Functional Brace Principles!

Functional braces are not magic! They have their strengths and capabilities as well as their limitations. In order to understand what functional braces can and cannot do on the leg, it is first necessary to understand the working principles of functional braces. The two factors that enhance control of any external device are leverage and surface contact area. The factor that provides the greatest limit to control is soft tissue deflection. The stretching and movement of skin and muscle around the knee joint produces large tissue translations that bracing must accommodate. The thickening and thinning of muscle groups during flexion and extension causes the position of the bones inside the muscle mass to vary. Finally, the shape of the leg changes considerably as these motions take place. Braces must be able to accommodate these changes to remain comfortable as well as supportive.

The hinge system utilized on functional braces is important. The large range of knee motion which a functional brace must withstand (0-140 degrees) requires a hinge that tracks closely with knee motion. This means using a polycentric or eccentric cam type hinge. The hinge must be capable of proper placement on the leg based on the design of the hinge arms, shells, and straps. Just as important, is the ability to maintain the hinge in the proper place during activity through an appropriate suspension mechanism. Since functional braces tend to be shorter than their postoperative counterparts, the only place to provide adequate suspension is the slightly smaller circumference of the proximal calf muscles. The hinge should be placed in a slightly superior and posterior position during application. This allows for the effect of gravity forcing the brace lower, the forced migration produced by the cone shape of the leg, and the forced migration produced by the translating skin and muscles of the distal posterior thigh. To optimize suspension, the proximal posterior calf strap should be slightly lower than the anterior strap, and must be free pivoting to provide a locking motion on the calf muscles as the brace is forced distally. The best brace design in the world is of little use if the brace will not remain in place.

Each end (thigh and calf) of every hinged brace is a three-point lever system. These two levers share a common third point at the hinge that does not contact the leg. The remaining points on the arms of the brace where the brace straps attach to the leg form a four-point force system. Every brace ever made with a hinge is a four point brace. Maximizing length or leverage is important to brace control. The market continues to ask for shorter braces. In fact, braces need to be longer to gain better control. This is particularly true on those portions of the lever arms or shells that compress into a lot of soft tissue. Surface contact area must be maximized on these portions of the leg to increase control. The point on the leg where the least compression occurs, is the anterior tibia. There is very little soft tissue to deflect. Therefore, the overwhelming majority of brace manufacturers have chosen to use a pre-tibial shell as a center fixation point.

As long as the anterior tibial shell of a brace is held firmly in contact with the front of the tibia, it will move as the tibia moves. For instance, if the tibia subluxes anteriorly (as with a missing ACL), it will carry the tibial shell of the brace with it. This leaves only the posterior distal thigh strap and the proximal anterior shell of the brace to indent into the skin, fat, and muscles in an attempt to limit the subluxation motion. Most tibial subluxation occurs as the leg is rapidly extended in preparation for foot strike in maneuvers such as stopping, running downhill, landing from a jump, or moving laterally. These are open kinetic chain maneuvers that involve quadriceps contraction before foot strike. Due to the slow reflex arc of the hamstring muscles after loss of the mechanoreceptors that were present in the original ACL, the hamstring muscles are slow to react. This permits the posterior distal thigh strap of the brace to compress easily into the flaccid hamstring muscles resulting in very little resistance to anterior subluxation. This previous example demonstrates why most braces offer little resistance to anterior tibial movement.

Simply tightening the straps of a brace does not eliminate soft tissue compression, translation, and rotation. Strap tension is limited by patient comfort and blood circulation. Obviously, those patients with more soft tissue will experience less control from any external device. It is easy to brace the patient that is 6 ft. tall and weighs 95 pounds. It is almost impossible to brace the patient that is 5 ft. tall at 250 pounds. It is difficult to control the position of the bones and joints through the Jello-like soft tissues of the leg. This places an upper limit on the required strength and stiffness of a functional brace. Once this limit is reached no additional control is gained by making the brace stronger or stiffer. Even a one inch thick solid stainless steel cylinder cast would be limited by these same soft tissue limits.

Functional braces are divided into three categories: Passive Braces, Static Counter Force Braces, and Dynamic Braces. These categories are defined based upon how the brace provides resistance to abnormal movement, and whether force pre-loaded against a pathological movement is static (i.e. fixed strap force) or dynamic (muscle powered to work against a pathological movement). The particular design of the brace forces it into one category or another.

Passive braces are those which are not capable of being adjusted to provide a counter shear force against a specific pathological movement (e.g. anterior tibial subluxation). They can be recognized by their design. They usually have bars or shells anteriorly on the leg with straps opposing the shells to attach the brace to the leg. This strap opposing shell configuration prevents them from being adjusted to push the femur forward and the tibia back or vice versa. Tension in the straps only creates circumferential pressure without causing shear force. Therefore, they simply sit on the leg and act as a buttress that the leg can run into when abnormal motions occur. Soft tissue greatly limits their effectiveness. They provide sufficient resistance to movement for most medial or lateral collateral ligament injuries but are mechanically ineffective at preventing anterior or posterior tibial subluxation. Their primary role on the leg is therefore proprioceptive.

Static counter force braces have been designed to permit pre-compressing the soft tissue on only the anterior or posterior half of the leg with static strap tension. Since the distal posterior thigh strap is unopposed by a shell, it is possible to provide more pressure in an anterior direction than is achievable with a passive brace. Static counter force braces usually provide enough tissue pre-load in one direction to provide increased resistance against tibial subluxation for the reconstructed ACL or for ACL deficient patients with mild instability, and they function the same as passive braces against medial or lateral bending of the knee. While the amount of tibial subluxation permitted by a static counter force brace is usually less than passive braces, the tension of the straps and pre-compression of the soft tissue is again limited by blood circulation and patient comfort. Pre-bending a brace in a varus or valgus direction to a greater extent than the normal varus or valgus bend angle of the leg causes it to be a type of static counter force brace. In this case the static counter force is in a medial or lateral direction. These braces are sometimes used for uni-compartmental osteoarthritis, high tibial osteotomies, or collateral ligament conservative treatment.

Dynamic braces are an entirely new category of bracing pioneered by Bledsoe Brace Systems. These braces use muscle powered leg movement to translate a hinge lever, shell, or strap that works against a particular pathological movement or condition. First, It is necessary to understand the pathology that exists in the knee (e.g. tibial subluxation, medial or lateral joint space opening from thrusting osteoarthritis, or varus deformity), and then to design a brace which works against pathological movement at a certain point within the range of motion. Dynamic braces use the power of the muscles to pre-compress the soft tissue in order to achieve high forces that are necessary to control specific pathological conditions. The tension can sometimes be adjusted to produce forces high enough to briefly limit circulation. However, as soon as the leg is moved out of this high force position the forces are reduced and circulation is restored. These braces are patient adjustable to permit just the right amount force to eliminate sensations of instability, pain, and certain symptoms. The patient can optimize the force to create a balance between reduction of symptoms and comfort.

In addition to the mechanical support provided by a brace, there is also a much larger benefit from increases in proprioception and joint position sense. In fact, for some passive or static counter force braces the proprioceptive effect may be the overwhelming benefit. All functional braces to some extent act as external bio-feedback devices to provide information that helps the patient overcome confusion in his force and muscle pattern systems. The proper combination of stiffness and flexibility as well as the appropriate points of contact from the condyle pads and straps optimize this effect. Dynamic braces produce a variable force as the leg is extended and flexed which provides greatly increased information on the position of the knee compared to passive or static counter force braces. Furthermore, it is virtually impossible to mechanically limit certain types of pathological movements due to soft tissue deflection unless special mechanisms (such as a dynamic brace or a smart brace using a muscle stimulator) are utilized to pre-compress the soft tissue.

An important contribution of a brace is the ability to recognize when a force is placed on the body earlier than can be recognized through the mechanoreceptors in the connective tissue. It requires a certain amount of time to perceive excessive strain in the connective tissues, because the body must differentiate between normal strain and the excessive strain created by a specific maneuver. However, as abnormal motions occur, the body runs into the brace causing an increase in force that is obviously different from the normal feel of the brace. This creates an early perception of the force, and opens the front-end of the perception window. It also requires a certain amount of time for the muscles to react and the peak torque of the muscle to be achieved. If the force rises too rapidly for the muscles to counteract, the result can be failure of some connective tissue structure. Braces tend to slow the rate of loading. In other words, the brace stiffness (up to a limit) slows down the rate at which the movement occurs. This gives more time for the muscles to react opening the back end of the perception window. The result is an increased ability to perceive and react to certain forces when wearing a brace. The majority of patients (92 %) exhibit increased confidence, decreased pain and swelling, more rapid return to sports play, decreased incidence of giving way, and decreased sensations of instability when wearing functional braces. If we realize that the mechanical effectiveness of the brace to prevent injury is sometimes questionable, then we must also realize that some other effect is creating these patient benefits.

Most patients do not absolutely require braces any more than they absolutely require ACL reconstructions. Many patients can modify their activity and get along just fine without the reconstruction. However, highly athletic individuals can perform better at a higher activity level for a longer period of their life with the reconstruction than without. The same is true for braces. The patients are more comfortable, more certain about their movements, and both physically and psychologically more protected when wearing a brace than without. The increased perception window alone makes it worthwhile for many patients to wear a brace. Furthermore, for 33% of the patients, a brace may be necessary to help compensate for a lack of kinesthetic awareness and compensatory capability that results in quadriceps inhibition and continued atrophy.

Following ACL reconstruction, a reasonable percentage of patients never recover their quadriceps strength or overcome quadriceps inhibition. The reconstructed ACL is at increased risk of failure or stretching due to lack of a primary reflex arc in the hamstring muscles. The graft has no mechanoreceptors to trigger the hamstring reflex. Until ligament maturation is almost complete the muscle and force patterns cannot be rebuilt in a stable fashion. The muscle and force patterns must be built on a stable platform not a moving target.

Physicians can permit patients to return early to sports play without a brace, but they can not change the fact that the patient has an increased risk of failure or stretching with no sensory input from the reconstructed ACL. In fact, some patients may never compensate for the lack of neuro-sensory input from the original ACL. These patients are forever at risk unless the hamstrings muscles are re-trained to remove the strain from the ACL graft as the leg is rapidly extended during open kinetic chain maneuvers such as landing from a jump, running downhill, stopping, or lateral moves.

There is a great deal more to understanding functional braces than simply selecting the lightest and prettiest from a brace tree. It depends a great deal on the patient's proprioception, muscle tone, athletic ability, and the amount of soft tissue present. It also depends on the correct design and proper placement of the brace, as well as the ability to change shape slightly with the changing leg shape. Proper placement of straps, adequate leverage, sufficient surface contact area, and the ability to remain in the proper place are very important factors in proper brace function. Lightweight and comfort are also key ingredients in the patient's acceptance of the brace. The true challenge is not whether to brace or not, but in learning which patients can gain the greatest benefit from the proper type of functional brace.

There is a difference!

The difference is in the details!