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# Radiological and clinical evaluation amongst types of tibial tunnel widening and choice of graft fixation implants in ACL reconstruction

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**Abstract**
**Objective**: To study incidence of tibial tunnel widening and its functional correlation in patients operated with ACL reconstruction with four fold hamstring tendon autograft. To evaluate radiologically and clinically tunnel widening when tibial side of graft is fixed with suture disc or interference screw and to study type of tunnel widening (cavity type, cone type and line type) and its functional correlation.
**Introduction**: Arthroscopic ACL reconstruction is most commonly done ligament reconstruction surgery in orthopaedic with gratifying results. However, it is also associated with complications. Tunnel widening (TW) as one of the complications has been topic of discussion in orthopaedic literature recently. Type of graft fixation in tibia has been considered as cause of tunnel widening. We compared TW in grafts fixed with suture disc and interference screw, evaluated type of tunnel widening in tibia and its correlation in terms of radiology and function.
**Methodology**: A cohort of 30 patients operated with arthroscopic ACL reconstruction were evaluated over a period of three years. Patients were divided between suture disc group and interference screw group for tibial fixation and femoral fixation was kept same in both the groups i.e. suspensory. We assessed amount of tunnel widening in tibia with radiographs and CT scan at 3 months 6 months and 12 months, divided TW into cavity type, cone type and line type. We tried to correlate amount of TW with type of tibial fixation and its functional score. We also tried to correlate type of TW and functional score.
**Results**: Amount of TTW was more with interference screw group than suture disc group at 12 months. Lysholm score was almost equal in both the groups. Type of tunnel widening: cavity type is more common 53 %, followed by cone type 26% and then line type 21 %. TTW was highest i.e. 12.11mm in cavity type, followed by 12.04 in cone type and 11.72 in line type. Functional score was almost similar in all types.
**Conclusion**: Both the groups i.e. suture disc and interference group had considerable tunnel widening but the difference between them is negligible to conclude superiority of on over the other. Functional score is similar in both the groups. Regarding type of tibial tunnel widening, cavity type TTW is most common (53%), followed by cone type (26%) and least common is line type widening (21 %). Maximum tunnel widening is in cavity type and if it's less than 12 mm then functional score is good in those patients. There is no significant correlation between the type of TTW and clinical stability and functional scores. But it has surgical implications as more tunnel widening leaves lesser bone bed for revision ACL reconstruction.

**Keywords:** ACL, TTW- tibial tunnel widening, suture disc and interference screw, *cone*, *cavity*, *line*

## Introduction
Arthroscopic ACL reconstruction is a commonly done orthopaedic surgery with good results due to better understanding of ACL anatomy and advances in technology. It is also associated with complications like stiffness, recurrent instability and infection due to various reasons. One of the complications is bone tunnel widening during early follow up. This can theoretically have clinical implications of loss of strength of ligament leading to recurrence of instability. There are research articles showing association between early graft failures and tunnel widening [1, 2] But it still remains a topic of controversy.
Bone tunnel widening depends of many factors like type of graft, graft fixation systems elastic or rigid, single or double bundle fixation, and aggressive rehabilitation.

Giovanni in his study showed that tunnel widening was more when grafts are fixed with elastic suspension systems like endobutton than rigid compression system like interference screws. The possible explanation is that with endobutton, the fixation point of graft is distant from the joint line than the screw fixation. This increases the lever arm and force momentum during knee movement leading to higher amount of tunnel widening when compared to screw fixation [3].

The etiology of tunnel enlargement is currently unknown. Many theories have been put forth to explain this complication. Mechanical theory states that there is possibility of micromotion of the graft relative to the tunnel wall in suspensory fixation, leading to an inflammatory response in the tunnel. There is also suspected stress shielding of the tunnel wall proximal to the interference screw in tibia causing bone tunnel widening [4].

The biological theory says there is involvement of nonspecific inflammatory response cells, heat necrosis due to drilling, cytokine response like TNF, interleukin-6, nitric oxide from the synovial fluid [5].

Purpose of this study was to evaluate radiologically and clinically the incidence of tunnel widening in ACL reconstruction where hamstring tendon was fixed with suture disc and interference screw, and secondly to study types of tunnel widening and its effect on function of the knee.

## Materials and methods

Our prospective cum retrospective study included 30 patients who were operated within a period from May 2013 to May2016 at our institute. After primary treatment after injury three weeks was a waiting period for surgery for bone edema to settle down.

### Inclusion criteria

1. Complete ACL tear proved both clinically and on MRI.
2. Young physically active patients of age group 18 to 50 years.
3. Patient willing to give consent for the study.
4. No previous fractures to the affected limbs
5. Painless knee range of motion up to at least 90 degrees.

### Exclusion criteria

1. Coronal malalignment of the lower limb with joint space reduction.
2. Associated Multiligament injury
3. Associated Chondral injury
4. Retear after previous ACL surgery.

All patients were clinically evaluated by Lachman's test, Drawer test, Pivot shift test and Mc Murray's test. After initial investigations and consent, they underwent arthroscopic ACL reconstruction by single surgeon at our institute. The meniscus tear was evaluated for reparability. Irreparable meniscus tears were trimmed with shaver to achieve stable meniscus rim. Fresh tears in red- red zone were repaired by appropriate suturing method. All patients were operated with medial portal technique for ACL reconstruction. Four fold semitendinosus graft was used to achieve minimum diameter of 8 mm. All patients had tunnel diameter 8mm both femoral and tibial. Femoral fixation in all patients was extracortical fixation (endobutton with a polyester loop or tight rope device). On tibial side fixation was either with a suture disc or an interference screw. Minimum 15 mm graft was considered adequate for femoral tunnels. Details of the graft and drill size were noted down. Patient's knee was immobilized with a long leg knee brace.

### Postoperative protocol

Postoperatively, patients were kept in long leg knee brace for 2 weeks. From second postoperative day, static quadriceps strengthening, ankle toe pumps and hip strengthening exercise was started. After two weeks, gradual range of motion was started. Partial weight bearing was done with walker and knee brace up to four weeks. After one month as patients gained good quadriceps strength they were asked to walk full weight bearing with hinged knee brace. Full range of motion was achieved by the end of 6 weeks. Third month after the surgery, patients were asked to resume their daily routine activities like walking, stair climbing and jogging. Patients were asked to resume sports activities six to eight months after the surgery.

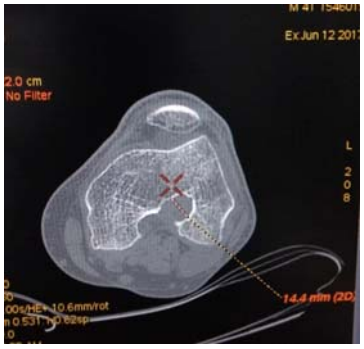
Functional scoring was done using Tegner Lysholm Knee Scoring Scale preoperatively and during follow up. Objective assessment of knee stability was done by single surgeon in ideal positions with Lachman's Test, Drawer's Test and Pivot Shift test.

### Radiographic evaluation

All patients were called after 3 months, 6 months and 12 months for clinico-radiological evaluation. Antero posterior and lateral radiographs of the knee were taken at each follow up and tibial tunnel diameter was measured at three levels (at mouth, at middle and at the exit). On CT scan tunnel diameters were noted in coronal, sagital and axial sections. Femoral tunnel diameter was measured at the widest point which is mouth or inta articular end of the tunnel as the cortical end was of 4.5 mm size. Measurements were taken with digital scales to eliminate magnification bias both on x rays and CT scans. This was also confirmed by comparing with size of the metallic implant (screw) used in the surgery. At the same time, type of tunnel widening was noticed and classified into cone type, line type and cavity type. The data was analyzed with chi square test and student t test.

**Pic 1:** CT Scan 12 months postop coronal image showing cavity type TTW. S

**Pic 2:** CT Scan 3 months postop shows line type TTW in screw type tibial fixation.




**Pic 3:** Axial CT cuts at12 months postop showing femoral tunnel widening.


**Pic 4:** AP radiograph showing line type TTW.


**Pic 5:** Lateral radiograph 6 months after surgery.

## Results

Out of 35 patients who were initially included in the study, two patients had infection one month after surgery for which arthroscopic lavage was given. Three patients were lost to follow up. So total 30 patients were considered for final evaluation. Mean age of the patient was 28.26 years (range20 to 44 years). There were 26 male and 4 female patients. Out of 30 knees 12 were right and 18 were left knees. 17 of these patients had sport related injury and 13 injured there ACL during road traffic accident. Seven patients had associated lateral meniscus injury and 8 had medial meniscus injury. Remaining 19 had isolated ACL injury. On tibial side suture disc was used in 17 patients and interference screw was used in 13 patients. Patients were divided into suture disc group and screw group. Our observations were as follows:

Tibial tunnel diameter in disc group increased from 8 mm to 10.51 mm at 3 months, 12.30 at 6 months and 12.14 mm at 12 months.

**Table 1:** tunnel diameter in screw group increased to 9.80 at 3 months, 12.26 at 6 months and 12.86 at 12 months.

| | Tibial Tunnel Diameter(TTW) in mm | | |
|---|---|---|---|
| **Tibial Fixation Group** | **3 months** | **6 months** | **12 months** |
| Disc | 10.51 | 12.30 | 12.14 |
| Screw | 9.80 | 12.26 | 12.86 |

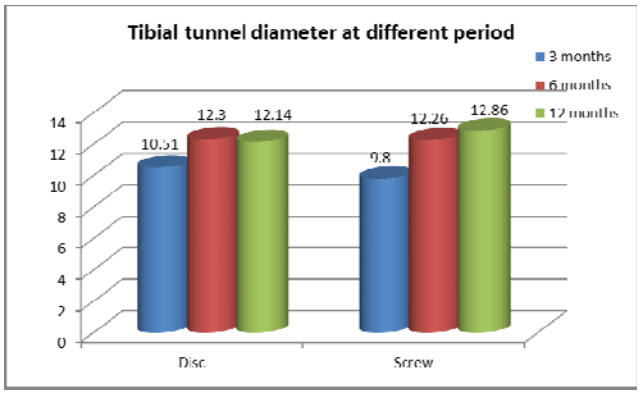


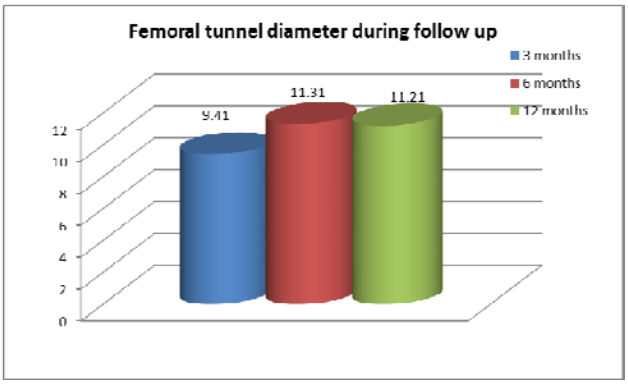

**Table 2:** tunnel diameter at follow up 12 months by group

| Group | Count | Mean | Standard Deviation | P value |
|---|---|---|---|---|
| **Disc** | 16 | 12.14 | 1.12 | 0.19 (NS) |
| Screw | 14 | 12.86 | 1.74 | T test |

Femoral tunnel diameter increased from 8 mm to 9.41 mm at 3 months, 11.31 mm at 6 months and 11.21 mm at 12 months.

### Femoral tunnel diameter (mm) at follow up

| 3 months | 6 months | 12 months |
|---|---|---|
| 9.41 | 11.31 | 11.21 |




### Functional score

Lysholm score was above 90 for T TW of 12.01mm. Eighty to 90 score was found in TW of 11.88mm. Patients with score less than 80 had TTW 12.54mm (p value 0.002).

**Table 3**

| Lysholm score | No of patients | Mean TTW | Standard Deviation | P value |
|---|---|---|---|---|
| Up to 80 | 5 | 12.54 | 1.39 | 0.002 |
| 80-90 | 14 | 11.88 | 1.52 | (S) |
| Above 90 | 11 | 12.01 | 1.10 | T test |

There was no significant difference in functional score between disc group and screw group (p value = 0.11). At final follow up Lysholm score in disc group was 89.38(SD 6.02) and in screw group, Lysholm score was 90.71 (SD 5.14).

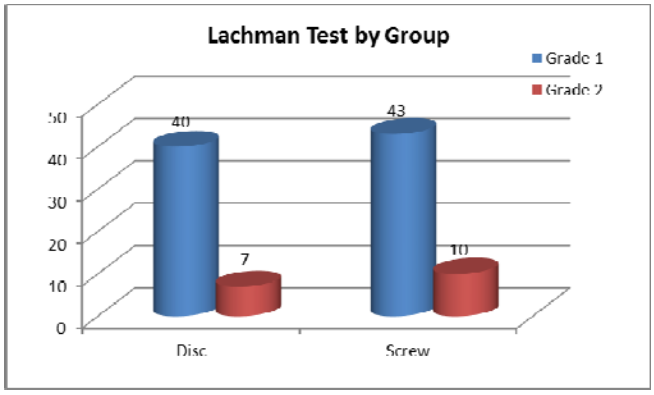
**Table 4:** Lysholm score in tibial fixation groups

| Group | No. of patients | Mean | Standard Deviation | P value |
|---|---|---|---|---|
| Disc | 16 | 89.38 | 6.02 | 0.11 (NS) T test |
| Screw | 14 | 90.71 | 5.14 | |

Lachman's test was grade 2 in 7% (2 out of 12 patients) in disc group and10% (3 out of 13 patients) in screw group. As p value was 0.743, this finding was not significant to come to any conclusion.

**Table 5:** Lachman's Test in two tibial fixation groups

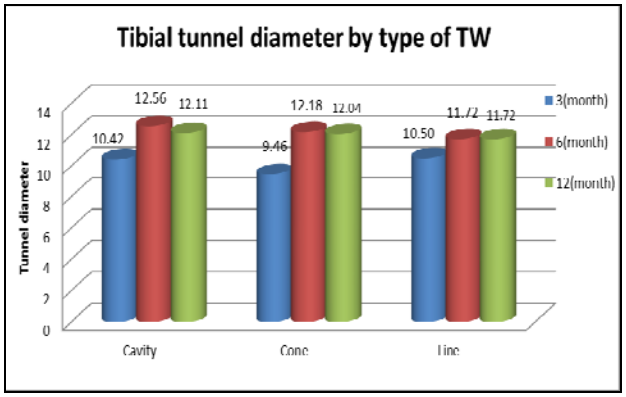
| Group | Grade 1 | Grade 2 | P value |
|---|---|---|---|
| Disc | 12 (40%) | 2 (7%) | 0.743 (NS) Chi Square test |
| Screw | 13 (43%) | 3 (10%) | |




Amongst type of tunnel widening, we classified tunnel widening *into cone type, cavity type and line type.* Cavity type TTW is most common (53%), followed by cone type (26%) and least common is line type widening (21%).
The amount of tunnel widening at the end of 12 months was maximum with cavity type followed by cone type and line type in descending order which was statistically significant (p value= 0.01).

**Table 6:** tunnel diameter by type of TW

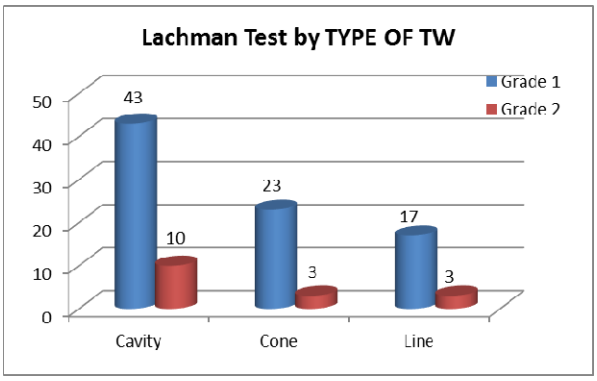
| Group | Count | Mean (months) | | | P value |
|---|---|---|---|---|---|
| | | 3 | 6 | 12 | |
| Cavity | 16 | 10.42 | 12.56 | 12.11 | 0.01 (S) T test |
| Cone | 8 | 9.46 | 12.18 | 12.04 | |
| Line | 6 | 10.50 | 11.72 | 11.72 | |




3 out of 17 cavity type cases had grade 2 laxity. One out of 5 line type cases had grade 2 laxity. Three of 8 cone type cases had grade 2 laxity (p value 0.928).

**Table 7:** Lachman's Test by TYPE OF TW

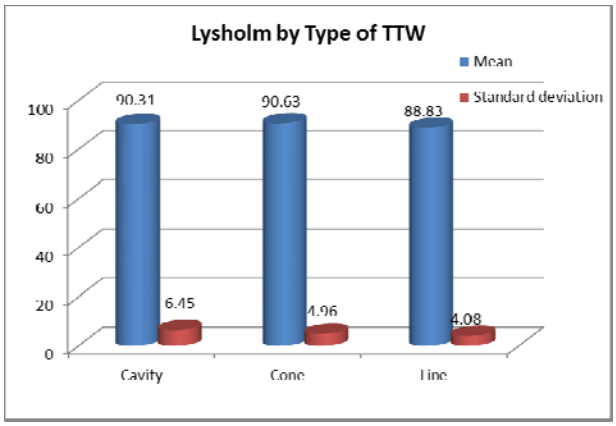
| Group | Grade 1 | Grade 2 | P value |
|---|---|---|---|
| Cavity | 13 (43) | 3 (10) | 0.928 (NS) Chi Square test |
| Cone | 7 (23) | 1 (3) | |
| Line | 5 (17) | 1 (3) | |




Lysholm score was 90.63 in cone type, 90.31 in cavity type and 88.83 in line type (p value = 0.12)

**Table 8:** Lysholm by Type of TTW

| Type of TW | count | Mean | Standard deviation | P value |
|---|---|---|---|---|
| Cavity | 16 | 90.31 | 6.45 | 0.12 (NS) T test |
| Cone | 8 | 90.63 | 4.96 | |
| Line | 6 | 88.83 | 4.08 | |




## Discussion

Arthroscopic ACL reconstruction is a common procedure done for traumatic ACL ruptures in orthopaedic. Better understanding of anatomy and improvement in technology has allowed us to refine the technique and achieve good to excellent results especially in sports persons. But this is associated with number of complications like postoperative stiffness, infection, impingement, graft failure. One of the complication is tunnel widening etiology of which is still in debate. Tunnel widening after ACL can has clinical implications in terms of instability. Few studies have shown that tibial tunnel widening is associated with excessive anterior tibial translation [2]. Wide tunnels can also pose as a difficult situation in revision surgery as bone loss is a major challenge for graft healing &tunnel placement.
Normal anterior cruciate ligament has ultimate tensile load of 1725 ± 269 N and the stiffness, 182 ± 33 N/mm [7]. Commonly used autografts for reconstruction of torn ACL are four fold hamstring tendons or bone patellar tendon bone graft. The four fold hamstring graft has an ultimate tensile load reported to be as high as 4108 N and that for BTB is

approximately 2300 N and stiffness approximately 620 N/mm [8, 9]. Hence both the grafts are being used for ACL reconstruction with good clinical results. We have used hamstring tendon as donor graft as it has less donor site morbidity, no anterior knee pain.

Association between Tunnel widening and type of graft has been discussed in literature by many authors. Hamstring tendon graft has higher incidence of tunnel widening than patellar tendon BTB graft. Webster *et al* showed that using hamstring tendons for ACL causes more widening of tibial tunnel compared to patellar tendon group in early period (4months) though it doesn't increase after one year [10]. This association has been explained by L'Insalata JC [3]. According to him, as hamstring tendon graft is generally fixed away from the joint line, there is a larger force moment during knee movement as point of fixation is away from the joint line.[3] This may be because in majority of cases, because hamstring grafts are fixed with suspensory implants and patellar tendon is fixed with the interference screws. In our study, we have used only hamstring tendon as a graft choice so that graft type doesn't become a confounding variable when we compare screw group and disc group.

On the other hand, allografts were found to have greater amount of tunnel widening than the patellar tendon autograft [11]

Graft fixation systems have been described with different names in literature like anatomic vs. nonanatomic, elastic vs. rigid, suspensory vs. cortical fixation or outlet fixation.

Giovanni has classified graft fixation systems into following: [2]

1) Compression system like interference screw which holds the tendon graft tightly against the bone tunnels more rigidly. This can be also called as rigid system which holds the graft in near the joint line.
2) Suspension system uses cortical fixation points to hold the graft with a button and a loop (endobutton or tightrope). This system is elastic and can allow graft motion along its length in the tunnel allowing synovial fluid entrance into the tunnel. This is known as *bungee cord effect*.
3) Expansion system which expands the graft in the femoral tunnel by a transverse pin.
4) Cortico-cancellous suspension fixation where the graft is held orthogonally around the transverse pin passing through the tunnel.

This tunnel widening is found more when grafts are fixed with suspension systems than the compression system. The possible explanation is that with endobutton, the fixation point of graft is distant from the joint line than the screw fixation. This increases the lever arm and force momentum during the knee movement leading to higher amount of tunnel widening when compared to screw fixation [3]. In his cadaveric study, Hoher found that, there is movement of the graft longitudinally in the tunnel up to 3mm (bungee cord effect) which allows the synovial fluid entry into the tunnel preventing the graft healing and tunnel widening.[3] He also concluded that, shorter loop lengths had lesser graft tunnel movement than the longer loops. As it was a cadaveric study, tunnel widening was based only on mechanical principles. Our study tried to evaluate similar hypothesis in our patients comparing suture disc group and interference screw group. We also tried to use endobutton with shorter loop lengths 15 or 20mm to minimize this complication.

We used four fold semitendinosus graft and fixed it with suspensory device on femoral side. On tibial side those tunnels where suture disc was used had average tunnel widening of 12.14mm. Those tunnels where interference screw was used, average tunnel diameter was 12.86mm, though this difference was not significant. Another observation in our study was tunnel widening increased from 3 months to six months and then either remained constant or reduced in size.

Other devices like rigid fix have been found to have greater degree of tunnel enlargement than endobutton as observed by Lopes *et al* & hence they were not considered [14].

Compression system also can have the tunnel widening if the graft is not fixed near the joint line leading to stress shielding of the unloaded proximal bone. Leonardi found up to 70% tunnel widening in cases where grafts were fixed distant from the articular surface when compared to 23% in anatomic fixation [15].

As we have used interference screw on tibial side fixing the graft rigidly, we expected these cases to have lesser amount of tunnel widening. Results of this study shows that, tunnel widening is marginally higher in screw group (12.86mm) than the disc group(12.14mm) though it is not statistically significant( p value=0.19).

We attribute this to the fact that, as screw makes extra space in the bone with threads while entering in the tunnel, tibial tunnel diameter is slightly more to begin with.

Lysholm score was above 90 for TW of 12.01. Eighty to 90 score was found in TW of 11.88mm. Patients with score less than 80 had TTW 12.54mm (p value 0.002). So we can conclude that TTW less than 12mm at the end of 12 months have good functional scores.

Double bundle reconstruction has different pattern of tunnel enlargement. As two different tunnels are used in tibial and femoral sides, they can't be compared with conventional single bundle technique. Kawaguchi found lesser incidence of femoral tunnel enlargement in cases of double bundle ACL reconstruction than single bundle ACL reconstruction [16]. Yoon *et al* found that on tibial side, between AM and PM bundles, there was significant enlargement of anteromedial bundle which was statistically significant [17].

Postoperative rehabilitation is also said to be a contributory factor in tunnel widening by many authors. Raffale had lesser amount of tunnel widening when postoperative rehabilitation was slower with 2 weeks immobilization in full knee extension [18]. Hoher *et al* concluded that early stress on graft in postoperative period may cause graft- tunnel motion before graft incorporation leading to tunnel widening [13]. According to cadaveric study by Rodeo, early motion in the postoperative period is detrimental to graft healing in the femoral tunnel [19].

In our cases, we had maintained standard protocol of rehabilitation of 2 weeks immobilization in extension followed by gradual knee bending up to 90 degree and full weight bearing at the end of one month. We had used transportal technique to drill the femoral tunnels to place the footprint as anatomical as possible as it was found that non anatomical or anterior tibial tunnel placement was found to have higher tunnel enlargement due to mechanical stress on the graft [20].

The etiology of tunnel enlargement is currently unknown. Possible factors responsible for bone resorption include mechanical theory which states that there is a micromotion of the graft relative to the tunnel wall which causes synovial fluid bathing of the graft, leading to an inflammatory response in the tunnel. Also stress shielding of the tunnel wall proximal

to the interference screw can cause weakening of the bone [6, 20, 21]

Biological factors include nonspecific inflammatory response cells, heat necrosis due to drilling, cytokine response like TNF, interleukin-6, nitric oxide from the synovial fluid and foreign body response to allograft [22, 23]

There are different patterns of osteolysis at tibial tunnel described by Peyrache where patellar tendon bone graft was fixed with screw. These are cone type, cavity type and line type [7] We evaluated similar changes in our patients and tried to evaluate its clinical and functional correlation.

Maximum tunnel widening was found in cavity type (12.11) followed by cone type TTW (12.04) and least in line type (11.72). The trend of widening was different in each group. For cavity group, TTW peaked at 12.56 at 6 months and stabilized to 11.59 at 12 months. In cone group, TW peaked from 9.46mm at 3 months to 12.18mm and then settled to 12.04mm at 12 months.The line group had different trend wherein TW increased from 10.50 at 3 months to 11.72 at 6 months and remained to 11.72 mm at 12 months.

## Conclusion

Overall tunnel widening of less than 12mm had good or excellent functional score and those with more than 12.5mm had fair functional score and those with tunnel diameter. This can be affected by the amount of physical demand of patients and their rehabilitation protocol, as some were sports person and others were nonsportsmen. This need to be further studied by RCT as patent sample size was less.

Both the groups i.e. suture disc and interference group had considerable tunnel widening but the difference between them is negligible to conclude superiority of on over the other. Another observation in our study was tunnel widening increased from 3 months to six months and then either remained constant or reduced in size.

Regarding type of tibial tunnel widening, cavity type TTW is most common (50%), followed by cone type (26%) and least common is line type widening (24 %). Maximum tunnel widening is in cavity type and if it is more than 12 mm then functional score is fair in those patients. There is no significant correlation between the type of TTW and clinical stability and functional scores. But it has surgical implications as more tunnel widening leaves lesser bone bed for revision ACL reconstruction.

Drawbacks of this study were it is not a randomized control trial. Our sample size was less.

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