SOFT TISSUE BALANCING IN PRIMARY TOTAL KNEE ARTHROPLASTY
The principles of total knee arthroplasty that govern good to excellent clinical outcomes and longevity include proper alignment in all three planes, maintenance of joint line, proper sizing and lateralization of the component, secure fixation with cement and most importantly, soft tissue balance in both extension and flexion.

Dr. Rossi has invited guest contributors who are experts in the field of orthopaedic surgery. This book provides a detailed description, principles on advanced surgical techniques for total knee arthroplasty with special emphasis on soft tissue balancing in total knee arthroplasty based on preoperative deformity. The chapters on diagnosis, management and treatment of patellofemoral issues and stiffness are special. I recommend this book for Residents, Fellows and Orthopaedic Surgeons interested in total knee arthroplasty.

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To my mother and father for their guidance and inspiration
To my wife, Micaela, and our wonderful daughters, Francesca and Cecilia, for their love, friendship and never-ending support
R.R.

To my parents and sister, who made me who I am.
To Cecilia, beloved wife and wonderful mother.
To Edoardo, my brand new angel.
M.B.
Soft Tissue Balancing in Primary Total Knee Arthroplasty is proposed as a practical text for the management of soft tissue balancing, presenting step-by-step descriptions of surgical technique. The text was intended to be a pragmatic reference for students, residents, fellows and attending surgeons engaged in the treatment of patients who have undergone knee replacement surgery. This book uses “how to” approach for many of the complex issues confronting us in total knee arthroplasty, written by some expert authors. It is devoted to issues relating to primary total knee arthroplasty – from simple to the most complex. The first and second chapters include the primary technique in knee arthroplasty outlining tips and pearls during the surgical procedure. Some of the chapters emphasize principles of primary in cruciate retaining and posterior stabilized implants underlining the differences in soft tissue balancing and showing the use of navigation system. The last chapters show “how to” perform the soft tissue balancing in different deformities, such as varus and valgus, flexed and stiff knees. Last, but not least, the final chapter draws attention in extensor mechanism issues.

We feel glad to have received the support of so many well-know master surgeons who have contributed to the text. We are grateful to all of them and are proud to have been able to present their combined experience in the proceeding book. It is a true honour for us to have collaborated with outstanding friends, colleagues and mentors in publishing this textbook.

As editors, we have each learned a great deal from the authors who have contributed to this text. We expect that their efforts will be equally valuable to you.

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INTRODUCTION

Clinical results in primary total knee replacement (TKR) are influenced by the surgical technique. The goal of primary TKR is to reestablish the normal mechanical axis with a stable and well fixed prosthesis. Evaluating patient expectations is a key-point for a successful total knee replacement: the surgeon and the patient should have realistic goals, because even a well-placed total knee will neither feel nor function like a normal knee.  

PREOPERATIVE STUDY

Obtaining a good history (clinical history, previous fractures or surgery, important medical risk factors...) and performing a complete clinical examination of the patient (i.e. range of motion, stability, fixed or reducible deformities affecting the whole inferior limb, previous scars) are essential in preoperative evaluation.  

A radiologic preoperative study should include a standing Anterior-Posterior (AP) and lateral view, a skyline of patella and a full-length radiograph from the hip to the ankle (Figure 1.1). On standing AP view one can observe tibial e femoral deformity and bone loss and alignment. On standing lateral view the surgeon can evaluate the presence of posterior osteophytes that must be removed during surgery, the position of the patella (Insall-Salvati Ratio), the tibial slope and the entrance point of intramedullary nail of the femur. A subluxation of the femur on the tibia can indicate a popliteus tendon contracture in AP view or a pivot ligaments deficiency in lateral view. The skyline view of patella is important to determine potential subluxation (shifting and tilting) or thinning of the patella. A full-length radiograph is fundamental to determine mechanical and anatomical axis and to point out possible extra-articular deformities. The cuts are planned at 90° to the tibial axis and usually 3° to 6° valgus to the femoral axis in valgus and varus knees respectively. The femoral neck-shaft angle must be considered to adjust the femoral cut.

SURGICAL APPROACH

The most commonly used surgical approach starts with an anterior medial incision. not end on the tibial tubercle (where the vascularization of the skin is poor and a scar can be painful during kneeling), but we recommend to end slightly medial to the tibial tubercle (Figure 1.2). If previous longitudinal scars are present one should incorporate it, choosing the longest and the most lateral scar extending it as necessary, since the vascularization of the anterior aspect of the knee comes from medial to lateral. In some cases it may be necessary to incorporate or to cross an old transverse incision: as a general rule, any new incision should intersect an old incision at a right angle as much as possible avoiding to engage an old incision with an acute angle (>60°). If no previous incision is appropriate for surgery, a skin flap of at least 3-4 centimeters from prior incisions should be utilized to avoid skin necrosis of the flap between the two incisions. Thereafter a parapatellar medial arthrotomy is performed. Before proceeding it is useful to mark with a marking pen the quad and the patellar tendon at the level of the superior and inferior border of the patella, just to avoid a patella baja or alta during the closure (Figure 1.3). Capsular incision is performed along the medial border of quadriceps tendon leaving 2-3 mm of tendon attached to the muscle. The capsular incision is extended distally to the medial border of tibial tubercle, just proximally to the pes anserinus insertion.
Figure 1.1—Pre-operative standard X-Ray study with AP (A), Lateral (B) and patella sky-line view (C); a full-length radiograph from the hip to the ankle (D) is also obtained: the red line indicates the mechanical axis.

Figure 1.2—Skin incision is planned with a marking pen. The incision ends slightly medial to the tibial tubercle.

Figure 1.3—The patellar and quadriceps tendons are marked transversally at the superior and inferior border of the patella, in order to avoid a change in patellar height during closure.
The anterior horn of the medial meniscus is dissected. The medial joint capsule is then elevated—
together with the medial meniscus—from the me-
dial tibial flare at least to the midline of the tibia
subperiostally, externally rotating the leg, to bet-
ter dislocate the knee (Figure 1.4). An optimized
subvastus approach can be performed in selected
cases by more expert surgeons. To obtain a good
lateral exposure one should remove the posterior
half of infrapatellar fat pad with the lateral menis-
cus. It is important to find the interval between
the patellar tendon anteriorly and the Hoffa fat
pad directly posterior: one can use a finger be-
tween tendon and fat pad to clearly identify the
interval and protect patellar tendon from the elec-

trocautery, with the knee in full extension (Fig-
ure 1.5). With the knee in the same position, the
patella is dislocated and can be either everted or
not: we usually perform a section of patellofemo-
ral ligament and an inside-out lateral release after
peripatellar osteophytes removal to reduce tension
during eversion (Figure 1.6). With the knee flexed
at 90°, the incision of cruciate ligaments (in pos-
terior stabilized implants) allows anterior disloca-
tion of the tibia and a complete exposure of tibial
plateau (Figure 1.7).

During all maneuvers that place tension on the
extensor mechanism, especially knee flexion and
patellar retraction, attention should be paid to the
patellar tendon attachment to the tibial tubercle.
The elevation of the proximal medial 1/3 of the patella tendon’s attachment to the tibial tubercle can be helpful but must be performed with extreme attention. Avulsion of the patellar tendon is difficult to repair and can be a devastating complication. We recommend to use a pin into the tendon to prevent a partial detachment. Once the exposure of the tibial plateau is complete we suggest to 1) remove the menisci and the osteophytes, 2) identify and coagulate the lateral inferior geniculate vessels.

**Bone Cuts**

There are five basic principles for TKR:

1. restoration of the mechanical axis;
2. restoration of the joint line;
3. balancing of the soft tissues;
4. equalizing flexion and extension gaps;
5. restoration of patella-femoral alignment and mechanics.

The surgical procedure comprises five essentials bone cuts, whether the prosthesis is cemented or press-fit. An additional sixth cut for the removal of intercondylar notch is performed in PCL sacrificing prosthesis.

These cuts are the same regardless for the amount of bone loss, presence of osteophyte, and soft tissues balance.

The essential bone cuts for any TKR are:
- transverse osteotomy of the proximal tibia;
- resection of the distal femoral condyles angulated at 3° to 6° of valgus alignment;
- anterior and posterior condylar resection according to the selected size of prosthesis;
- anterior and posterior chamfers for the distal femur depending on prosthetic design;
- retropatellar osteotomy;
- optional resection of intercondylar notch for PCL substituting prosthesis.

There is no-fixed order to perform the bone cuts, because the proximal tibial and distal femoral osteotomies are independent from one another. We usually begin with the tibial cut; nevertheless in tighter knee or in presence of important posterior osteophytes, it is preferable to start with distal femoral osteotomy to gain space, allowing a better view of tibial plateau.

**Proximal Tibial Osteotomy**

The proximal tibia should be resected at 90° on the coronal plane (a varus cut maximum of 3° is acceptable) whereas in the sagittal plane the posterior slope of the tibia is dictated by prosthetic design. The proximal tibial osteotomy can be performed with intramedullary or extramedullary guide. With intramedullary guide one of the keys is the entry point on tibial plateau; this point is usually lateral to the insertion of the anterior cruciate ligament. The extramedullary guide should be pointed proximally on tibial spines and distally,
at the ankle, on tibialis anterior tendon, and run parallel to the anterior tibial crest. Once the tibial guide is positioned, one has to decide the level of tibial osteotomy. The depth of the tibial cut should correspond to the thickness of the tibial insert. This cut is usually 10 mm below the level of normal tibial plateau. In presence of bone defect no effort should be made to remove bone to go to the bottom of the defect. Only if a minimal additional resection (1-2 mm) should completely eliminate the defect one can consider to make that cut. During osteotomy two homann retractors are placed medially and laterally to protect medial and lateral collateral ligament and patellar tendon.

At the end of tibial osteotomy one can check the amount of bone cut compared to preoperative planned cut. The varus-valgus alignment of the cut should be checked at this point with a spacer block associated with an alignment rod.
The mask must be positioned perpendicularly to the tibial intercondylar line to avoid an obliquely sloped cut. Especially in loose knees, we recommend to cut less than 10 mm (7-8 mm): the remaining necessary space will be obtained through the soft-tissues release. We suggest to remove the tibial resected bone just in one piece rotating from medial to lateral. (Figure 1.9).

**Distal Femur Osteotomy**

The distal femur osteotomy is performed in the most of the cases with an intramedullary guide. The entry point for the femoral rod is few millimeters medial to the midline and just anterior to the origin of PCL. A large drill hole is made at this point to allow the rod insertion. During the drilling you should place the fingers on anterior shaft of the femur to estimate the correct direction (Figure 1.10). Before inserting the rod, we suggest to insert suction inside the femoral canal to avoid excessive increase of intramedullary pressure during rod insertion. The distal femoral guide has a variable angle usually fixed from 3° to 6° of valgus. For slightly varus or normal knee an angle of 5° of valgus is indicated, while in valgus knee a 3° cut is preferable. The cutting block is then fixed on the anterior aspect of the femur to estimate the correct direction (Figure 1.10). Before inserting the rod, we suggest to insert suction inside the femoral canal to avoid excessive increase of intramedullary pressure during rod insertion. The distal femoral guide has a variable angle usually fixed from 3° to 6° of valgus. For slightly varus or normal knee an angle of 5° of valgus is indicated, while in valgus knee a 3° cut is preferable. The cutting block is then fixed on the anterior aspect of the femur to estimate the correct direction (Figure 1.10).

**Tips and pearls of Proximal Tibial Osteotomy**

Most of the time we observe cases with a varus proximal tibial alignment (meta-diaphysis angle average of 3-4° of varus). If we want to obtain a perpendicular proximal tibial cut, we need to use the extramedullary guide with a slightly valgus alignment (medializing the guide close to ankle of 4-5 mm) (Figure 1.8). In obese patients we suggest to use the tibialis anterior tendon as distal reference for alignment, since it is easy to palpate at the distal 1/3 of the tibia. The position of the mask determines the direction of the tibial slope. The mask must be positioned perpendicularly to the tibial intercondylar line to avoid an obliquely sloped cut. Especially in loose knees, we recommend to cut less than 10 mm (7-8 mm): the remaining necessary space will be obtained through the soft-tissues release. We suggest to remove the tibial resected bone just in one piece rotating from medial to lateral. (Figure 1.9).
shaped sign on the lateral condyle that indicates the height of the entrance point in the femoral canal. (Figure 1.13) Once the cutting block is pinned on the anterior aspect of the femur one can check the correct amount of resection inserting the sickle in the slot between the two condyles: when it results tangent to the cartilage, the resection is about 10 mm. (Figure 1.14).

**Anterior and posterior femoral condylar osteotomy**

These cuts determine the rotation and the dimension of the prosthesis and the knee balancing in flex-

8 to 12 mm. After a correct cut it is possible to see a “figure of eight” configuration on the cut surface (Figure 1.11). If the cut is too distal you can see two ovals, whereas if the cut is too proximal you will see a surface with all contiguous bone (Figure 1.12). At this stage one can evaluate and if necessary correct the extension gap with the spacer block and check the alignment with the spacer in place associated with alignment rods.

**Tips and Pearls of Distal femoral cut**

To evaluate the correct position of the entry point of the rod one can observe a reversed V shaped sign on the lateral condyle that indicates the height of the entrance point in the femoral canal. (Figure 1.13) Once the cutting block is pinned on the anterior aspect of the femur one can check the correct amount of resection inserting the sickle in the slot between the two condyles: when it results tangent to the cartilage, the resection is about 10 mm. (Figure 1.14).
The femoral component rotation influence the flexion gap, the knee stability and the patellofemoral tracking. There are several methods to determine the correct rotation of femoral component, none of which is perfect, so the surgeon have to familiarize with all of them to double- or triple-check. The most important are: measured 3° to 5° of external rotation to posterior femoral condyles, tension technique to obtain rectangular flexion gap (parallel-to-tibial-cut technique), the transepicondylar axis and perpendicular to trochlear notch line of Whiteside. In most knees, correct rotation is approximately 3° of external rotation compared to the posterior condylar axis so the guide is placed on distal femur and then rotated from 3° to 5° (dependant on preoperative planning) to obtain the correct femoral rotation in a simple way. An important exception is in valgus knee and in presence of important bone loss on posterior condyles. The transepicondylar line and the Whiteside line are other important references to establish the femoral rotation and represent a reproducible landmark. You should identify medial and lateral epicondyle and then trace a line between them (transepicondylar line). The guide should be rotated parallel to this line. Alternatively, a perpendicular line to the axis of the center of the trochlea and the intercondylar notch (Whyteside line or AP femoral axis) can be considered. This line has been demonstrated to be perpendicular to the transepicondylar line. The flexion gap technique for femoral rotation is based upon the reference to the tibial cut with the collateral ligaments balanced in flexion. The knee is dis-
Once the rotation is established one should determine the size of the prosthesis. The guide for this measurement can have a posterior or an anterior reference. Posterior referencing instruments are theoretically more accurate in recreating the original dimensions of the distal femur; however, anterior referencing instruments have less risk of notching the anterior femoral cortex and place the anterior flange of the femoral component more reliably against the anterior surface of the distal femur. When the measure doesn’t match exactly the available sizes it is preferable to downsize the prosthesis to avoid excessive tightness in flexion. When the correct size has been determined, the correspondent cutting block is positioned and the cuts are performed taking care to protect the collateral ligaments (Figure 1.15). You can observe at this point the “ground piano” sign (Figure 1.16) on the anterior surface of the femur. If you don’t need additional soft tissue balancing, a rectangular flexion gap uniform to the extension gap can be observed. To check flexion stability a varus and valgus stress test with knee at 90° of flexion is performed with spacer blocks in site (Figure 1.17).

Anterior and posterior chamfers

These osteotomies depend on prosthetic design and often are integrated into the same block used for anterior and posterior femoral cuts.

After the main femoral cuts are performed, using laminar spreaders with the knee at 90° of flexion, posterior osteophytes must be removed using curved osteotomes and curettes. Any possible pos-
Retropatellar Osteotomy

With everted patella one should remove all soft tissues, synovium and fat around the patella especially at superior pole, to avoid the “clunk syndrome” (when the residual synovium hitch on anterior flange of the prosthesis) and to fully visualize patellar thickness. The patellar cut should be parallel to the anterior cortical surface, to the lateral patellar facet and to the insertion of quadriceps tendon and the thickness should be equal to or less than the original thickness. A caliper can be used to determine the measure of patella before and after the osteotomy. The amount of bone resected depends on thickness of patella before and after the osteotomy. The osteotomy can be performed both with a guide or by a free-hand technique (Figure 1.19).

A caliper should be used before and after the resection to check the amount of resected bone. The size and the position of patellar component is then determined: the size should be as large as possible and the position as medial as possible to improve patellar tracking. Once the size and the position are chosen, the holes for patellar pegs are drilled.

TRIAL REDUCTION

After the osteotomies have been completed, one should remove all soft tissue debris and any possible bone cut residual and the trial reduction is per-
formed. When placing the femoral component, one should to take care to have the intercondylar box with adequate size and orientation, to avoid a splitting of the femoral condyles. With flexion and extension the tibial plateau should be stable without any raising or rotation more than few degrees. The knee may also be elastic at varus-valgus stress with few millimeters of laxity both in flexion and in extension. A soft tissue release should be performed if necessary at this point, in order to obtain a rectangular flexion and extension gap. We recommend a pie-crusting inside out release of the tight structures. Care should be taken to avoid common peroneal nerve injury when releasing the posterolateral capsule. The ROM should be carefully checked: a full extension and an adequate flexion (110/130°) should be achieved in all cases. To check the full extension you can use the press sign (Belly test) (Figure 1.20), positioning the foot of the patient on your abdomen and pressing the leg in extension; if a full extension has been achieved, the leg will remain in this position, otherwise the knee bends in case of flexion contracture. Finally the patello-femoral tracking is checked and if necessary a progressive release of thickened structures in the lateral retinaculum is performed.

**TIBIAL PREPARATION**

Various techniques exist for establishing tibial rotational alignment during total knee arthroplasty (TKA). One of them is the ROM technique. Once the ligaments are balanced and the femoral, tibial and plastic insert trials are positioned in the knee, the knee is then manipulated through a full arc of motion several times, allowing the tibial tray to float and orientate itself in the best position relative to the femoral component. However the ROM technique has a disadvantage to depend on rotation of femoral component and tissue balancing. We recommend to use a Posterior Lateral Corner Locked Technique (PLCL). After the tibial cut is performed, the proximal tibia is completely visualized with the knee fully flexed. The posterolateral corner of the tibia is carefully isolated and marked. The corresponding posterolateral corner of the correct sized tibial trial is positioned at that level and pinned; the tibial trial has to completely cover the bone surface, without overhanging the edges. The trial is then externally rotated until a perfect correspondence of its anteromedial border with the anteromedial tibial cor-

tex. The tray is definitively fixed on the medial side (Figure 1.21). Both techniques (ROM or PLCL) showed comparable results in literature, however the PLCL method seems to be easier and more reproducible and moreover this technique is not affected by suboptimal femoral component rotation or poor soft tissue balancing. When tibial tray is placed a central drill and then a broach are used to prepare the proximal tibia for the tibial stem.

Once all the trial components are placed and the trial implant have a satisfying stability, ROM and patellar tracking, the prosthetic components are ready to be positioned.

If a cemented implant is chosen the tourniquet is inflated and trial components are removed, abundant irrigation is performed and the bony surface is carefully dried.

Cement can be applied as same on cut bone, on prosthesis components or on both of them. You should avoid applying the cement on posterior condyles. A full or hybrid cementing technique can be used. With the knee in full flexion, you should position the tibial component first, then impact the component on the bone and remove the excess cement. If you observe a sclerotic tibial plateau zone, you can drill some hole with a 3 mm drill bit to create a cement digitation. The second step is cementation of femoral component taking care to center correctly the intercondylar box. Now you should position a plastic insert and put the knee in full extension and minimal valgus stress to pressurize the cement. You can now cement the patellar component always keeping the knee in full extension. When the cement hardened the last check of ROM and stability is performed and the definitive plastic insert is positioned; copiously irrigation of the knee is performed and the wound is then closed with one drain, doing a very careful subcutaneous closure. We do then a Jones bandage in mild flexion (70° of flexion) to increase intra-articular pressure and reduce bleeding during the first three hours postoperatively.

**POSTOPERATIVE PROTOCOL**

We remove the drain in first postoperative day and then we encourage the patient to keep active and passive motion of the knee, with the help of continuous passive motion machine. Day by day we increase the ROM focusing on conserving a full extension. From first to second day postoperatively (dependant on patient conditions) we start a physiotherapy in step program with full weight...
bearing. The discharge to a rehabilitation structure takes place on fifth to seventh postoperative day.

REFERENCES