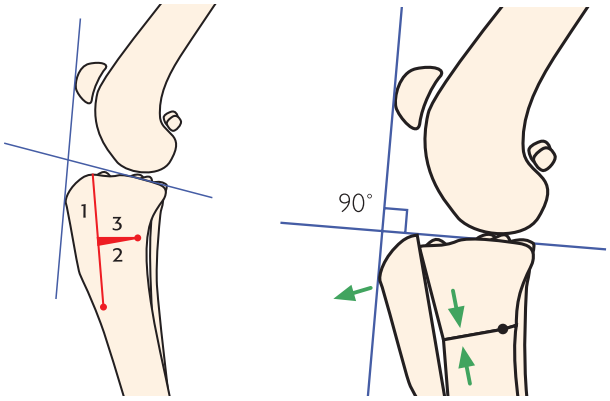
Triple Tibial Osteotomy (TTO)

Objective: This operation is based on the biomechanical analysis performed by Dr Slobodan Tepic, which revealed that in order to remove the shear strain from the cranial cruciate ligament the tibial plateaux should be perpendicular to the patellar ligament. There are two ways to achieve this; i) advance the tibial crest (the basis of the Tibial Tuberosity Advancement (TTA) technique described by Professor Montavon) and ii) alter the alignment of the tibial plateaux to the patellar ligament to 90° (a modification of the Slocum technique). Dr Warrick Bruce reasoned that rather than doing one technique or the other, there is merit in doing a little of both to achieve the same outcome, but with less radical angular changes. In the operation of triple tibial osteotomy (TTO) a partial tibial crest osteotomy and small closing wedge osteotomy are performed; closing the wedge simultaneously advances the tibial crest (see figures below).



Pre-operative patient assessment

Every patient is assessed for the degree of lameness, overall alignment of the limb, stifle range of movement, as well as the degree of stability within the joint.

Pre-operative radiographic assessment

Standard medio-lateral and cranio-caudal views of stifles are required.

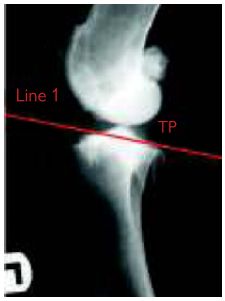
The stifle is positioned in extension for the medio-lateral view (fully extending the joint without forcing it). This is achieved by securing the upper contralateral limb cranially so that the paw of this limb is positioned up near the dog's ear. Ensure that there is no cranial subluxation of the tibia (however, with this degree of stifle extension the collateral ligaments should be tight and therefore the tibia should not be subluxated but, when in doubt, compare it with the contralateral side). The hip is packed up and the femur and tibia positioned parallel to the plate.

Ideally, in the medio-lateral view, the femoral and tibial condyles should be superimposed on top of each other. Sometimes this is very difficult to do! We have performed cadaver studies, in large breed dogs, looking at the effects of limb positioning on the apparent radiographic position of the tibial plateaux (TP) and comparing this with its true anatomical position. These studies showed that there was little effect on the radiographic position of the TP if the femoral and tibial condyles were superimposed with less than 3mm of disparity in any direction. When there was 3mm or more disparity in cranio-caudal superimposition, tibial condylar mal-alignment introduced more errors in determining the position of the TP than femoral condylar mal- alignment. However, alignment in the proximo-distal plane was the most critical as valgus or varus positioning of the stifle introduced the most errors in determining TP position.

The X-ray beam should be centred at the tibial plateaux. The exposure should be coned-down to the area of the stifle. There is no need to include the hock joint.

A summary of the pre-operative radiographic calculations is as follows:

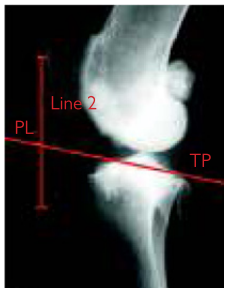
Line 1:
Define the position of the tibial plateaux (TP) (line 1). This is done by estimating the position of the surface of the medial tibial condyle, which is slightly convex in shape. There are two ways in which this can be done.



1. The conventional method determines the location of the TP by identifying the cranial and caudal points and drawing a line between them. The cranial most point of the medial tibial condyle is visible as a small discrete step.
The caudal point is the point of insertion of the CaCL -the apex of the popliteal notch is a useful point of reference. In some osteoarthritic stifles, osteophyte formation can obscure these landmarks and in these cases the tangential method may be more useful.

2. In the tangential method a line is drawn tangential to the convex surface of the medial tibial condyle at the point of contact between the medial femoral and tibial condyles.

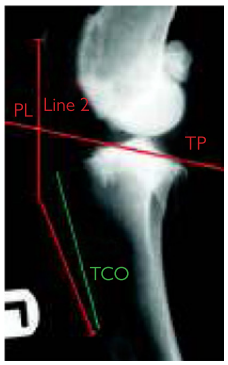
Note that the Tibial Plateaux angle, although of interest in other tibial plateaux adjusting techniques, is not involved in calculations used in the TTO. The important relationship in the TTO technique is that between the tibial plateaux and the straight patella ligament.



Line 2:

Draw a line marking the cranial edge of the straight patellar ligament (PL). Position a straight-edge cranial to the stifle and slide it caudally until it first touches points on the patella and the tibial crest. The distance between these points is the patellar ligament length (line 2).

Measure and record the length of line 2- in this patient it measured 60mm.



Tibial crest osteotomy (TCO):

Mark a point (at the endosteal surface of the cranial cortex of the tibia) exactly the length of the patellar ligament (line 2) distal to the patellar ligament insertion on the tibial tuberosity. This point marks the distal end of the tibial crest osteotomy (TCO).

Draw the tibial crest osteotomy line (TCO). Generally the TCO is made parallel to the axis of the tibial shaft and is usually parallel to the cranial aspect of the tibial crest. Its proximal end should terminate within the non-articular part of the proximal tibial, caudal to the patellar ligament insertion and cranial to the cranial edge of the menisci. Measure and record the length of the TCO in mm-in this patient it measured 70mm.

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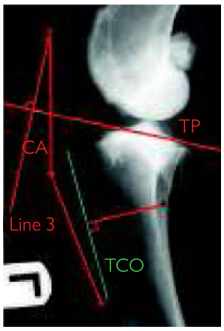
Triple Tibial Osteotomy (TTO)

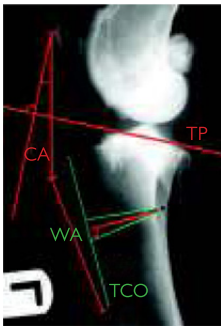


Calculating the Wedge Angle:

Create line 3 by drawing a line perpendicular to line 1 (TP) starting from the proximal end of line 2. Measure the correction angle (CA) in degrees using a protractor. The CA is the angle between lines 2 and 3. In this patient the angle measured 12˚.

Calculate the wedge angle (WA) by using the formula:

WA = (0.6 X CA) + 7



Define the wedge position:

The central axis of the wedge is located exactly halfway along the TCO. Draw in the central axis of the wedge as a line extending caudally and perpendicularly from the TCO line at its mid point. The wedge to be resected is centred on this line; the apex of the wedge is located at the endosteal (cranial) surface of the caudal tibial cortex. The base of the wedge is located at the TCO with each side of the wedge equidistant (proximally and distally) from the central axis. The calculated wedge angle in this patient was 14˚.

Surgery: The patient is positioned in dorsal recumbency for the initial part of the surgery, which is to explore the medial aspect of the stifle joint.

Make a medial para-patellar approach to the stifle. Incise medial fascia and joint capsule together (electrocautery is great for this). Inspect the intra-articular structures. Remove the torn ends of the cranial cruciate ligament (CrCL). Inspect the menisci, if a meniscal injury is present then resect the injured portion(s). Perform a partial meniscectomy in preference to a complete meniscectomy whenever possible. The protocol for dealing with a case where there is no obvious meniscal pathology is:

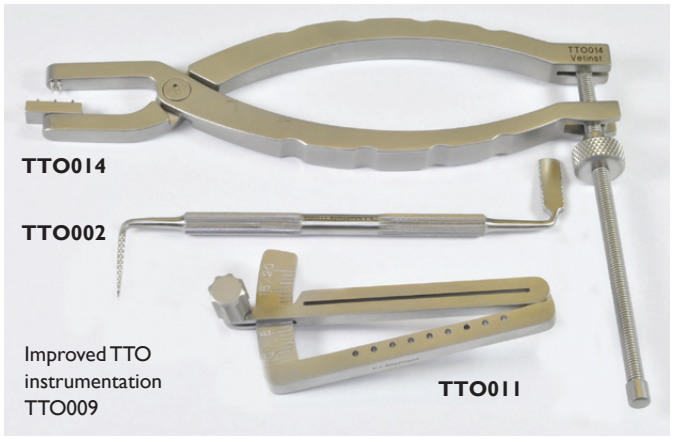
a. Fresh complete rupture with no meniscal pathology. Perform a "meniscal release" by incising the caudal menisco-tibial ligament of the medial meniscus.

b. Partial rupture with no meniscal pathology. Leave the menisci alone; just resect the ruptured portion of the CrCL. However, be sure to check the integrity of the remaining intact CrCL bands by placing a curved haemostat behind them and applying some pressure. Make sure they are not stretched or incompetent and have reasonable strength. If not the remainder of the ligament should be resected.

Lavage the joint space and partially close the capsule and fascia together in one layer using monofilament absorbable sutures (PDS or similar) in a cruciate pattern.

Instruments and Implants:

There are a few dedicated instruments designed to simplify the operation and improve accuracy. There is a **new TTO saw guide** with a 1.9mm guide pin; the mark II guide is designed to lock into the new **TTO osteometer**, which is used for the wedge cut. The **TTO wedgie** is used to hold the TCO open while the wedge is cut and reduced. The new **TTO clasper** is used to secure the combined saw guide and osteometer to the bone and to provide a point of fixation for the large fragment forceps during reduction of the wedge osteotomy.



Use the Vi angle finder and overlay to select a plate offering the best fit for the caudal 2/3 of the proximal tibia. Typically dogs weighing less than 35 kgs, require a medium VI TPLO plate (TPLO353557 or TPLO353555). For larger dogs use Vi TPLO plates (TPLO353579 or TPLO353562). Smaller plates are available for dogs less than 20kgs. It is recommended that the appropriate size of plate is pre-contoured by twisting the proximal portion of the plate 10-15° towards the midline.

With the patient now in lateral recumbency with the affected leg down and parallel to the operating table, the crural fascia is reflected from the medial aspect of the tibia, taking care to preserve the saphenous blood vessels distally and the medial collateral ligament proximally.

An appropriately sized pre-contoured TPLO plate is placed against the medial surface of the tibial to check that the plate is adequately contoured. Adjust the plate moulding accordingly.

Using a surgical ruler, measure the predetermined PL length (line 1) from the distal end of the patellar ligament distally along the cranial edge of the tibia. Mark the level of the distal extremity of the TCO with a bone scribe. The distal point of the TCO is located at this level but just caudal to the cranial cortex of the tibia (i.e. at the endosteal surface of the cranial tibial cortex). Check that there is enough room caudal to this point to apply the selected plate.

A 2mm hole is drilled at right angles to the sagittal plane of the tibia. Note that the tibial slopes cranially in this area and if the distal TCO hole is mistakenly drilled at right angles to the surface of the tibia then the TCO will be orientated in a cranio-medial to caudo-lateral direction. This orientation is incorrect and could result in damage to structures on the lateral side of the tibia (eg the long digital extensor tendon and sheath).

Drilling guide hole for saw guide

The pin on the TTO Saw guide is then inserted into this hole and the saw guide is aligned parallel to the tibial crest. Compare the position of the proposed TCO cut to the pre-operative radiographic plan. Double check that the dimensions and orientation of the TCO are the same as your radiographic plan.

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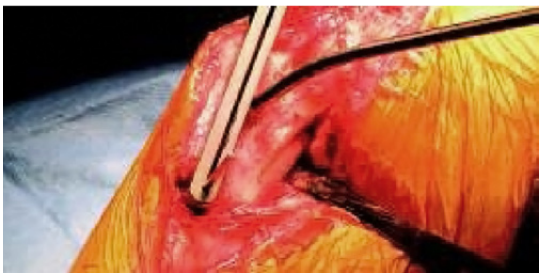
Triple Tibial Osteotomy (TTO)



Saw guide positioned for TCO

The TCO is completed with an oscillating saw from the distal hole in the tibia proximally into the joint. Ensure the patellar ligament is protected at all times and that there is copious lavage of the saw blade to prevent thermal necrosis of bone. The saw guide is useful to cut the bulk of the TCO however the final distal cut into the guide hole and the most proximal part of the cut is usually done free-hand. The TCO is checked to ensure that the osteotomy is complete.

Cutting the tibial crest osteotomy

The length of the TCO is measured. A point halfway along the TCO is marked and the wedge centre line is then scribed in the bone at right angles to the TCO. An orthopaedic ruler can be used as a set-square to achieve this accurately. Invariably this line transects the base of the medial collateral ligament and is located about one third of the distance up from the distal end of the tibial crest.

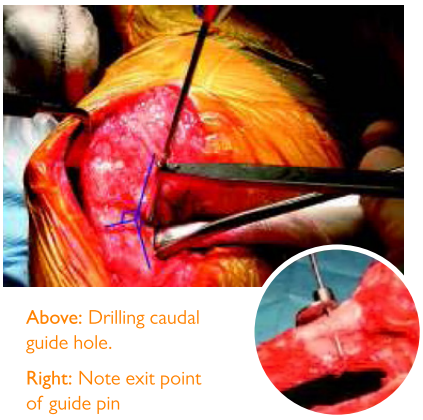
Marking the wedge centre line

The origin of popliteal muscle is elevated from the caudal aspect of the tibia in the area adjacent to this mark. A small Hohman retractor and a dry surgical swab are used to retract the soft-tissues at this point to prevent iatrogenic damage to the cranial tibial artery, located within the soft tissues lateral to the osteotomies.

Exposing the site of caudal guide hole

The proximal part of the TCO is then carefully and slowly forced apart using a periosteal elevator. Hinging the tibial crest forward like this will allow the insertion of the large blade of the TTO Wedgie proximally, or alternatively, the small blade of the TTO Wedgie more distally. The Wedgie is then carefully rotated, levering the tibial crest cranially, to give the maximal amount of tibial crest advancement. In some smaller dogs, it may be easier to position the larger blade of the Wedgie more proximally when performing the wedge ostectomy procedure. However, in all cases, the Wedgie must be positioned distal to the wedge ostectomy during the closure of the wedge.

A 2mm drill hole is placed at the caudal end of the wedge centre line. Its location is usually at the level of the endosteal surface which is located 2-3mm inside the caudal cortex of the tibia. As the bone in this region slopes away caudally, it is necessary to start drilling perpendicular to the bone surface until the drill bit engages the bone. Once this occurs the drill is then aligned perpendicular to the medial surface of the tibia.

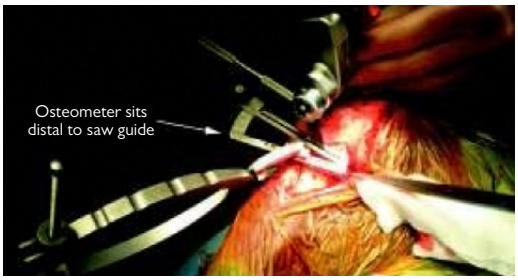


Above: Drilling caudal guide hole.

Right: Note exit point of guide pin

The caudo-medial anatomy of tibia in this area is ridge shaped, which means that the guide hole exits this ridge in the caudal region of the tibia. It is worth spending some time studying an anatomical specimen and working out where everything is prior to completing this location hole. When this is completed the pin on the saw guide is inserted into this drill hole and aligned along the marked centre line. If the location hole has been drilled perpendicular to the tibial surface the saw guide should lay flat along the medial surface of the tibia. If using Mark I TTO equipment, the hooked end of the TTO osteometer is placed between the saw guide and the tibia and hooked behind the saw guide pin. For Mark II equipment, the osteometer is hooked behind the saw guide pin by feeding it through the transverse central slot within the guide. Both Mk I and Mk II osteometers are marked on both sides and once hooked on should sit distal to the saw guide.

Cutting the wedge



The saw guide is aligned and set to half the wedge angle. For example, if the calculated wedge angle (WA) is 12 then the osteometer is rotated until half of this angle (i.e. the 6 mark) is positioned at the wedge centre line (and the centre of the slot in the saw guide). The osteometer is fixed in this position by either inserting a 1.4/1.6mm K-wire into the tibia through one of the fixation holes in the osteometer, or by using a pair of pointed reduction forceps to grasp the tibia whilst one point of the forceps is inserted into a fixation hole. When using the Mark II equipment, a specially designed TTO Clasper locks into the fixation holes on the osteometer and its alligator jaws securely fix it to the tibia.

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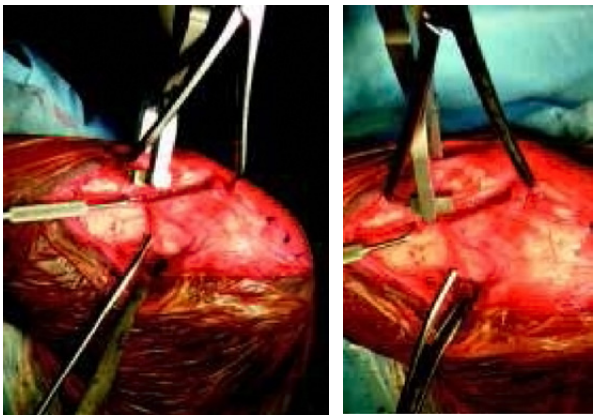
Triple Tibial Osteotomy (TTO)

The saw guide is then aligned alternatively with the 0 and 12 marks on the osteometer to create the appropriate sized wedge. With the Mark I equipment the saw guide needs to be held manually in the correct position however the Mark II saw guide has a knurled fixation nut which, when tightened, secures the guide to the osteometer. Alternatively the MKII saw guide can be locked at the mid point (for example 6) and then the osteometer and saw guide unit is positioned at right angles to the TCO before being secured by the Clasper. Once secure the knurled nut is released allowing the guide to be positioned for each cut.

A fine saw blade is used to cut a full thickness wedge from the proximal tibia. The slot in the saw guide is 1.0mm so it important that the blade cut (the width at the teeth) is less than 1.0mm. The oscillating saw blade is rested against the outer surfaces of the saw guide slot when cutting the wedge. Take care to ensure the cuts are made in parallel planes. Once the cis cortex is cut, the saw blade is orientated in a slightly cranial direction and the cranial part of the lateral tibial cortex is cut. Then the saw blade is orientated slightly caudally to cut the caudal and caudo-lateral parts of the lateral tibia. This blade orientation will ensure smooth cuts are made evenly through the lateral cortex. The cuts should enter the caudal locating hole, so once the wedge cuts are complete and the saw guide is removed the saw blade is used to extend the cuts caudally into the locating hole.

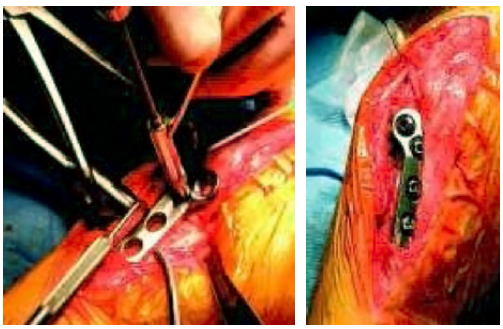
The wedge is removed and the tibial ostectomy checked to ensure that there are no bone ledges or edges left behind. Store the wedge in a blood soaked swab so that its cancellous part can be used as an autogenously bone graft later. The gauze swab and the retractor placed caudal and lateral to the tibia are removed. The TTO Clasper is used to grasp the tibial crest distal to the wedge ostectomy (alternatively a pair of Kern forceps can be used). Then one point of a pair of large speed- lock fragment forceps is inserted into the non-articular cranial aspect of the stifle joint and the other point is hooked into the fixation hole in the end of the TTO Clasper foot. When using Kern forceps, the fragment forceps engage the upper jaw of the Kern. The tibial wedge ostectomy is then gradually closed by using a combination of tightening the speed- lock nut and applying upward pressure on the foot (tibial thrust action). The resultant action serves to gradually close the gap but at the same time keeping the caudal tibial cortex intact.



Progressive closing of the wedge

Closing the tibial wedge causes the tibial plateau to rotate cranially which serves to hold the tibial crest in its new advanced location. If it is difficult to completely close the wedge it may be necessary to re-cut the apex of the wedge near the locating hole.

Plating the osteotomy



Once the wedge ostectomy has been closed, the plate is rechecked and any necessary moulding adjustments are made. The plate is then fixed to the bone using cortical screws using standard AO techniques. Cancellous screws can be used in the most proximal two holes without prior tapping if the cortices are very thin (eg in older German shepherd dogs). The load guide can be used to apply axial compression. Cancellous bone harvested from the resected wedge is used as a bone graft and placed into the triangular space left caudal to the tibial crest.

Following wound lavage, the fascia and the rest of the joint are closed with monofilament absorbable sutures (eg PDS). Bupivicaine (Marcain, 2mg/kg) or a mixture of bupivicaine and morphine (0.1mg/kg) can be injected into the stifle joint and beneath the crural fascia at this time.

If tibial crest (TC) fragment fractures at its distal hinge point, then the TC is stabilized using a single K-wire and a tension band wire passed in a fig-8 pattern between 1.5mm diameter holes drilled about 10mm proximal and distal to the fracture. In most cases, stable TCO fractures will be adequately stabilized by closing the surrounding soft tissues.

The remaining soft tissues are closed in a routine fashion. Post- operative films should be taken to assess bone alignment and implant position. A RJB is applied for 3-5 days post-operatively.

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Triple Tibial Osteotomy (TTO)

TTO Post-operative Care Instructions

Medications:

The following medications are suggested:

- A NSAID (e.g. carprofen, meloxicam, firocoxib) is used for a minimum of 7 days.
- Oral antibiotics (e.g. cephalosporins, clavulonate-amoxicillin) are used for 5 days.
- Pentosan polysuphate injections (eg Cartrophen-Vet, Pentarthron) starting at around 7 days post-operatively and subsequent injections are given weekly for 4 weeks.

Exercise:

Enforced rest is required for the first 6 weeks following TTO surgery. This means the dog should be confined to a small room or run for the duration of this period. The only exercise allowed is short-duration (15 minutes maximum), slow walks on a leash for toileting purposes. Walking up and down flights of stairs, jumping up, or any uncontrolled activity must be avoided. Take care to avoid slipping when walking on wet or smooth surfaces. An old towel can be used as a hind-quarter sling if it is placed underneath the abdomen.

Physiotherapy:

Postoperatively, physiotherapy in the form of passive range-of-motion exercises can be performed after RJB removal. Ideally, all joints of the affected limb should receive physiotherapy 2 to 3 times a day but instruct clients to concentrate mainly on the stifle joint if time is short. During each session, a minimum of 10 flexions and extensions should be performed on each joint. After flexion and extension of the individual joints, the entire limb should be cycled through its full, pain- free range-of-motion 10 times. It is very important never to force the joints or cause pain, but gently manoeuvre the limb through a range-of- motion that is well tolerated.

Longer-term follow-up and care:

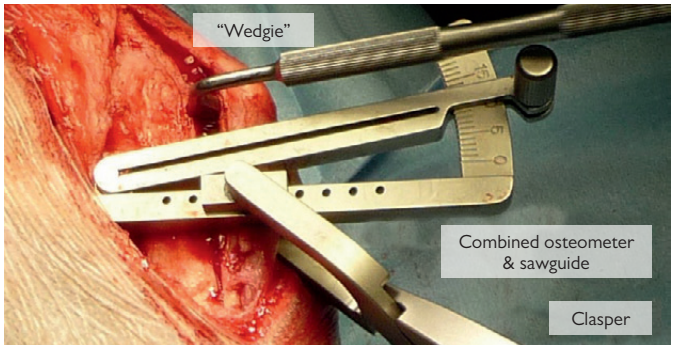
At around 6 weeks post-operatively a radiograph of the stifle to assess the progress of healing are recommended. All going well, controlled exercise on a leash may begin at this time. Leash walks should be minimal at first (15 to 20 minutes twice daily), and then gradually increased after 8 weeks post-operatively.

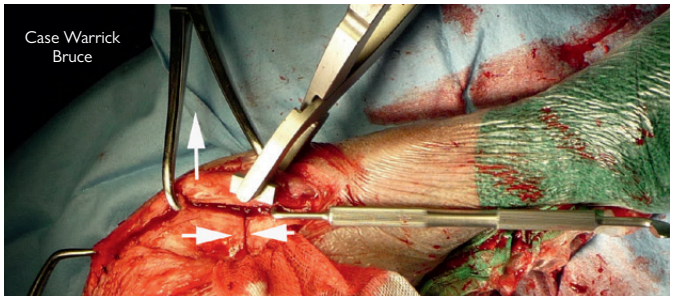
Sit/stand exercises should also begin around 6 weeks post-operatively. This can be achieved during leash walking by commanding the dog to"sit" and just before the dog assumesthe sitting position, the command to "walk-on" is given. This routine is repeated 10 or more times every walk and has the effect of building the quadriceps muscle mass, which is very important in rehabilitation following cruciate ligament repair.

There should be no unsupervised exercise, and running and jumping should be avoided during the 6 to 12 week post-operative period. Between 8 and 12 weeks, exercise can be increased slowly to 30 to 40minutes twice daily. Deep-water swimming for 10 to 15 minutes several times a week, if possible, is excellent therapy at this stage.

By 12 to 16 weeks the patient should have returned to near normal activity. However, there is a large variation in how quickly individuals return to full function following TTO surgery.

Special thanks to Warrick Bruce and Geoff Robins for preparing this guide.





Warrick Bruce has designed two new instruments to make the TTO procedure easier and to eliminate some of the practical difficulties encountered using the original instrumentation.

The new combined osteometer and saw guide interlock to become a single instrument which is much easier to manage than the original two separate instruments. The thumbscrew locks the osteometer onto the saw guide for secure accurate osteotomies. The osteometer still has holes for fixation to the tibia using 1.6 arthrodesis wires.

Alternatively Warrick's second new instrument 'the Clasper' may be used to lock the osteometer onto the tibia prior to cutting. The 'Clasper' has an additional role in that it is used to replace the kern bone holders in the original technique. The 'Clasper' grasps the tibia crest prior to closure and incorporates location holes for the very large fragment forceps to lock into.

The 'wedgie', used for manipulating the three osteotomies remains unchanged.

IMPROVED TTO (by Warrick Bruce)

TTO011	Improved Combination Osteometer/Sawguide
TTO014	'Clasper'
TTO002	Wedgie segment manipulator

The original instrumentation is very functional but not as easy to use as Warrick's new instruments.

Many TTO surgeons start off with the basic set and upgrade to the new items.

TTO KIT

TTO008	Basic TTO Instruments (3 items) kit price
TTO006	Basic Osteometer
TTO004	Saw Cutting Guide (Standard 62mm)
TTO002	Wedgie segment manipulator
TTO004L	Saw Cutting Guide (Long 76mm)
DVDALL	DVD Illustrating the procedure

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Triple Tibial Osteotomy (TTO)

TTO Plates

The standard TTO plate is a cloverleaf TPLO plate. Being positioned over the caudal 2/3 of the tibia the plate selected is typically a little smaller than is the case with a wedge TPLO. Use the free plate overlay for the final selection. Remember the profiles are actual size. Thicker plates are harder to contour and a selection of pre-contoured plates is available.

TTO AND TPLO BY WEDGE OSTEOTOMY PLATES

TPLO202026	2.0mm DCP 26mm overall length
TPLO242434	2.4mm DCP 34mm overall length
TPLO272739	2.7mm DCP 39mm overall length
TPLO273539	2.7/3.5 DCP 39mm overall length Allows use of 3.5 cancellous screw in head
TPLO273545	2.7/3.5 DCP 45mm overall length 2.5mm thick
TPLO353555	3.5mm DCP 55mm overall length
TPLO353557	3.5mm DCP 57mm overall length Heavy Duty
TPLO353562	3.5mm DCP 62mm overall length
TPLO353577	3.5mm DCP 77mm overall length xtra shaft hole
TPLO353577X	3.5mm DCP 77mm overall length
TPLO353579	3.5mm DCP 79mm overall length Heavy Duty
TPLO354579	3.5/4.5 DCP 79mm overall length Heavy Duty Allows 4.5 screws in head
TPLO 35456579	79mm overall length, Heavy Duty Allows 4.5/6.5 screws in head
TPLO 45659030	4.5mm DCP 90mm overall length Will accept 6.5 cancellous screws in head 3.0mm thick
TPLO 45659045	4.5mm DCP 90mm overall length Will accept 6.5 cancellous screws in head 4.5mm thick
TPLOO	Angle Finder & Plate Overlay

PRE CONTOURED TTO PLATES

TPLO353555PCR	3.5 mm Plate 55mm overall length Right
TPLO353555PCL	3.5 mm Plate 55mm overall length Left
TPLO353557PCR	3.5 mm Plate 57mm overall length Right
TPLO353557PCL	3.5 mm Plate 57mm overall length. Left
TPLO353579PCR	3.5 mm Plate 79mm overall length Right
TPLO353579PCL	3.5 mm Plate 79mm overall length Left