4 Primary Principles in Soft Tissue Balancing

Jacobus H. Müller and Willem van der Merwe

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Soft tissue balance and alignment are integral to the success of a total knee arthroplasty (TKA). In 1985 it was already reported that most failures can be attributed to incorrect ligament balance or incorrect alignment [1]. Since 1985, numerous new and improved total knee replacement systems, surgical instruments, surgical methods, and computer-assisted surgery tools have seen the light. Ligament balancing and alignment however still remain the biggest considerations that impact the successful outcome of a total knee arthroplasty.

Once the anterior cruciate ligament (and posterior cruciate ligament in non-cruciate retaining TKA) is resected, knee stability relies on the interaction between the remaining ligamentous structures and articular surface geometries [2]. Patient satisfaction and clinical outcome scores are superior in balanced knees [3–5], whereas the restoration of joint space is also conducive to proprioception and balance [6]. Imbalance in TKA is linked to increased component wear, instability, decreased active range of motion, and increased risks of joint pain [3–5]. Up to 40% of early revisions are avoidable if optimal balance was achieved during the primary surgery [4]. It is thus important to appreciate what is meant by a soft tissue balanced joint.

J.H. Müller
Biomedical Engineering Research Group, Department of Mechanical and Mechatronic Engineering, Stellenbosch University, Stellenbosch, South Africa
e-mail: cobusmul@sun.ac.za

W. van der Merwe (✉)
Sports Science Institute of South Africa Orthopaedic Clinic, Cape Town, South Africa
e-mail: willem@ssoc.co.za

S. Matsuda et al. (eds.), *Soft Tissue Balancing in Total Knee Arthroplasty*,
DOI 10.1007/978-3-662-54082-4_4

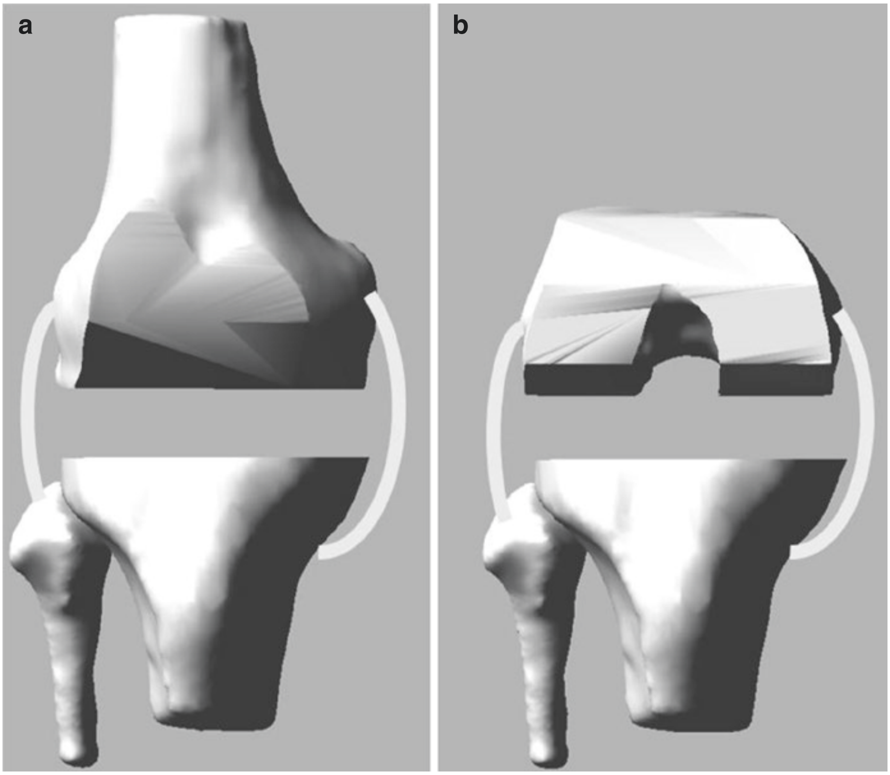

Fig. 4.1 Rectangular (**a**) extension gap and (**b**) flexion gap

A soft tissue balanced joint has been defined to have equal and rectangular gaps between the resected bone surfaces in extension and flexion to induce equal tension in the medial and lateral soft tissues [3] (Fig. 4.1). This is achieved through either or a combination of soft tissue release, modification to bone cuts, component size variation, and component rotation to ensure central tracking of the femoral component. This definition however only provides arbitrary criteria of what constitutes a balanced condition [5]. A better understanding may be established from the characteristics of a balanced knee [7]:

- A balanced knee will have a full range of movement.
- The flexion medial-lateral balance will be symmetrical to result in a rectangular tibiofemoral gap.
- The flexion-extension gap will be balanced with minimal to no medial-lateral tightness or laxity.
- The patella will track normal during the full range of motion due appropriate femoral rotation.
- Femoral roll back in deep flexion will be nonexcessive.
- There is proper rotational balance between the tibial and femoral components.

The resections of the tibia and femur during knee arthroplasty must result in rectangular flexion and extension gaps (equal medial and lateral soft tissue tensions) without changing the anatomical joint line [8].

Traditionally, resection of the femur and tibia can be done through three approaches, namely, the measured resection technique, the gap balancing technique, or a combination of the two techniques. The major difference between measured resection and gap balancing is the way in which femoral rotation is determined. During the measured resection technique, bony landmarks (Whiteside line, surgical epicondylar axis, posterior condylar axis, and the anterior-posterior axis) are used to set femoral component rotation, whereas the gap balancing technique relies on symmetrical tensioning of the medial and lateral soft tissues in flexion to set femoral rotation. The former technique may result in a wide range of soft tissue balance due to the difficulty of reproducibly identifying the bony landmarks intraoperatively [9]. This can lead to flexion gap asymmetry and condylar lift-off. To remedy the situation, the correct course of action depends on whether joint stiffness increase or decrease during flexion and the degree of asymmetry in the medial-lateral soft tissues and its variability with flexion [3]. Although the gap balancing technique provides better chances of achieving proper ligament balance in full extension and 90° flexion, midflexion stability is not guaranteed. This can be attributed to the risk of getting an incorrect tibial cut which serves as the platform from which the flexion gap is established [9]. Secondary to that is the uncertainty in the application and magnitude of the correct distraction force [9]. Since soft tissue balance can be manipulated by varying the medial-lateral extension and flexion gaps, incorrect resection may result in instability due to ligament imbalance.

Varus or valgus instability refers to a trapezoidal extension gap due to asymmetric contracture or laxity in the collateral ligaments (Fig. 4.2). This type of laxity can be either symmetric or asymmetric [8]. Symmetric instability may result due to excessive cartilage loss on the affected condyle. Alternatively, the patient might have had a varus or valgus alignment before the pathology set in. For these cases, a rectangular extension gap may then result in a pronounced varus or valgus alignment even though the ligaments might be balanced. On the other hand, asymmetric instability refers to contracture or excessive laxity of one of the collateral ligaments. Traditionally, surgeons employing gap balancing have relied on spacer blocks and distractors to achieve proper soft tissue balance [3]. Since these techniques rely solely on tactile feedback and subjective assessment [4, 10], success is strongly related to the skill level and experience of the surgeon. An attempt to circumvent this has seen the introduction of instrumented tibial trials and distractors with which the medial-lateral load components can be objectively measured [3]. Unfortunately, these new developments still shed little light on what the surgical steps should be to achieve a balanced condition [3].

Although there are no clear guidelines, e.g., it is still unclear what level of extension gap tightness is appropriate to avoid postoperative flexion contracture [2], some values have been found to produce good outcomes. The amount of laxity should be governed by the patient’s perception of stability. A medial extension gap of 1–3 mm has been found to result in a stable feeling as well as not causing flexion contracture,

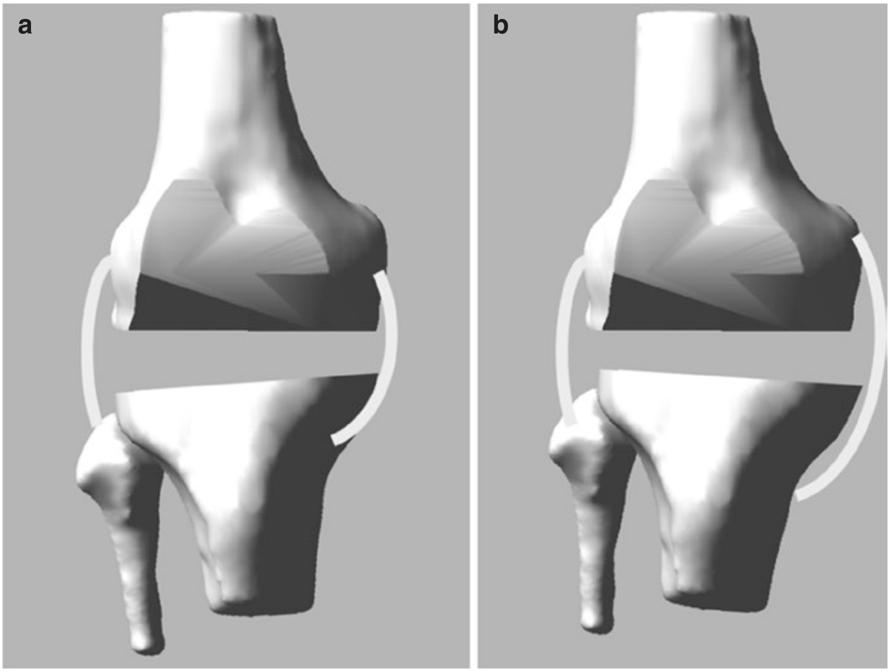

Fig. 4.2 Varus and valgus deformities after resection. (**a**) Varus deformity and (**b**) valgus deformity

whereas the lateral side should be 2.5° laxer than the medial side [2]. The medial flexion gap should be similar or close to the extension gap. This will achieve near-normal articulation, function, and patient satisfaction [2]. Unfortunately, there are no clear evidence on what constitutes a safe range for the lateral flexion gap other than some degree of laxity being acceptable [2]. Instrumented distractors and tibial trials have necessitated the need to quantify the flexion and extension gap balance in terms of force values.

Ideal force target values have not as of yet been validated; a medial-lateral ratio ranging between 0.5 and 0.55 is suggested [3, 4]. A case series ($n = 189$) has shown that a medial-lateral force differential less than 60 lb will result in good outcomes [4], whereas a more conservative ratio of less than 15 lb has also been ascribed [11]. It is however difficult to maintain this ratio throughout flexion [3] and furthermore unclear whether it is important to maintain the same ratio throughout flexion [10]. A recent case series ($n = 12$) measured the differential at 10°, 45°, and 90° [5]. The differentials (medial load min lateral load) were, respectively, 5.6, 9.8, and 4.3 lb. Laxities in the native knee are not uniform, and there is a need for more in depth analysis to determine appropriate target values [12]. Fortunately, there are qualitative measures and guidelines to address varus deformities, valgus deformities, flexion contracture, and genu recurvatum through soft tissue balancing.

A varus-deformed knee requires release of the deep medial collateral ligament and removal of osteophytes [8]. Persistent contracture may require release of the distal superficial medial collateral ligament in combination with the posterior-medial capsule and semimembranosus insertion [8]. Sacrifice of the posterior cruciate ligament will significantly increase the flexion gap on the medial side with little influence on the extension gap [13]. In cases with persistent deformity, it may be necessary to advance the lateral collateral ligament. It has been shown that lateral soft tissue laxity increased with increasing severity of knee deformities, while the medial side did not contract with increasing varus deformity [2]. This result suggests that release on the medial side may be unnecessary to make a space for implant replacement, even in severely deformed knees. Contrary to this, release of different parts of the medial collateral ligament will increase laxity at discrete ranges of flexion [14].

Valgus deformity is associated with tight lateral stabilizers and abnormal femoral lateral condylar anatomy. There is no consensus on what approach should be followed to address this type of deformity [8]. In general, the sequence of release starts off with the lateral collateral ligament followed by the posterior-lateral capsule, iliotibial band, posterior cruciate ligament, popliteus tendon, and biceps femoris. It should be noted that in one study ($n = 37$), valgus deformity was addressed solely through over resection of the distal femur and a constrained total knee arthroplasty system with no reported cases of loosening or instability at a 7.8-year follow-up [15]. This approach has merit, since it has been shown that lateral tissue release to address valgus deformities frequently produces asymmetric flexion-extension gaps and ligament instability [16]. The lateral flexion gap is affected most by the lateral collateral ligament, whereas the iliotibial band influences the extension gap size the most [16]. In the same study, a release sequence starting with the posterior cruciate ligament, posterior-lateral capsule, iliotibial band, popliteus tendon, and lateral collateral ligament resulted in a symmetric flexion-extension gap. The best approach however is to examine the flexion and extension gap after each step in a release sequence regardless of what sequence is used [8].

Flexion contracture arises due to the soft tissue contracture of the posterior capsule [8] (Fig. 4.3). The approach to address contracture typically entails release of the posterior capsule from the distal femur and then the proximal tibia after bone resection and removal of osteophytes. Genu recurvatum (Fig. 4.3) is generally a symptom of weak quadriceps structures since these patients rely on recurvatum during gait to compensate for their weaker quadriceps muscles [8]. This can be dealt with during surgery by reducing the extension gap. Care should be exercised when correcting recurvatum in patients with weak quadriceps muscles, since complete correction may result in their inability to lock their knees.

Perfect soft tissue balance during surgery remains elusive even with careful application of the surgical methods described above and in the remainder of this book. Reasons can be attributed to slight inequalities in the normal knee [17]. Stress relaxation occurs during surgery, which directly influences soft tissue balancing. Medial-lateral laxity has been shown to increase by 1 mm, whereas passive maximum extension can increase up to three degrees intrasurgery [18]. The lateral gap tends to be larger than the medial gap, whereas the extension gap is normally larger than the flexion gap [17]. On the upside, a larger extension gap aids in the prevention of flexion contracture and flexion instability. It may therefore be beneficial to

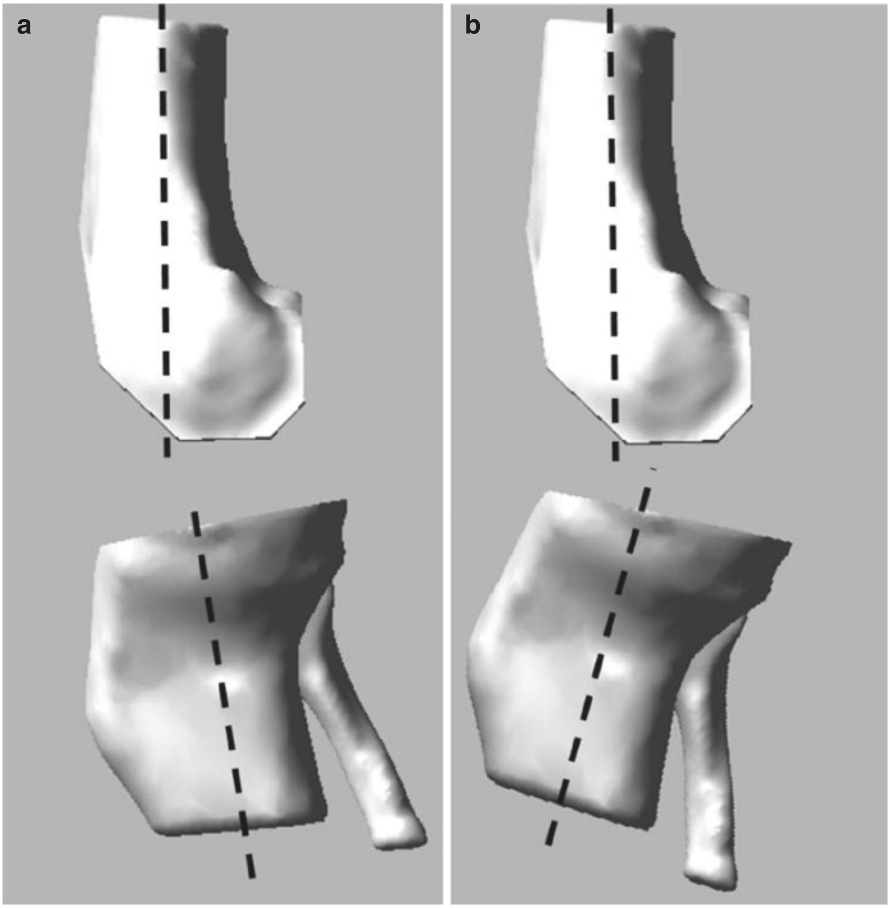

Fig. 4.3 (**a**) Flexion contracture and (**b**) genu recurvatum

have the extension gap somewhat larger than the flexion gap if it is not possible to achieve equal gap distances [17]. One remaining consideration is the impact of soft tissue balancing on proprioception. Proprioception significantly improves in knees that are balanced in both flexion and extension [19].

Insall et al. [1] in 1985 stated that "new methods will have to prove themselves against the standard already established for cemented prostheses." The same can be said of the ligament balancing technique. Reported results on the use of kinematic alignment are still inconclusive on whether it is truly better in comparison to the more traditional soft tissue balancing techniques. Although kinematic aligned knees tend to produce good functional outcomes (2-year follow-up, [20]), it remains to be seen whether this holds for longer periods. Of concern is the resistance to wear by the tibial insert which now also sees an increased shear load due to the oblique anatomic joint line. On the other hand, "a fresh look at soft tissue balancing is required" [21]. Too many times patients are still dissatisfied with the outcome after total knee arthroplasty. Soft tissue balancing techniques only require consideration of the flexion and extension gap, with little attention or tools available to objectively assess midflexion stability. Further work is therefore necessary to incorporate findings from studies such as [12] that compared laxities between full extension, 45° flexion, and 90° flexion into the surgical methods to establish proper ligament laxity throughout the entire range of knee flexion.

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