed as Schatzker's type-1, 02 (04.76%) patients diagnosed as Schatzker's type-2, 05 (11.91%) patients diagnosed as Schatzker's type-4, 13 (30.95%) patients diagnosed as Schatzker's type-5 and 06 (14.29%) patients diagnosed as Schatzker's type-6 based on X-ray alone. A total 12 cases were included in Schatzker's type 1. Management of 01 case was drastically changed, that of 03 cases had subtle changes and that of 08 cases remained unchanged. Plan of 01 case out of 04 included in Schatzker's type 2 was changed drastically, 02 underwent subtle changes while that of 01 was unchanged. Only 01 case was included in Schatzker's type 3. Its management underwent subtle change. 02 cases were diagnosed as type 4. Treatment of 01 underwent subtle change while that of 01 remained unchanged. Plan of 02 cases out of 06 included in type 6 were drastically changed. 04 had no changes.
Conclusion: CT scan contributes significantly in management of proximal tibia fractures especially in Schatzker's type 1 and type 4. It reveals articular depressions and fracture fragments that are often obscured on X-rays. It helps surgeons to prevent dreadful postoperative complications.

Keywords: CT scan, Schatzker's type, Tibia

Introduction
Proximal tibia is one of the most critical weights bearing part of the human body. Fractures of the plateau affect knee alignment, stability, and motion. Early detection and appropriate treatment of these fractures are critical for minimizing patient disability and reducing the risk of documented complications, particularly post-traumatic arthritis. These fractures are caused by strong bending forces combined with axial loads, e.g. a car striking a pedestrian on the side of the knee (hence the term "bumper fracture") or a fall from a height in which the knee is forced into valgus or varus. One or both tibial condyles are crushed or split by the opposing femoral condyle [1].
The surgical treatment of these fractures is dependent upon several factors, including the type of fracture, the degree of the fracture depression, and fracture fragment separation as well as the patient's age and physical condition. The degree of the plateau depression is a particularly important criteria for surgical-treatment planning. However, the anatomic configuration of the proximal tibia is such that the fractures of these regions are not adequately visualized on

conventional radiographs [2]. CT can be performed without removal of the knee brace or cast and usually requires less than 12 axial images. Furthermore, the exact degree of fracture separation and depression can be measured by computerized technique [3]. The need for additional diagnostic interventions also depends on experience level of the operating surgeon. Majority of experienced surgeons can dictate the appropriate surgical approach, pattern of fixation and potential complications just by looking at plain radiographs [4]. But it is difficult to do so for the young surgeons with limited experience. These surgeons need better visualization and evaluation of the fracture pattern before commencing the surgery. CT scan can be such a tool [5]. Hence the present study was conducted to decide whether pre-operative CT scan significantly changes the line of action and plan of surgery, against simple digital radiographs, in managing fractures of the upper tibial condyles and hence should it be an essential investigation for treatment in proximal tibial fractures.

Materials & Methods

The present cross-sectional, prospective study was conducted on 42 cases (males-37, females-5) of traumatic fractures of the proximal tibia coming to the Department of Orthopaedic in Index Medical College, Hospital and Research Centre, Indore (M.P).

The study was explained in detail to the patient and/or his/her legally acceptable representative regarding risks, benefits, surgery, approach etc. After obtaining their verbal consent, a voluntary written informed consent was taken from them, prior to initiation of any study related procedures. The patient's clinical history and examination findings were recorded prospectively in a case record form. Then radiological investigations like X-ray and CT scan were ordered.

Opinions of operating consultant surgeon were taken in two separate proformas regarding their findings, diagnosis and plan of management. First opinion was taken on the basis of the X-ray alone and second opinion was taken after showing the CT scans. Any change in the plan of management was noted. Roentgenogram of the involved knee joint with leg (antero-posterior and lateral views) was done. (GE DX 300mA X-ray machine, Care stream Dry view CR system, Care stream Dry view 5950 laser imager were used). Computed tomography was done after taking opinion of the operating surgeon on the basis of roentgenogram (Siemens Somatom Definition AS scanner and Carestream Dryview 5950 laser imager were used).

The changes in plan of management of each case were divided into 3 groups: "No change", "Subtle change" and "Drastic change".

Those cases in which there was no change in the plan of management after seeing X-ray and CT scans were included in "No change" group. Those cases where there was a minor change in management like change in reduction maneuvers, supplementation of fixation with CC screws, immobilization and restriction of weight bearing for longer durations were included in "Subtle change" group. In cases where after seeing the CT scans, operating surgeon advised a major change in the treatment strategy like complete change in modality of treatment, change in method of fixation, change of plate position, addition or removal of one or more plates, change in surgical approach or addition of bone grafting, were included in the "Drastic change" group. The data from proforma was transferred onto Microsoft Excel (Microsoft Office Professional Plus 2013). P value less than 0.05 was considered significant.

Results

Table I: Distribution of patients according to age

Age group	Number	Percentage
< / = 30 years	16	38.09
31-45 years	17	40.48
46-60 years	08	19.05
61-75 years	01	02.38
Total	42	100.00

Table I shows that there were 16 (38.09%) patients in age group of < / = 30 years, 17 (40.48%) patients in age group of 30-45 years, 8 (19.05%) patients in age group of 45-60 years and only 1 (2.38%) patient is the age group of 60-75 years.

Table II: Distribution of patients according to Diagnosis on X-ray

Diagnosis on X-ray	Number	Percentage
No fracture	02	04.76
Schatzker's type 1	14	33.33
Schatzker's type 2	02	04.76
Schatzker's type 3	00	00.00
Schatzker's type 4	05	11.91
Schatzker's type 5	13	30.95
Schatzker's type 6	06	14.29
Total	42	100.00

Table II shows that there were 02 (04.76%) patients diagnosed to have no fracture based on X-ray, 14 (33.33%) patients diagnosed as Schatzker's type-1, 02 (04.76%) patients diagnosed as Schatzker's type-2, 05 (11.91%) patients diagnosed as Schatzker's type-4, 13 (30.95%) patients diagnosed as Schatzker's type-5 and 06 (14.29%) patients diagnosed as Schatzker's type-6 based on X-ray alone.

Table III: Distribution of patients according to management on X-ray

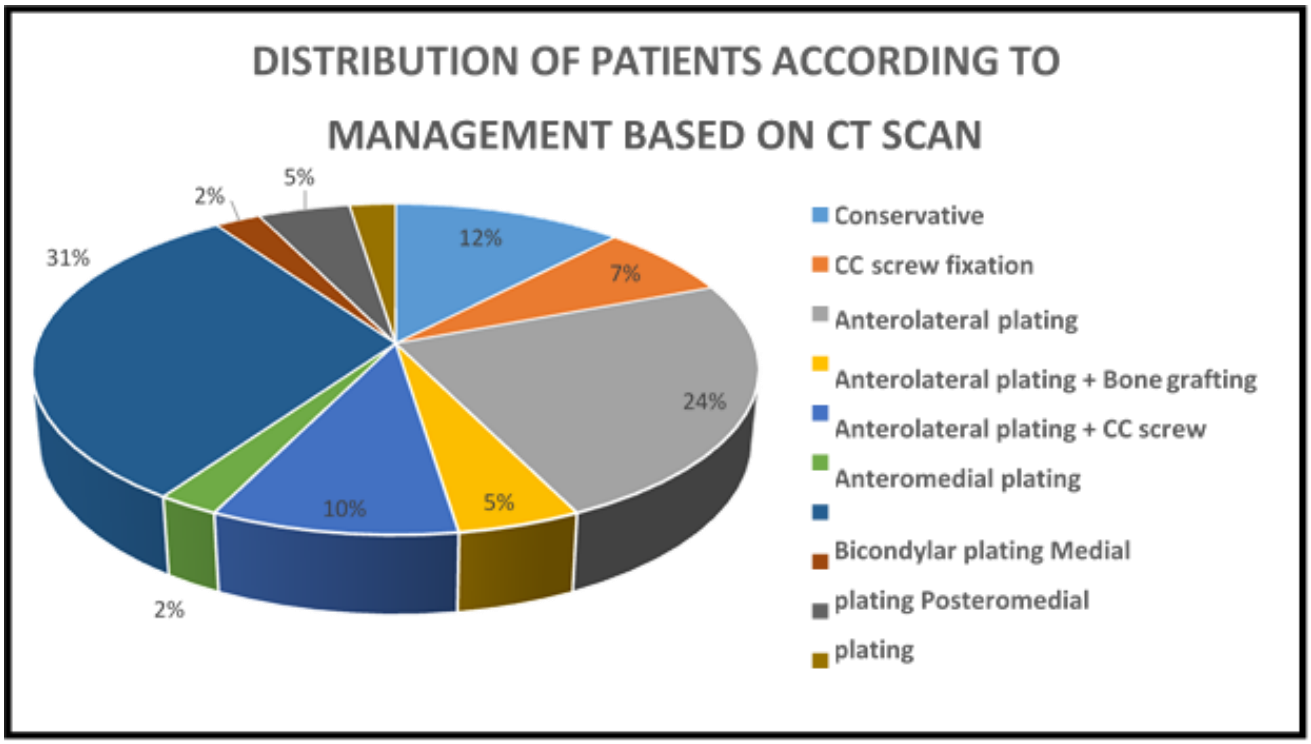
Procedure planned on X-ray	Number	Percentage
No treatment required	02	04.76
Conservative	04	09.54
CC Screw fixation alone	03	07.14
Antero-lateral plating	16	38.09
Antero-lateral plating + CC screw	01	02.38
Antero-medial plating	01	02.38
Bi-condylar plating	10	23.81
Medial plating	01	02.38
Postero-medial plating	03	07.14
Postero-medial plating + CC screw	01	02.38
Total	42	100.00

Table III shows that in 02 (04.76%) patients it was thought that no treatment is required, 04 (09.54%) patients were planned to be managed conservatively, in 03 (07.14%) patients fixation with CC screws was planned, in 16 (38.09%) antero-lateral plating was planned, in 01 (02.38%) patients antero-lateral plating supplemented with CC screw was planned, in 01 (02.38%) patients antero-medial plating was planned, in 10 (23.81%) patients bi- condylar plating was opted for, in 01 (02.38%) patients medial plating was planned, in 03 (07.14%) patients postero-medial plating was to be done and in 01 (02.38%) patients CC screw in addition to postero-medial plating was planned. The two most commonly opted plans of management were Antero-lateral plating and Bi-condylar plating.

Table IV: Distribution of patients according to Diagnosis on CT scan

Diagnosis on CT scan	Number	Percentage
No fracture	00	00.00
Schatzker's type 1	12	28.58
Schatzker's type 2	04	09.53
Schatzker's type 3	01	02.38
Schatzker's type 4	02	04.73
Schatzker's type 5	17	40.49
Schatzker's type 6	06	14.29
Total	42	100.00

Table IV shows that after CT scanning, 12 (28.58%) patients were classified as Schatzker's type-1, 04 (09.53%) were classified as type-2, 01 (02.38%) were classified as type-3, 02 (04.73%) were classified as type-4, 17 (40.49%) were classified as type-5 and 06 (14.29%) patients were classified as type-6 fractures. Schatzker's type-5 was the most commonly found fracture, followed by type-1.



Graph I: Distribution of patients according to Management on CT scan

Graph I shows that after CT scan, 05 (11.91%) cases were planned to be treated conservatively, in 03 (07.14%) patients CC screw fixation was planned, in 10 (23.81%) patients antero-lateral plating was planned, in 02 (04.76%) patients antero-lateral plating with bone grafting was planned, in 04 (09.52%) patients antero-lateral plating with CC screw fixation was planned, in 01 (02.38%) patients antero-medial plating was planned, in 13 (30.96%) patients bi-condylar plating was planned, in 01 (02.38%) patients medial plating was planned, in 02 (04.76%) patients postero- medial plating was planned and in 01 (02.38%) patients postero-medial plating with CC screw was planned.

Table V: Distribution of patients according to change in diagnosis after CT scan

Diagnosis on X-ray	No	%	Change of diagnosis after CT scan	No	%
No fracture	02	04.76	Schatzker's type 1	01	02.38
			Schatzker's type 3	01	02.38
Schatzker's type 1	14	33.33	Schatzker's type 1	11	26.19
			Schatzker's type 2	03	07.14
Schatzker's type 2	02	04.76	Schatzker's type 2	01	02.38
			Schatzker's type 5	01	02.38
Schatzker's type 3	00	00.00	-	-	-
Schatzker's type 4	05	11.91	Schatzker's type 4	02	04.76
			Schatzker's type 5	03	07.14
Schatzker's type 5	13	30.95	Schatzker's type 5	13	30.96
Schatzker's type 6	06	14.29	Schatzker's type 6	06	14.29
Total	42	100.00	Total	42	100.00

Table V shows that 02 (04.76%) patients were thought to have no fracture in X-ray. 01 (02.38%) patient turned out to be Schatzker's type 1 and 01 (02.38%) to be Schatzker's type 3 on CT scan. In X-ray, 14 (33.33%) patients were diagnosed as Schatzker's type 1. After CT scan, diagnosis of 11 (26.19%) patients remained unchanged and 03 (07.14%) patients were included in Schatzker's type 2. Bi-condylar plating was the most commonly opted treatment plan followed by antero-lateral plating. 02 (04.76%) patients were diagnosed as Schatzker's type 2 on X-ray but after seeing CT scans, diagnosis of 01 (02.38%) patient was changed to Schatzker's type 5 while 01 (02.38%) remained unchanged. Though no patients were included in Schatzker's type 3 based on X-rays, 01 (02.38%) case which was earlier thought to have no fracture was included in this group. 05 (11.91%) patients were Schatzker's type 4 on X-ray. 03 (07.14%) patients‟ diagnosis was changed to Schatzker's type 5. 02 (04.76%) patients‟ diagnosis were unchanged. Schatzker's type 5 cases were 13 (30.96%) in number. Diagnosis of all of them was unchanged after CT scan. Schatzker's type 6 cases were 6 (14.29%) in number. Diagnosis of all of them was unchanged after CT scan. Schatzker's type 1 and type 4 involved the most changes in diagnosis after CT scans were made available.

Table VI: Distribution of patients according to change in management after CT scan

Plan on X-ray	No	%	Change of Plan on CT scan	No	%
No treatment required	02	04.76	Conservative	02	04.76
Conservative	04	09.54	Conservative	03	07.15
			CC screw fixation alone	01	02.38
CC Screw alone	03	07.14	CC screw fixation alone	02	04.76
			Postero-medial plating	01	02.38
Antero-lateral plating	16	38.09	Antero-lateral plating	09	21.43
			Antero-lateral plating + BG	02	04.76
			Antero-lateral plating + CC	03	07.15
			Bi-condylar plating	02	04.76
Antero-lateral plating + CC screw	01	02.38	Antero-lateral plating + CC screw	01	02.38
Antero-medial plating	01	02.38	Antero-medial plating	01	02.38
Bi-condylar plating	10	23.81	Antero-lateral plating	01	02.38
			Bi-condylar plating	09	21.43
Medial plating	01	02.38	Medial plating	01	02.38
Postero-medial plating	03	07.14	Bi-condylar plating	01	02.38
			Postero-medial plating	01	02.38
			Postero-medial plating + CC	01	02.38

Table VI shows distribution of patients according to change in management after CT scan.

Table VII: Comparison of diagnosis (on X-ray) and change in management plan

Diagnosis on X-ray	Drastic Change	Subtle Change	No change	Total
No fracture	00	02	00	02
Schatzker's type 1	02	04	08	14
Schatzker's type 2	00	01	01	02
Schatzker's type 3	00	00	00	00
Schatzker's type 4	02	02	01	05
Schatzker's type 5	02	02	09	13
Schatzker's type 6	02	00	04	06
Total	08	11	23	42

Table VII shows that subtle change was seen in 02 cases which were thought to have no fracture on X-ray. Out of total 14 cases included in Schatzker's type 1, 02 underwent drastic change, subtle change was seen in 04 cases while surgical decision of 08 cases remained unchanged. There were 05 cases of Schatzker's type 4.Management of 02 cases was drastically changed, 02 cases underwent subtle changes and 01 cases plan was not changed. Management of 09 cases out of 13 included in Schatzker's type 5 remained unchanged, while 02 were changed drastically and 02 had subtle changes. Total 06 cases were included in Schatzker's type 6. Drastic changed in surgical plan were observed in 02 cases and plan of 04 cases remained unchanged. Out of total 42 cases included in this study, some change (Drastic or Subtle) was observed in 19 (45.24%) cases.

Table VIII: Comparison of diagnosis (on CT scan) and change in management plan

Diagnosis on CT scan	Drastic Change	Subtle Change	No change	Total
Schatzker's type 1	01	03	08	12
Schatzker's type 2	01	02	01	04
Schatzker's type 3	00	01	00	01
Schatzker's type 4	00	01	01	02
Schatzker's type 5	04	04	09	17
Schatzker's type 6	02	00	04	06
Total	08	11	23	42

Table VIII shows that total 12 cases were included in Schatzker's type 1. Management of 01 case was drastically changed, that of 03 cases had subtle changes and that of 08 cases remained unchanged. Plan of 01 case out of 04 included in Schatzker's type 2 was changed drastically, 02 underwent subtle changes while that of 01 was unchanged. Only 01 case was included in Schatzker's type 3. Its management underwent subtle change. 02 cases were diagnosed as type 4. Treatment of 01 underwent subtle change while that of 01 remained unchanged. Plan of 02 cases out of 06 included in type 6 were drastically changed. 04 had no changes.

Discussion

Tibial plateau fractures involve a complex anatomy. They can present as isolated fracture or as a part of poly trauma. They often have complicated surgical repair due to highly complex nature of fractures and intra- articular involvement [6]. Their management is further complicated by the fact that multiple fracture patterns can be seen which usually don't fit into one classification system. Soft tissue condition at the time of presentation plays a crucial role in dictating the line of management. Highly invasive surgical interventions leave the proximal tibia with relatively scarce soft tissue coverage [7].

Plain radiographs contribute largely to the primary diagnostic procedure, they are quick and easy to perform, low-cost and widely available. CT scan is a diagnostic modality that every patient can't afford, especially in developing countries like India. These are usually available in tertiary care hospitals and private medical setups [8]. These expose the patients to much more radiation than X-rays but give valuable additional information that cannot be obtained by plain radiographs. With the advancement in technology, many adjuvants to CT scan (like Multi-slice CT, MDCT) have been developed that make them even more desirable to operating surgeons [9].

Traditional classification systems like Schatzker, AO and Duparc systems classify them according to the fracture morphology on plain radiographs. Most of them fail to include the vast variety of fracture patterns that are commonly seen in clinical practice. So they don't always contribute in management plan of these types of fracture [10].

CT scan is fast and easy to perform. Though CT scan exposes the patient to radiation more than X-ray, the risk: benefit ratio validates the use of CT scanning for better functional outcome. Coleman *et al.* [42] stated that cross-sectional imaging can improve accurate classification and may change management plan. They recommend that CT scan should be done when radiographs show condylar widening, articular incongruity and depressed articular surface [11].

Taking X-ray requires the patient to change positions to provide different views. Sometimes this is difficult in patients with unbearable pain due to acute trauma. Furthermore, it can cause injury to neurovascular structures while shifting. Many times we have to make do with X-rays taken in improper angles because patient is unable to give proper position required for X-ray.[12] Splints and braces need to be removed before taking radiographs which aggravates the situation for the patient. These produce artefacts which interfere with accurate diagnosis of the fracture. CT scans can be done without removing these aids and a single position is maintained by the patient throughout the procedure. So patient is more comfortable and co-operative. The artefacts can then be digitally subtracted leaving a clear picture for diagnosis. Rafii *et al.* [13] stated that CT scan superior to X-ray as it is easier, more accurate method and can be performed without removal of the knee brace or cast.

In our study we found that tibial plateau fractures are more common in males than females. It is commonly found in adults of age group 30-40 years. Most common cause of injury was road traffic accidents. Left side knee is more commonly affected than right. Most common cause of fracture in road traffic accident and 22.6% have associated injuries like meniscal and capsulo-ligamentous injuries, fracture fibula, fracture shaft of femur, fracture supracondylar humerus and calcaneal fractures [14].

Sometimes depressions and undisplaced fractures are not evident on X- rays. This was observed in 02 cases in our study. In one case, no bony injury was observed on X-ray but due to suspicion of ligament injury, MRI was done. In MRI, lateral plateau depression was observed so patient was classified as type 3 and conservatively managed. One case was similarly diagnosed with lateral plateau split fracture and was included in Schatzker's type 1. Immobilization in above knee cast was done for 6 weeks.

Antero-lateral plating was the opted for in 16 out of 42 cases. After confirming with CT scan, antero-lateral plating was done in 09 cases, in 02 cases bone grafting was required to elevate the depressed articular fragment, in 03 cases antero-lateral plating had to be supplemented with CC screws and in 02 cases one more plate had to be added to provide the medial support.

Zhu *et al.* [15] compared the inter- observer reliability of CT-scan based Three-column classification with radiograph based AO & Schatzker's classifications and found that 3D reconstructions can identify the posterior column fracture better, "Substantial agreement" was found with CT scans.

Wirbel *et al.* [16] in their study suggested that combination of Schatzker's and Three-column classification is highly applicable in posterior tibial fractures. They reported no significant changes in preoperative management plans after addition of 3D CT scans. Chen *et al.* [17] in 2016 found only "fair" to "substantial" inter-observer reliability of fracture characteristics in 3D and traditional CT scans. Addition of 3D CT over 2D CT did not improve agreement between observers and diagnostic accuracy.

Conclusion

CT scan contributes significantly in management of proximal tibia fractures especially in Schatzker's type 1 and type 4. It reveals articular depressions and fracture fragments that are often obscured on X-rays. It helps surgeons to prevent dreadful postoperative complications. Although plain radiographs are indispensable for initial evaluation of patients with acute knee trauma, they should not be replaced by CT scan. Rather CT scan should be used to supplement the plain radiographs for better diagnosis, pre-operative evaluation and management of proximal tibia fractures.

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