TIBIAL FIXATION

Dr. Sagar Kakatkar, Dr. Jonathan Herald

INTRODUCTION:

Tibial fixation in Anterior cruciate ligament reconstruction is the Achilles heel for the whole construct[1]. Tibial fixation is the most stressed segment of the reconstructed ACL. Published literature also suggests that failure of the ACL graft is more commonly seen on the tibial side of the graft, and there are various reasons for the same[2-7]. For instance, cancellous bone morphology in the metaphyseal region of the proximal tibia makes it anatomically weaker to act as a holding ground for the reconstructed ACL[8,9,10]. Also, the tail end of the soft tissue grafts is difficult to secure[11]. Finally, the forces acting on the ACL tibial graft are parallel to the tibial tunnel which makes it prone for slippage[3-6].

Most of the studies done for tendon to bone healing on the tibial side have been primarily animal studies and the results have been extrapolated to humans[11]. Hence it is difficult to make conclusive comments about ideal tibial fixation method which will have adequate pull out strength, least tunnel widening and which can enhance the graft to tunnel healing.

WAYS TO DO THE TIBIAL FIXATION AND REVIEW OF LITERATURE:

There are various aspects of the tibial fixation which should be considered before selecting a tibial fixation method (Figure 1)

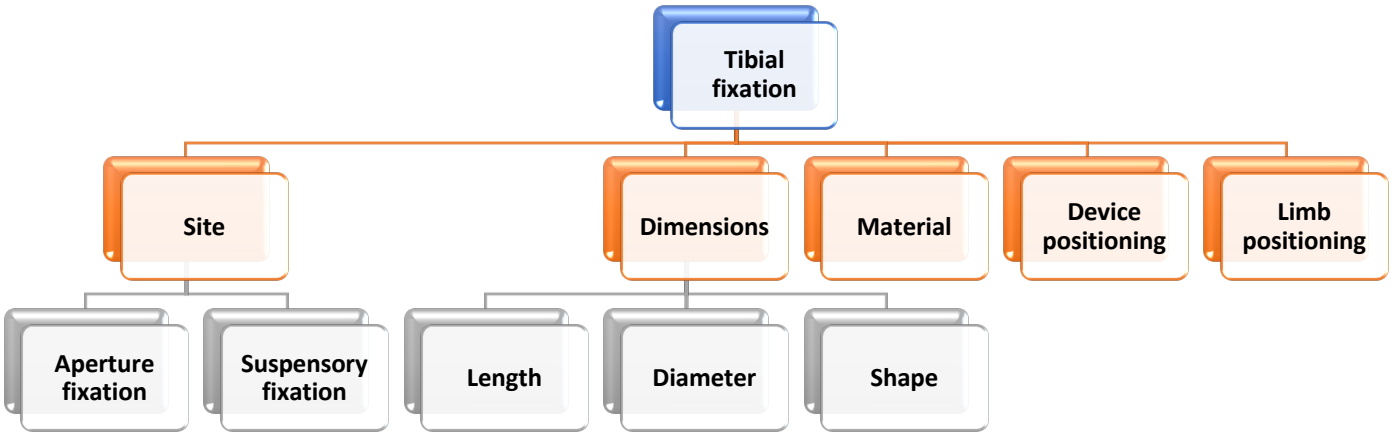


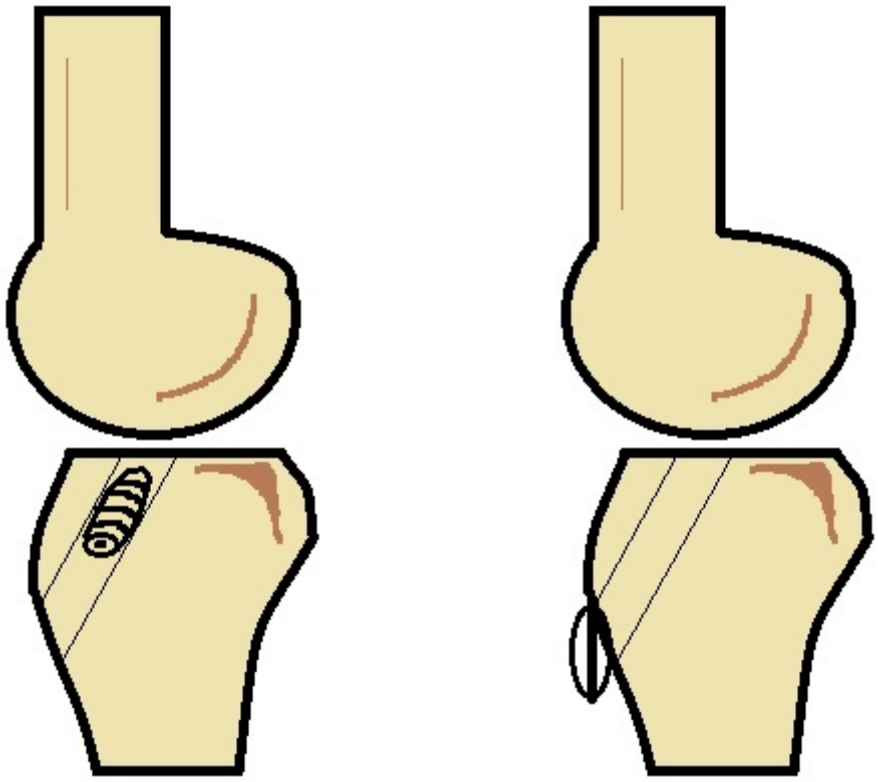
Figure 1: Tibial fixation aspects

A) Site:

- Based on the site of tibial fixation, it can be either an 'Aperture fixation' or 'Suspensory fixation'.
- In Aperture fixation, such as with interference screw fixation the graft is fixed closer to the tibial joint line. This decreases the micromotion of the graft by decreasing the length of the intra tunnel mobile segment of the

graft. Shorter mobile segments have an advantage that they cause less tunnel dilatation (Figure 2a) [12-21]

- Since Aperture fixation is based on the principle of compressing the graft on metaphyseal tibial bone in the tunnel, its strength vastly depends on the quality of tibial metaphyseal bone. Being a cancellous weak bone, tibial fixation is the weak link leading to graft pull out or slippage especially if patient is started on aggressive physiotherapy in early post-operative period[22-27].
- Suspensory fixation is the other type of tibial fixation in which fixation is done outside the tibial tunnel on the tibial cortex. Since the cortical bone is stronger it gives better pull out strength to the construct[22-27].
- But the mobile segment of the graft in the tunnel with suspensory fixation is longer which increases the working length. When subjected to early and aggressive rehabilitation, there are high chances of tunnel widening because of 'wind-shield wiper effect' (Figure 2b)[28-33].



a. b.

Figure 2: Aperture fixation and suspensory fixation.

- Also, excessive micromotion at the graft tunnel interface interferes with the incorporation of the graft[29-32].

B) Dimensions of the fixation device:

- Dimensions of the fixation device are vital in aperture fixation, since these devices are in contact with the graft and their structural properties affect the biomechanics of the construct.

- Length: Shorter interference screws i.e. less than 23mm can't resist loads on a greater scale and have poor pull out strength. While screws which are longer in length and which engage in both proximal and distal cortices prevent graft slippage[34-37].
- Diameter: Apart from few studies such as by Morris et al. which showed that wider screws can lead to serious structural damage to the graft; most of the literature supports use of wider screws. Interference screw diameter which is at least 1mm wider than the tunnel diameter gives better strength to the construct and increases pull out strength[34-37].
- Shape: Tapered screws are shown to reduce the damage to the graft during the screw insertion. But these screws reduce the advantages of having better graft compression closer to the joint line since the distal part of the screw being tapered can't compress the graft to the tunnel[35,36].

C) Material:

- Bioabsorbable screws have similar or better fixation strength compared to the metallic screws and they cause less damage to the graft during the insertion compared to metallic screws[38-41].

- These bioabsorbable screws don't interfere with tunnel to graft incorporation[41,42].

D) Device positioning:

- Positioning of interference screws is a topic of debate when bone patellar tendon bone graft is used. Screws when put on the cancellous side of the bone plug compress the cortical side of the bone plug to the wall of the tunnel which can hamper graft incorporation. Hence most studies recommend putting the screws on the cortical side of the bone plug. But there are also chances of suture cut outs while putting the interference screws on the cortical side of the bone plug. These sutures which hold the bone plug and allow traction to be applied on the graft during fixation if cut, can lead to graft slippage[43].

E) Limb positioning:

- Conventional technique of doing ACL tibial side fixation with knee in flexion led to decreased knee extension in patients who had physiological hyperextension.
- Hence Pinczewsk et al. recommended fixing the ACL tibial side with knee in extension or hyperextension. But literature regarding the same

doesn't show much difference in long term outcome following ACL tibial fixation by hyperextension method and by conventional method[14].

- Hybrid tibial fixation using two modalities of tibial fixation has been found to be biomechanically more stable. With such fixations, aggressive rehabilitation strategies can be followed.
- The hybrid fixations can also be used when the tibial metaphyseal bone quality is very poor or in revision cases[45-47].

ACT OF BALANCING…. THE WAY WE DO IT:

- We have always used the aperture fixation with interference screws for the ACL tibial side fixation and bio absorbable screws are our implants of choice (Figure 3A).

- 
- We always use tibial screws longer than 25mm length which tend to compress the graft at both proximal and distal ends of the tibial tunnel.
- For the BPTB graft, we put the screws on the cortical side of the bone plug so that the cancellous side is compressed against the bone tunnel which promotes healing. We often use stronger suture material such as No. 2 FiberWire® (Arthrex, Naples, FL) passed through the bone plug which doesn't get damaged during interference screw insertion next to the bone plug.
- In our patients with hyperextension of the knee on the unaffected side, we perform tibial fixation with the knee in full extension (Figure 3B).

- We choose a screw diameter 1-2 mm larger than the size of the tunnel for soft tissue ACL grafts but whenever we have to use a metallic interference screw, we use a screw of the same diameter as that of the tunnel to avoid excessive soft tissue graft damage by the screw.
- We do not usually perform double fixation routinely unless the tibial bone quality is poor. In this situation, we first use a screw 2 mm larger and if too loose (e.g. revision situation) use cortical fixation with a Suture Washer® (Smith and Nephew, Andover, MA) or bi-cortical screw post with washer or staple.

PITFALLS IN TIBIAL FIXATION:

- Using interference screw shorter than 23 mm is associated with low pull out strength.
- When using interference screws which are not extending up to the tibial joint line, aggressive post-operative mobilization should be avoided.

References:

1. Chizari M, Wang B, Snow M, and Barrett M (2008) Experimental and numerical analysis of screw fixation in anterior cruciate ligament reconstruction. AIP Conf Proc 1045:61–70
2. Burks R, Daniel D, Losse G, et al. (1984): The effect of continuous passive motion on anterior cruciate ligament reconstruction stability: Am J Sports Med 12:323-327
3. Ishibashi Y, Rudy TW, Livesay GA, Stone JD, Fu FH, Woo SL. The effect of anterior cruciate ligament graft fixation site at the tibia on knee stability: evaluation using a robotic testing system. Arthroscopy. 1997;13(2):177-182.
4. Kousa P, Jarvinen TL, Vihavainen M, Kannus P, Jarvinen M. The fixation strength of six hamstring tendon graft fixation devices in anterior cruciate ligament reconstruction: part II. Tibial site. Am J Sports Med. 2003;31(2):182-188.
5. Martin SD, Martin TL, Brown CH. 2002 Anterior cruciate ligament graft fixation. Orthop Clin North Am.;33(4):685-696.
6. Robbe R, Paletta GA Jr. 2004 Soft-tissue graft fixation in anterior cruciate ligament reconstruction. Oper Tech Sports Med.;12(3):188-194.

7. Scheffler SU, Sudkamp NP, Gockenjan A, Hoffmann RF, Weiler A 2002.Biomechanical comparison of hamstring and patellar tendon graft anterior cruciate ligament reconstruction techniques: the impact of fixation level and fixation method under cyclic loading. Arthroscopy. 2002;18(3):304-315
8. Brand JJ, Pienkowski D, Steenlage E et al (2000) Interference screw fixation strength of a quadrupled hamstring tendon graft is directly related to bone mineral density and insertion torque. Am J Sports Med 28:705–710
9. Vuori I, Heinonen A, Sievanen H et al (1994) Effects of unilateral strength training and detraining on bone mineral density and content in young women: a study of mechanical loading and de-loading on human bones. Calcif Tissue Int 55:59–67
10. Shatzmann L, Brunner P, Staubli HU (1998) Effect of cyclic preconditioning on the tensile properties of human quadriceps. Knee Surg Sports Traumatol Arthrosc 6(Supp1): S56–S61
11. Mahmoud Chizari, Martyn Snow, Bin Wang (2009): Post-operative analysis of ACL tibial fixation: Knee Surg Sports Traumatol Arthrosc 17:730–736

12. Berg EE, Pollard ME, Kang Q (2001) Interarticular bone tunnel healing. Arthroscopy 17:189–195
13. Eriksson K, Kindblom LG, Wredmark T (2000) Semitendinosus tendon graft ingrowth in tibial tunnel following ACL reconstruction. A histological study of 2 patients with different types of graft failure. Acta Orthop Scand 71:275–279
14. Nebelung W, Becker R, Urbach D et al (2003) Histological findings of tendon-bone-healing following anterior cruciate ligament reconstruction with hamstring grafts. Arch Orthop Trauma Surg 123:158–163
15. Pinczewski LA, Clingeleffer AJ, Otto DD et al (1997) Integration of hamstring tendon graft with bone in reconstruction of the anterior cruciate ligament. Case report Arthroscopy 13:641–643
16. Yamazaki S, Yasuda K, Tomita F et al (2002) The effect of graft tunnel diameter disparity on intraosseous healing of the flexor tendon graft in anterior cruciate ligament reconstruction. Am J Sports Med 30:404–498
17. Nam-Hong Choi, Jung-Hoon Lee, Kyung-Mo Son, Brian N. Victoroff Tibial tunnel widening after anterior cruciate ligament reconstructions with hamstring tendons using Rigidfix femoral fixation and Intrafix tibial fixation Knee Surg Sports Traumatol Arthrosc (2010) 18:92–97

18. Tsuda E, Fukuda Y, Loh JC, Debski RE, Fu FH, Woo SL-Y (2002) The effect of soft-tissue graft fixation in anterior cruciate ligament reconstruction on graft-tunnel motion under anterior tibial loading. Arthroscopy 18:960–967

19. Buelow J-U, Siebold R, Ellermann A (2002) A prospective evaluation of tunnel enlargement in anterior cruciate ligament reconstruction with hamstrings: extracortical versus anatomical fixation. Knee Surg Sports Traumatol Arthrosc 10:80–85

20. Antonio Herrera, Fernando Martínez, Daniel Iglesias, José Cegoñino, Elena Ibarz and Luis Gracia: Fixation strength of bio-composite wedge interference screw in ACL reconstruction: effect of screw length and tunnel/screw ratio. A controlled laboratory study *BMC Musculoskeletal Disorders* 2010, **11**:139

21. Shelbourne KD, Klotz C: What I have learned about ACL: utilizing a progressive rehabilitation scheme to achieve total knee symmetry after anterior cruciate ligament reconstruction**.** *J Orthop Science* 2006,11:318-325

22. Beynnon BD, Amis AA (1998) In vitro testing protocols for the cruciate ligaments and ligament reconstructions. Knee Surg Sports Traumatol Arthrosc 6(1):S70–S76

23. Papageorgiou CD, Ma CB, Abramowitch SD et al (2001) A multidisciplinary study of the healing of an intraarticular anterior cruciate ligament graft in a goat model. Am J Sports Med 29(5):620–626
24. Park MJ, Lee MC, Seong SC (2001) A comparative study of the healing of tendon autograft and tendon-bone autograft using patellar tendon in rabbits. Int Orthop 25(1):35–39
25. Singhatat W, Lawhorn KW, Howell SM et al (2002) How fourweeks of implantation affect the strength and stiffness of a tendon graft in a bone tunnel: a study of two fixation devices in an extraarticular model in ovine. Am J Sports Med 30(4):506–513
26. Zantop T, Weimann A, Wolle K et al (2007) Initial and 6 weeks' postoperative structural properties of soft tissue anterior cruciate ligament reconstructions with cross-pin or interference screw fixation: an in vivo study in sheep. Arthroscopy 23(1):14–20 736 Knee Surg Sports Traumatol Arthrosc (2009) 17:730–736
27. Jagodzinski M, Scheunemann K, Knobloch K, et al. Tibial press-fit fixation of the hamstring tendons for ACL-reconstruction. KneeSurg Sports Traumatol Arthrosc. 2006;14(12):1281-1287.

28. Becker R, Schroder M, Ropke M, Starke C, Nebelung W. Structural properties of sutures used in anchoring multi-stranded hamstrings in anterior cruciate ligament reconstruction: a biomechanical study. Arthroscopy. 1999;15(3):297-300.

29. Brand J Jr, Hamilton D, Selby J, Pienkowski D, Caborn DN, Johnson DL. Biomechanical comparison of quadriceps tendon fixation with patellar tendon bone plug interference fixation in cruciate ligament reconstruction. Arthroscopy. 2000;16(8):805-812

30. Fink C, Zapp M, Benedetto KP, Hackl W, Hoser C, Rieger M. Tibial tunnel enlargement following anterior cruciate ligament reconstruction with patellar tendon autograft. Arthroscopy. 2001;17(2):138-143

31. L'Insalata JC, Klatt B, Fu FH, Harner CD. Tunnel expansion following anterior cruciate ligament reconstruction: a comparison of hamstring and patellar tendon autografts. Knee Surg Sports Traumatol Arthrosc. 1997;5(4):234-238.

32. Jansson KA, Harilainen A, Sandelin J, Karjalainen PT, Aronen HJ, Tallroth K. Bone tunnel enlargement after anterior cruciate ligament reconstruction with the hamstring autograft and endobutton fixation technique: a clinical,

radiographic and magnetic resonance imaging study with 2 years' follow-up. Knee Surg Sports Traumatol Arthrosc.1999;7(5):290-295.

33. Hoher J, Moller HD, Fu FH. Bone tunnel enlargement after anterior cruciate ligament reconstruction: fact or fiction? Knee Surg Sports Traumatol Arthrosc. 1998;6(4):231-240

34. Herrera A, Martinez F, Iglesias D, Cegonino J, Ibarz E, Gracia L. Fixation strength of bio composite wedge interference screw in ACL reconstruction: effect of screw length and tunnel/screw ratio. A controlled laboratory study. BMC musculoskeletal Disord. 2010; 11:139

35. Selby JB, Johnson DL, Hester P, Caborn DN. Effect of screw length on bioabsorbable interference screw fixation in a tibial bone tunnel. Am J Sports Med. 2001;29(5):614-619.

36. . Harvey AR, Thomas NP, Amis AA (2003) The effect of screw length and position of fixation of four-stranded hamstring grafts for anterior cruciate ligament reconstruction. Knee 10:97–102

37. Brown GA, Pena F, Grontvedt T, Labadie D, Engebretsen L: Fixation strength of interference screw fixation in bovine, young human, and elderly human

cadaver knees: Influence of insertion torque, tunnel bone block gap, and interference**.** *Knee Surg Sports Traumatol Arthros* 1996, 3:238-244**.**

38. Caborn DNM, Cohen M, Neef R, Hamilton D, Nylan J, Johnson DL: Quadrupled semitendinosus-gracilis autograft fixation in the femoral tunnel: A comparison between a metal and a bio absorbable interference screw**.** *Arthroscopy* 1998, 14(3):241-245.

39. Kousa P, Järvinen TLN, Pohjonen T, Kannus P, Kotikiski M, Järvinen M: Fixation strength of a biodegradable screw in anterior cruciate ligament reconstruction**.** *J Bone J Surg Br 77 B* 1995:901-905.

40. Walton M: Absorbable and metal interference screws: Comparison of graft security during healing**.** *Arthroscopy* 1999, 15(8):818-826.

41. Woo SL, Wu C, Dede O, Vercillo F, Noorani S: Biomechanics and anterior cruciate ligament reconstruction**.** *J Orthop Surg Res* 2006, 25(1):2-11.

42. Shapiro JD, Jackson DW, Aberman HM, Lee TQ, Simon TM: Comparison of pullout strength for seven- and nine-millimetre diameter interference screw size as used in anterior cruciate ligament reconstruction arthroscopy**.** *Arthroscopy* 1995, 11:596-599.

43. Danial Cooper, Tad Wilson, et al. (1996): clinical failure of tibial interference screw fixation after anterior cruciate ligament reconstruction – A report of two cases. Am J Sports Med vol. 24, number 5.
44. Pinczewski LA, Clingeleffer AJ, Otto DD et al (1997) Integration of hamstring tendon graft with bone in reconstruction of the anterior cruciate ligament. Case report Arthroscopy 13:641–643
45. Smith KE, Garcia M, McAnuff K, et al. Anterior cruciate ligament fixation: is radial force a predictor of the pullout strength of soft-tissue interference devices Knee. 2012;19(6):786-792.
46. Stadelmaier DM, Lowe WR, Ilahi OA, Noble PC, Kohl HW III. Cyclic pull-out strength of hamstring tendon graft fixation with soft tissue interference screws: influence of screw length. Am J Sports Med.1999;27(6):778-783.
47. George C. Balazs, Alaina M. Brelin, Patrick D. Grimm, Jonathan F. Dickens, David J. Keblish and John-Paul H. Rue (2016): Hybrid Tibia Fixation of Soft Tissue Grafts in Anterior Cruciate Ligament Reconstruction: A Systematic Review. *Am J Sports Med* 44: 2724