

Knee Disarticulation

A Whirlwind Tour

Tony Fitzsimons

NSWPAR, 27 June 2008



Knee Disarticulation

- Surgery
- Advantages
- Disadvantages
- Biomechanics
- Prosthetics
 - Socket
 - Knee
- Physiotherapy



Knee Disarticulation

- First described 1824.
- 2% of amputations in US (total 50-60000 per year)
(Smith 2004, Faber et al 2001, Cull et al 2001)
- 2.43% in Australia, 522 amputations

(RehabTech website)

- ☞ Circulatory (1.71%)
- ☞ Congenital (1.66%)
- ☞ Infective (17.8%)
- ☞ Inflammatory (8.2%)
- ☞ Neoplastic (1.74%)
- ☞ Traumatic (6.9%)
- ☞ Other (5.1%)



Indications / Criteria

- Potential to use a prosthesis, but who did not have capacity for wound healing at the below-the knee level (Pinzur et al 1988).
- Children (retains distal femoral epiphyseal growth plate – distal femur accounts for up to 70% of femur length).
- The only contraindication to TKA is the possibility of a successful below-knee amputation with a short, functional, pain-free calf stump (Kock et al 2004).
- Vascular patients with potential to ambulate with a prosthetic limb, and could not be considered a candidate for BKA (Cull et al 2001).
- High-risk patients whose only chance of survival was amputation surgery of a gangrenous limb. However, if the patient survives, the amputation should not compromise rehabilitation (Moran, 1990).

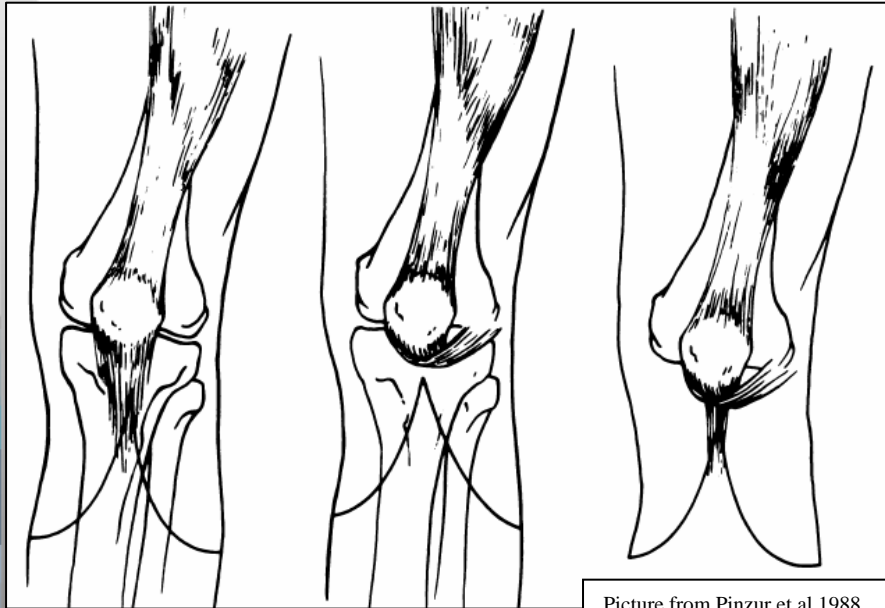


Indications / Criteria

- Patients who would be non-ambulatory (Anderson 2005, Moran 1990, Siev-Ner et al 2000).
- Should be avoided in older vascular patients who are unsuitable for high BKA as they are unlikely to have adequate healthy tissue to heal (Anderson, 2005).
- Long skin flaps needed to cover the stump have a poor record of healing (Utterback et al, 1973).
- Avoid in cases where there is trauma around the knee, as presence of a soft tissue injury may preclude the stump from having good, comfortable, scar-free padding that would allow end-weight bearing (Smith, 2004).
- Severe hip flexion contracture which persists under analgesia would suggest an AK rather than TK (Baumgartner 1983).

Surgery – Sagittal Flaps

Vitali (1986)

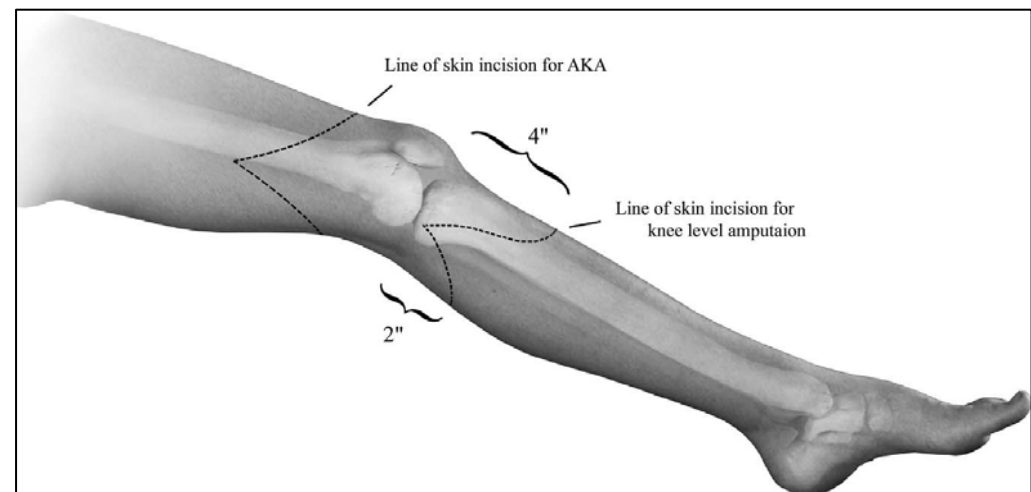


Picture from Pinzur et al 1988

- From tibial tubercle, incision made medially & laterally to 7cm below joint line, and back up posteriorly to 1cm below knee crease.
- Deep fascia dissected, patella ligament dissected at tibial tubercle, anterior capsule dissected, cruciate ligaments severed at their tibial insertions.
- Gastrocnemius divided at its' origin, and hamstrings just below joint line.
- Popliteal vessels dissected. Popliteal nerves pulled down, divided and allowed to retract.
- Patellar ligament and hamstring tendons sutured to cruciate ligaments.

Surgery – Anterior Flap (“Classic”)

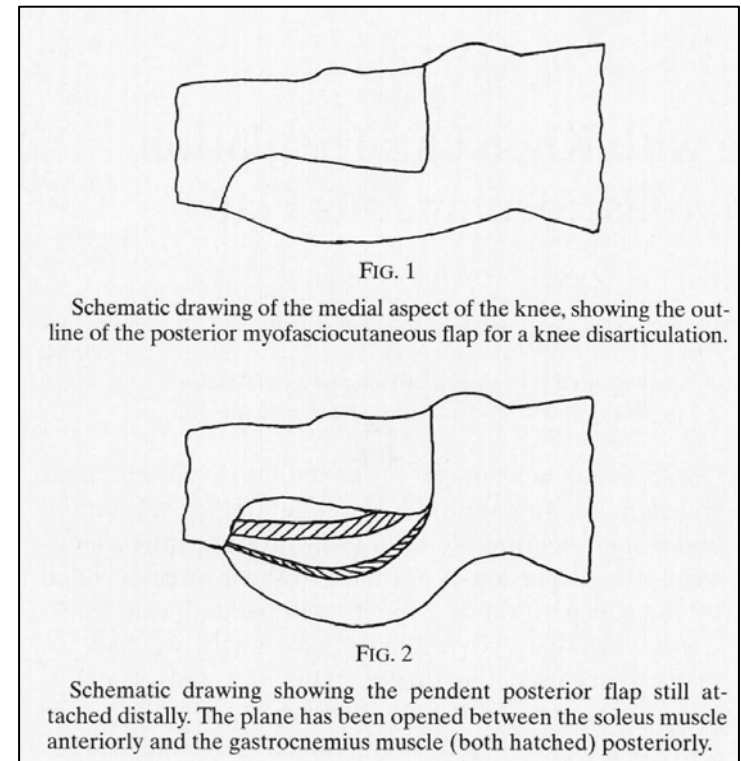
- Symmetric anterior curvilinear incision from joint line to distal tibial tuberosity, includes fascia & periosteum to add durability to covering over stump.
- Similar dissection of patellar ligament, collateral & cruciate ligaments, hamstrings & popliteal nerves and vessels as sagittal flap surgery.
- Develop posterior flap, approximately 1/3 length of anterior, gastrocs is separated from soleus & divided several centimetres from origin to preserve superior geniculate artery.
- Suture patellar ligament and hamstrings to cruciates.



Anderson (2005)

Surgery – Long Posterior Flap

- Anterior incision at level of knee joint, moving medial & lateral to midline, then longitudinally to level of distal gastrocnemius muscle belly, then join posteriorly.
- Gastrocs is separated from soleus.
- Similar dissection of patellar ligament, collateral & cruciate ligaments, hamstrings & popliteal nerves and vessels as sagittal flap surgery.
- Patellar tendon sutured to cruciates with hip in extension
- Gastroc belly may be thinned, or one head removed entirely, then sewn to knee capsule / extensor retinaculum to provide distal padding and retention of superior geniculate artery (blood supply to skin and subcutaneous tissue).



Picture from Bowker et al 2000.

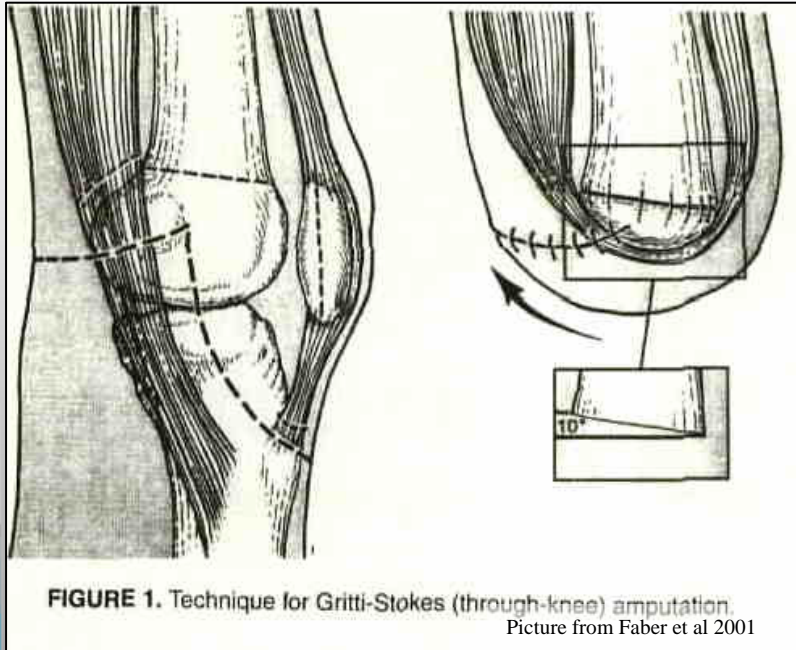
Klaes & Egler (1985)



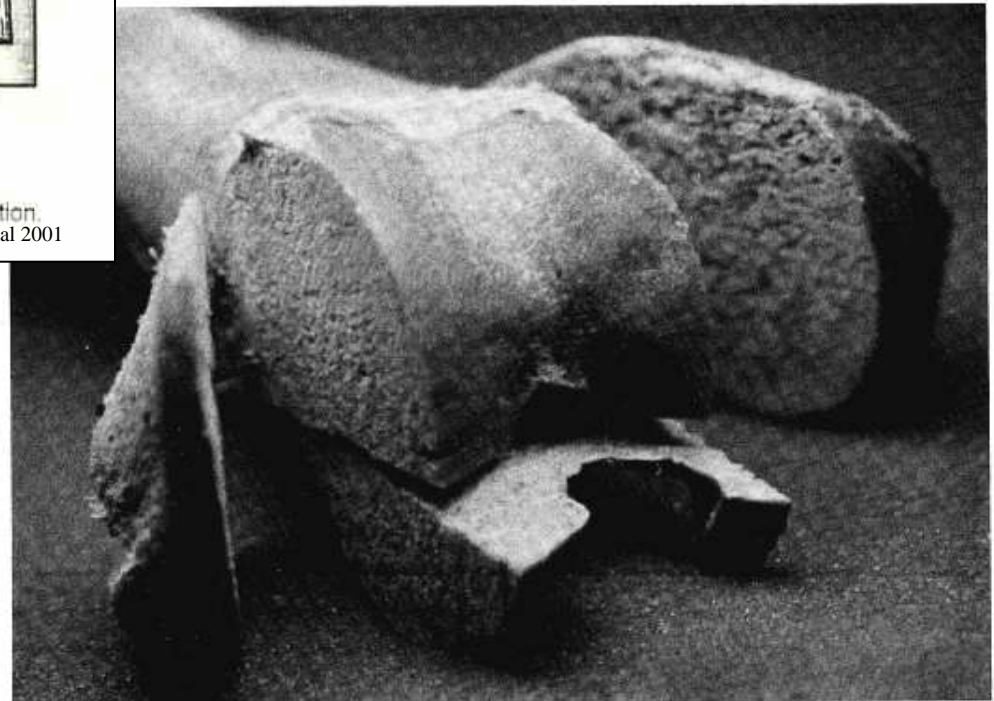
Surgery - Variations

- Gritti-Stokes: remove condyles with 10° bevel, patella anchored inside the end of femur.
- Burgess (1977): removes patella & portions of the condyles.
- Youkey: removes patella and completely removes the condyles.
- Nellis/Van de Water: removes the femoral condyles without bevel, and anchors the patella over the distal end of the femur.
- Mazet (1966) removes the patella and shaves the sides and distal end of the condyles to form a truncated / conical stump.
 - These could be considered as modifications of a transfemoral amputation, with a very long femoral stump.

Surgery - Variations



Gritti-Stokes amputation



Mazet 1977

Photo from Utterback et al
1979



Surgery – Keep Patella or Not?

■ For:

- ↳ Patients like the feel of movement as they activate quads
- ↳ Protects quadriceps tendon as it goes over the bone, and keeps the tendon at full strength.
- ↳ May contribute to preventing rotation of socket (in addition to the femoral condyles).

■ Against:

- ↳ Presence of arthritic changes
- ↳ Fractures
- ↳ Cartilage damage.
- ↳ Easier to fit prosthesis.



TKA Advantages

- Least traumatic of amputation surgeries: less blood loss, no bone or muscle sectioning, can be done under regional/local anaesthetic (Moran 1990, Pinzur 1993).
- Resistance to infection by maintaining the cartilage barrier over distal femur (Pinzur 1993).
- Eliminates possibility of bony overgrowth where a bone is transected & new bone forms spikes / spurs (Smith 2004).
- In children, retains the distal femoral epiphyseal growth plate, which accounts for most of the length of the femur (Smith 2004).
- With growth inhibition in paediatrics, eventually femur ends up shorter than sound limb, allowing equalising of knee heights and use of better / more standard componentry (Stark 2004, Pinzur et al 1999).
- In cases of tibial cancer or trauma, the femur & its musculature remain intact with good soft tissue for padding (Smith 2004).



TKA Advantages

- Muscles retain their strength as they are transected at the distal tendinous insertion, not through their bellies – less swelling, decrease healing time & scarring (Smith 2004, Anderson 2005).
- Retains the long, powerful, muscle-stabilised femoral lever for prosthetic control (Pinzur 1993).
- Less chance of flexion or abduction contractures (Anderson 2005), especially in cases of spasticity (Smith 2004).
- Self suspension over bulbous distal end (Moran 1990).
- Triangular distal stump prevents rotation within the socket (Moran 1990, Houghton 1989).
- As weight is borne on the femur, not ischium, amputee retains good proprioception, control over the prosthesis, and sensation of weight bearing (Moran 1990, Faber 2001).
- Because of the greater length of the stump compared to AK, area to apply forces is greater, implying lower contact pressures between stump & socket (Hughes 1983).



TKA Advantages

- Lower profile socket improves comfort when sitting, and easier to don / doff than AK prostheses (Hagberg 1992, Smith 2004).
- Amputees more likely to use their prosthesis (Smith 2004, quoting Hagberg 1992: no use of prosthesis = 4%TTA, 12%TKA, 39%TFA).
- There is some inherent stability in the four-bar linkage knee joints, as well as limb shortening during swing phase (Pinzur 1993, Greene 1983).
- For those not using a prosthesis, longer lever arm & intact musculature facilitates bed mobility, sitting balance & transfers (Moran 1990).
- Avoids risk of ulceration of BK stumps in bedridden patients, where stumps are generally held in flexed positions (Moran 1990, Pinzur et al 1988).
- Crawling is possible without a prosthesis (Moran 1990).



TKA - Disadvantages

- Amputees may not like the look of the bulbous stump (Smith 2004).
- Requires suitable coverage over distal end of stump, and such skin & soft tissue may be of dubious quality in vascular and traumatic amputees (Anderson 2005).
- As they are less common, prosthetists are less experienced, and have to work harder to get a good fit (Smith 2004).
- Unequal length of thigh segments in sitting (Smith 2004)
- Risk of patellar pain or anterior dislocation (Faber 2001).
- Greater failure and reamputation rates than AKA (Houghton 1989).



TKA - Disadvantages

- Shorter distal segment in mobility – unnatural looking swing phase with increased terminal impact. Claims of increased incidence of hip & back pain (little evidence) (Smith 2004).
 - Hip flexion contracture of $>15^\circ$, or an abduction contracture cannot be accommodated (Mazet et al 1966).
 - Bulbous distal end may rub on prosthesis, or incorrect fit may cause weight to be borne on one condyle more than the other, with risk of skin breakdown (Faber 2001).
- 👉 Note that some “disadvantages” have been reduced with improvements in prosthetic materials and technology.



Biomechanics

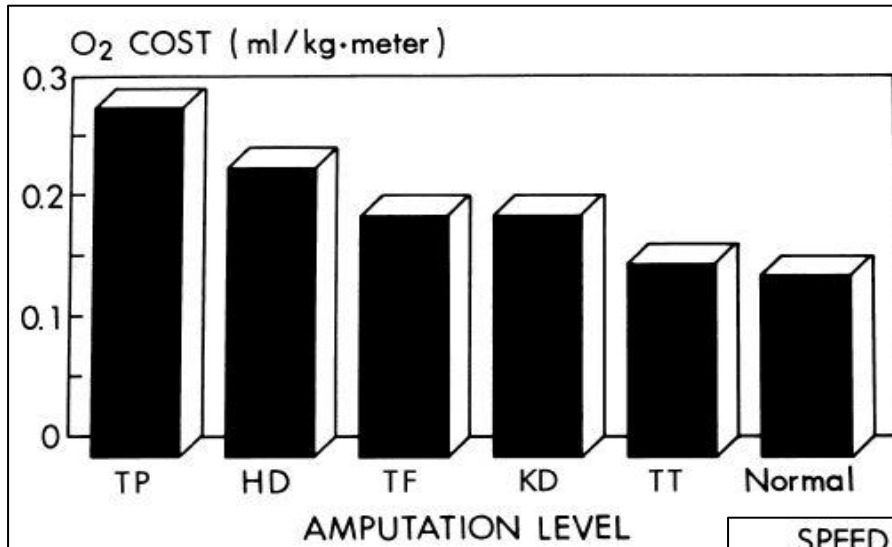
- Could find no literature describing knee disarticulation kinematics or kinetics. Baum et al (2006) describe greater trunk lean forward, lateral flexion, rotation excursions, and anterior pelvic tilt compared to normals, but their population included 9 TFA and only 1 TKA, and did not provide separate data.



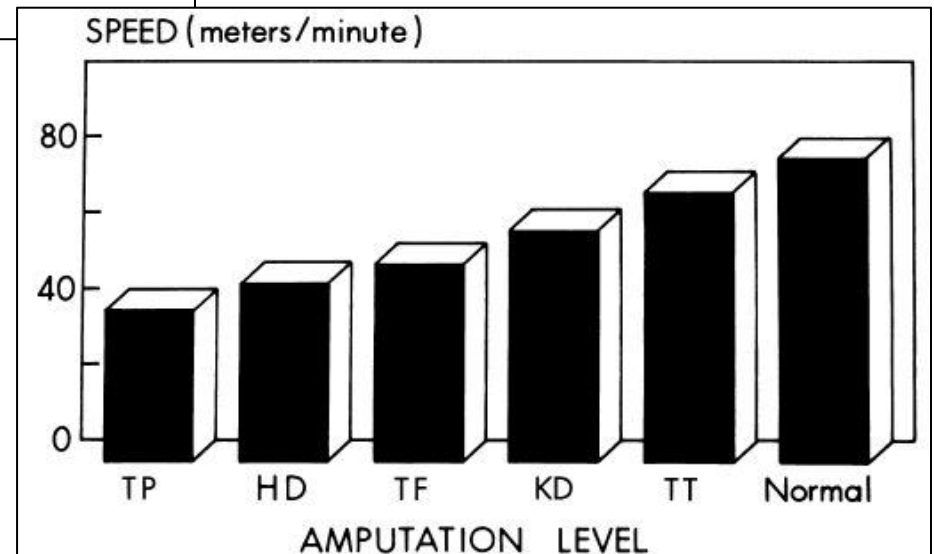
Biomechanics

- Generally, the higher the level of amputation, the slower the speed and cadence, and the greater the energy consumption (Smith 2004).
- The metabolic cost of walking for peripheral vascular insufficiency TKA's appears midway between TTA and TFA (Pinzur 1993, Waters).

Biomechanics



Graphs from
Waters



Graphs from
Waters



Biomechanics

- Pinzur et al (1993) looked at elderly, limited, bilateral amputees (BK/TK) and found that they would transfer more weight to the TKA side
- GRF 1st peak as body weight passes over the limb: 98%BW on the TKA side, 93%BW on BKA side.
- GRF 2nd peak corresponding to propulsion: 96%BW on the TKA side, 73%BW on the BKA side.
- Concluded that limited, household BKA ambulators do not adequately use their remaining thigh musculature, and in some instances a TKA with 4 bar linkage knee is more stable than the BKA.
 - Isakov et al (1996) suggested that the stump of the BKA has decreased involvement in ADL's such as sit-to-stand and walking, leading to disuse atrophy. They found decreased isokinetic concentric and eccentric strength, and decreased peak average maximal isometric strength in amputated limb compared to sound limb, especially in shorter stumps.



Prosthetics - Socket

- Requirements of the socket are (Botta et al 1983):
 - Total surface bearing in standing & sitting
 - End weight bearing
 - Free hip motion (no ischial seat).
 - Easy donning / doffing.
 - Self suspension – no straps, laces or suspenders.
 - No, or minimal extra width or length added to the thigh.
 - Easy to clean.
 - Can be fit with every available knee joint suitable for TKA, including locking or swing phase control.
 - No special adaptation of clothing or extra wear on clothing.



Prosthetics - Socket

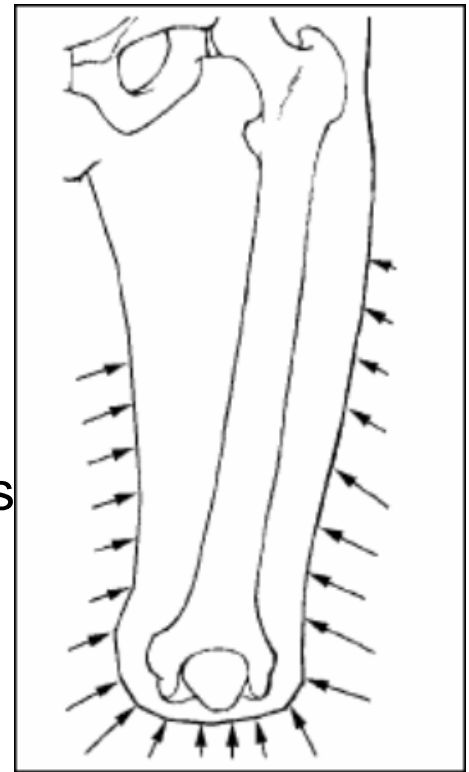
■ Requirements (cont'd)

- Minimal weight without loss of durability.
- Possibility to adapt to changes in stump volume and shape.
- Standardised manufacturing technique requiring no extra skill from the prosthetist.
- No extra cost compared to conventional prostheses.

Prosthetics - Socket

■ Manufacture:

- ❑ Concave proximal to medial condyle with relief for adductor tubercle.
- ❑ Lateral supracondylar area acts as the counterpressure for the medial contouring, however it should be flattened to avoid compression of nerves and ligaments.
- ❑ Proximomedial wall should be contoured as a concave surface; insufficient pressure along the medial wall is most common error, leading to lateral gapping.
- ❑ Lateral wall is flattened.
- ❑ Slight flaring proximally to increase comfort and alleviate possibility of tissue impingement during donning.
- ❑ There should be relief for adductor longus and the patella, if present





Prosthetics - Socket

■ Interface and suspension methods:

- Moulded leather, adjustable lace-up liner with back-check and extension assist straps to prevent terminal impact and extension bias (no longer used).
- Ischial-bearing (used when distal end of stump is unsuitable or cannot tolerate full weight bearing).
- Gel liner with air expulsion valve. Includes suction sockets for stumps where condyles have been shaved to allow stumps to slide in easily (Cull et al 2004).
- Gel liner with external binding catch for suspension.
- Medial door suspension with external strap.
- Pelite “stovepipe” build-up with medial split.



Prosthetics - Socket

■ Interface and suspension methods (cont'd):

- Integrated pneumatic pads or silicone bladders.
- Hypobaric socks which creates partial suction by providing a distal seal – still needs proximal suspension / waist strap.
- Zettl growth interface – distal end cup and supracondylar strap with a more proximal cuff connected by parasagittal bars which can be extended for growth compensation, and also allow less skin contact for those who require a more open interface.
- Small polyethylene liner (10cm) with socket made of carbon fibre and polyaramid (Kevlar), split laterally to create a flexible flap, adjustable with ski-buckles (Tingleff et al 2002).



Prosthetics - Knees

■ Advantages of polycentric knees:

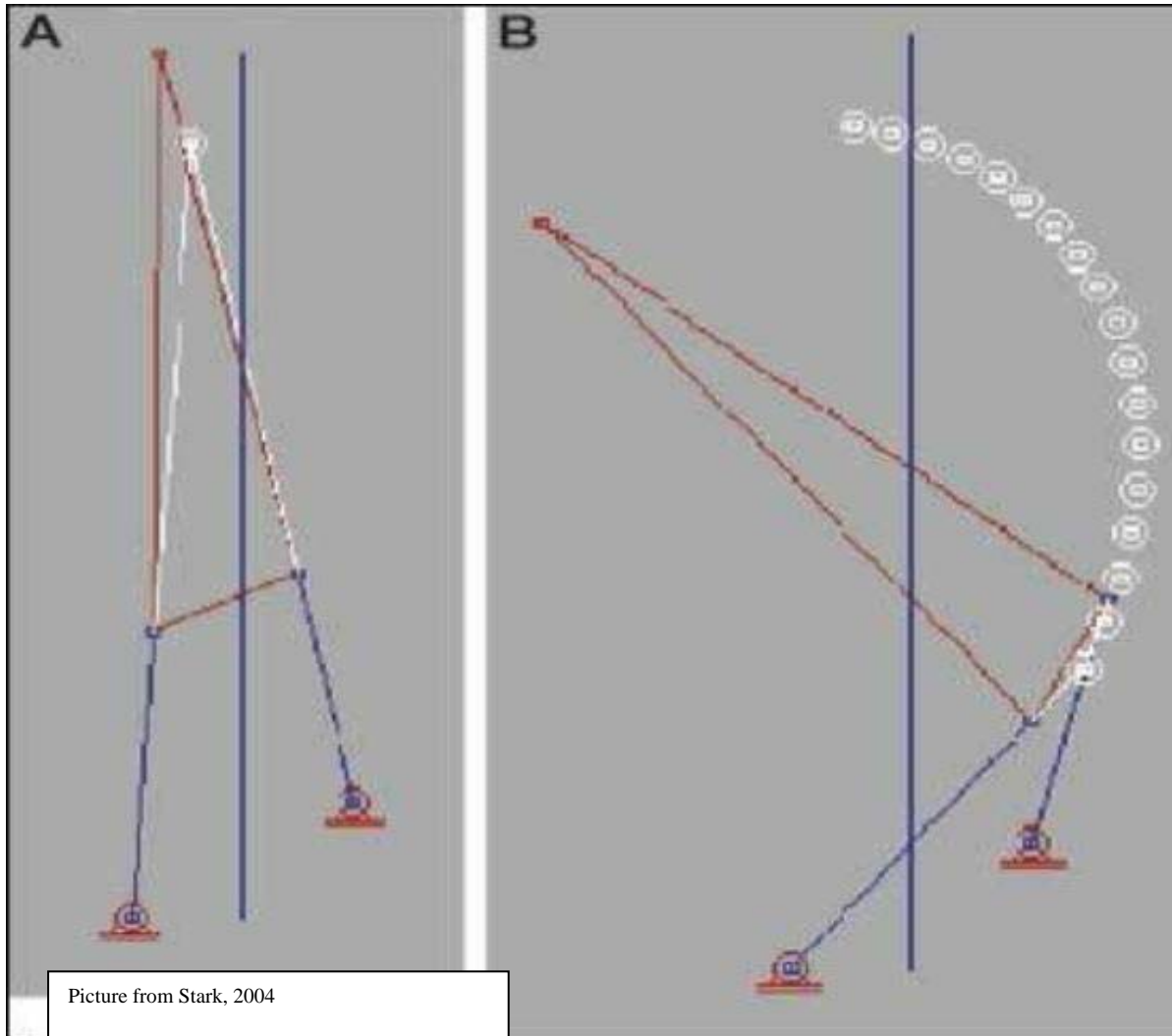
- Create a moving centre of rotation which lies proximal and posterior to the anatomic knee, and posterior to the TKA line, which creates an extension moment at the knee in stance phase (Oberger 1983, Pinzur 1993, de Vries 1995, Smith 2004, Stark 2004).
- Extension moment at the knee in stance reduces extensor force needing to be applied by the amputee, saving energy (Greene 1983).
- As the knee moves into flexion, the instantaneous centre of rotation can remain behind the TKA line for the first few degrees of flexion, enhancing stability during mid - late stance / toe-off (Greene 1983).



Prosthetics - Knees

- Advantages of polycentric knees (cont'd):
 - Because the centre of rotation moves, during late stance / early swing it moves closer to the TKA line, requiring less force / torque to flex the knee for swing phase (de Vries 1995).
 - The flexion at toe off can be achieved while there is still some weight bearing, achieving an aesthetically more normal looking push off, and saving energy (Oberger 1983).
 - Several models fold against the distal socket in walking, providing effective limb shortening and improving foot clearance. This also allows construction of “full length” prostheses (Greene, 1983)
 - Fold against the distal socket when sitting, reducing thigh length and letting the foot rest on the floor (Stark 2004).

Prosthetics - Knees



Picture from Stark, 2004

Prosthetics - Knees





Prosthetics - Knees

- Disadvantages of polycentric knees:
 - Heavier than single axis models (de Vries 1995).
 - Still contributes to a lengthening of thigh segment 25-30mm & shortening of shank – affects cosmesis, comfort when sitting, and some affect on swing phase.
 - Cannot make use of advanced technology available in some single axis knees.



Prosthetics - Knees

- Types:

- ➔ Free swinging with some sort of friction damping for heel lift and terminal swing:

- ➔ Springs

- ➔ Pneumatic

- ➔ Hydraulic

- ➔ Mechanical locking

- Also other models, eg 6-bar linkage designs which fold flatter for better cosmesis, improve stance stability and swing control, and have increased knee ROM, but at the cost of added expense and weight (Oberger, 1983).



Physiotherapy - Acute

- Chest Physio
- UL & LL ROM
- Isometric ex's emphasising extension
- Transfer & standing practice
- Oedema management: RD, semi-rigid, bandaging.
- Scar management.
- Pain management



Physiotherapy - Acute

- Beware of shape of stump – condyles and patella are extremely sensitive to external pressure, particularly posteriorly when the surgical wound is transverse (Baumgartner 1983) so during wound dressing & bandaging allow for relief / padding.
- Stump oedema must be fully reduced for correct fitting of the prosthesis, particularly as the femoral condyles are to be used for suspension (Mensch 1983).



Physiotherapy - Acute

- Mensch (1983) suggests manual pressure applied to distal stump to begin building tolerance to weight bearing. Progress to independent practice by using a towel sling around the distal end of the stump.
- Must maintain hip range of motion – flexion contractures $>15^\circ$ cannot be accounted for. Neither can abduction contractures. (Resting position of the femur in sitting is abduction / external rotation, which will contribute to abduction contractures and lengthening of extensors. Mensch 1983).



Physiotherapy – Prosthetic Gait

- **Early weight bearing:**
 - Interim prosthesis (Kock et al, 2004)
 - Plaster temporary (Jones et al, 1999)
 - Pneumatic aids or RD's with pylon
- **Scar must be mobile & pain-free:**
 - Massage & EPA modalities
- **Neuroma & stump pain management:**
 - TENS, ultrasound, massage (Jones et al 1999)



Physiotherapy – Prosthetic Gait

- Practice donning / doffing.
- Weight transference and stepping exercises.
- Practice weight bearing at heelstrike, midstance, and toe-off positions.
- Include initiation of hip flexion at toe-off.
- Correct gait faults.
- Progressions: outdoors, stairs, ramps & slopes, getting up off floor, uneven surfaces.



References

- Anderson KM (2005). Knee disarticulation and above-knee amputation. ???, 90-95.
- Baum BS, Lipton JS, Schnall BL, Tis JE (2006). Residual limb length and gait kinematics in transfemoral and knee disarticulation amputees: preliminary results. *Gait & Posture*, 24S, S265-S267.
- Baumgartner R (1983). Failures on through-knee amputation. *Prosthetics & Orthotics International*, 7, 116-118.
- Botta P & Baumgartner R (1983). Socket design and manufacturing technique for through-knee stumps. *Prosthetics & Orthotics International*, 7, 100-103.
- Bowker JH, San Giovanni TP, Pinzur MS (2000). North American experience with Knee Disarticulation with use of a posterior myofasciocutaneous flap. *Journal of Bone & Joint Surgery*, 82, 11, 1571-1574.
- Burgess EM (1977). Disarticulation of the knee. *Archives of Surgery* 112, 1250-1277.
- Cull DL, Taylor SM, Hamontree SE, Langan EM, Snyder BA, Sullivan TM, Youkey JR (2001). A reappraisal of a modified through-knee amputation in patients with peripheral vascular disease. *The American Journal of Surgery*, 182, 44-48.
- De Vries J (1995). Conventional 4-bar linkage knee mechanisms: A strength-weakness analysis. *Journal of Rehabilitation, Research & Development*, 32, 1, 36-41.
- Faber DC & Fielding P (2001). Gritti-Stokes (Through-Knee) amputation: Should it be reintroduced? *Southern Medical Journal*, 94, 10, 997-1001.
- Greene MP (1983). Four bar linkage knee analysis. *Orthotics & Prosthetics*, 37, 15-24.
- Houghton A, Allen A, Luff R, McColl I (1989). Rehabilitation after lower limb amputation: a comparative study of above-knee, through-knee and Gritti-Stokes amputations. *British Journal of Surgery*, 76, June, 622-624.



References

- Hughes J (1983). Biomechanics of the through-knee prosthesis. *Prosthetics & Orthotics International*, 7, 96-99.
- Isakov E, Burger H, Gregoric M, Marincek C (1996). Stump length as related to atrophy and strength of the thigh muscles in trans-tibial amputees. *Prosthetics & Orthotics International*, 20, 96-100.
- Jones ME, Bashford GM, Munro BJ (1999). Developing prosthetic weight bearing in a knee disarticulation amputee. *Australian Journal of Physiotherapy*, 45, 309-317.
- Kock HJ, Friederichs J, Ouchmaev A, Hillmeier J, Gumpfenberg S (2004). Long-term results of through-knee amputation with dorsal musculocutaneous flap in patients with end-stage arterial occlusive disease. *World Journal of Surgery*, 28, 801-806.
- Mazet R & Hennessy CA (1966). Knee Disarticulation. *Journal of Bone & Joint Surgery*, 48-A, 126-139.
- Mensch G (1983). Physiotherapy following through-knee amputation. *Prosthetics & Orthotics International*, 7, 79-87.
- Michael JW (1999). Modern prosthetic knee mechanisms. *Clinical Orthopaedics & Related Research*, 361, 39-47.
- Moran BJ, Buttenshaw P, Mulcahy M, Robinson KP (1990). Through-knee amputation in high-risk patients with vascular disease: indications, complications and rehabilitation. *British Journal of Surgery*, 77, 1118-1120.
- Oberg K (1983). Knee mechanisms for through-knee prostheses. *Prosthetics & Orthotics International*, 7, 107-112.
- Pinzur MS, Smith DG, Daluga DJ, Osterman H (1988). Selection of patients for through-the-knee amputation. *The Journal of Bone & Joint Surgery*, 70-A, 5, 746-750.
- Pinzur MS (1993). Gait analysis in peripheral vascular insufficiency through-knee amputation. *Journal of Rehabilitation, Research & Development*, 30, 4, 388-392.
- Pinzur MS & Bowker JH (1999). Knee disarticulation. *Clinical Orthopaedics & Related Research*, 361, 23-28.
- RehabTech Website, Monash University.



References

- Siev-Ner I, Heim M, Wershavski M, Adunsky A, Azaria M (2000). Why knee disarticulation (through-knee) is appropriate for non-ambulatory patients. *Disability & Rehabilitation*, 22, 18, 862-864.
- Smith DG (2004). The Knee Disarticulation: it's better when it's better and it's not when it's not. *InMotion*, vol 14, issue 1, Jan/Feb.
- Stark G (2004). Overview of knee disarticulation. *Journal of Prosthetics & Orthotics*, 16, 4, 130-140.
- Tingleff H & Jensen L (2002). A newly developed socket design for a knee disarticulation amputee who is an active athlete. *Prosthetics & Orthotics International*, 26, 72-75.
- Utterback TD & Rohren DW (1973). Knee disarticulation as an amputation level. *The Journal of Trauma*, 13, 2, 116-120.
- Vitali M, Robinson KP, Andrews BG, Harris EE, Redhead RG (1986). *Amputations and Prostheses*, 2nd ed. Bailliere Tindall, London, 149-160.
- Waters RL. The Energy Expenditure of Amputee Gait. In: *Atlas of Limb Prosthetics: Surgical, Prosthetic, and Rehabilitation Principles*, Chapter 15, O&P Virtual Library, www.oandplibrary.org