DYNAMIC BRACING AND IT'S EFFECT ON THE KNEE

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Dynamic bracing is the use of muscle power to cause a brace to work against the pathological movement of a joint. In the case of the knee, different pathological movements are possible depending on which stabilizing structures are injured. It is necessary to determine which structures are damaged, then to discover at what point in the range of motion these abnormal movements occur. This information permits designing an orthosis that uses leg extension or flexion to precompress soft tissues with increasing force to prevent pathological motion as the leg approaches the range where instability occurs. Good examples of pathological conditions which can be addressed with this type of brace are found in ACL deficient knees and knees with medial or lateral gonarthrosis.

The anterior cruciate ligament (ACL) is the most often injured ligament in the knee. The ACL can be torn in young athletes at a force of 33N per Kg of body mass, or 3.3 times body weight.[1] Even at such high force levels, 80% of the knees are injured with no external contact.[2]

In the absence of the ACL, the quadriceps muscles can sublux the tibia in the final range of extension.[3-7] The quadriceps muscle may also be inhibited by this subluxation.[8,9] This inhibition coupled with the immobilization that occurs after injury is believed to cause quadriceps atrophy.[7,10,11] To further complicate matters, the hamstrings reaction time may be greatly slowed, and increased co-contraction is typically present.[8] Symptomatic patients have been observed with changes in force and muscle pattern activation in activities as simple as level walking.[12] The rehabilitation of these injuries is time consuming for the average long periods of physical therapy with hamstrings training and a great deal of work to overcome quadriceps atrophy.[13-17]

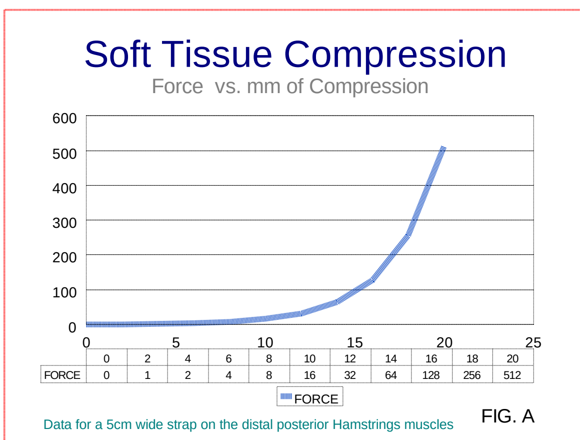
Most ACL deficient patients that are symptomatic have great difficulty in performing maneuvers such as stopping, landing from a jump, running downhill, or making rapid lateral maneuvers. In each of these maneuvers, rapid open kinetic chain extension of the leg, coupled with a greater degree of extension, occurs a brief instant before foot strike thus permitting free subluxation and subsequent sensations of instability or even Agiving way@ of the knee.[9]

The knee is not just a mechanical structure. It is also a neurological structure that is filled with four types of mechano-receptor nerves.[18-21] Each type of nerve functions at a different force threshold, and the various force and movement conditions are compiled to form a kinesthetic awareness that we call proprioception.[22-30] Slower movements permit direct feedback of information to control muscle function, joint position, and stability, while more rapid movements that are too fast to permit direct control cause changes in muscle and force patterns.[31]

ACL deficient knees have been shown to have reduced proprioception compared to normal knees.[32] The loss of proprioception is believed to be caused by the loss of the mechanoreceptors in the missing ACL.[33,34]
A part of proprioception that seems to be particularly affected is joint position sense.[25] Newberg found a significant difference in joint position sense between the operative and opposite knee up to 15 months post-op, while Barrack et al found it to be normal after 31

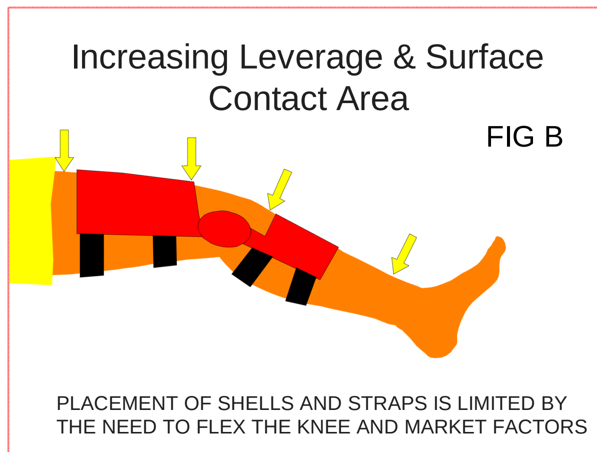
months.[32,35] This may explain why reconstructed knees may not Afeel@ normal to the patient for up to two years. Other researchers have found that muscle training, bracing, and the application of elastic bandages improves joint position sense.[36-38]

Functional bracing is intended to reduce or eliminate the instability of the knee following ligamentous injury.[39,40] It is currently indicated for frequent episodes of Agiving way@, poor quadriceps and hamstrings strength, high ligamentous laxity, and the desire to return to competitive sports.[39] Patients who wore functional braces reported fewer episodes of giving way, decreased pain and swelling, increased confidence, and an increased ability to return to their former level of activity.[41-45] The stability and comfort of functional braces depends on many factors including the design and proper placement of

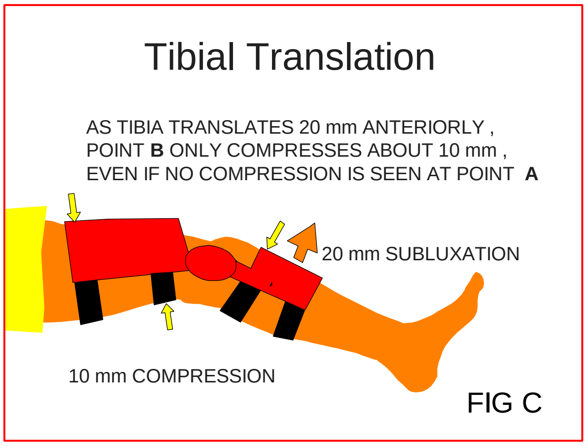


the brace.[46] To better understand brace design, it is first necessary to understand the factors that limit and enhance control of the leg.

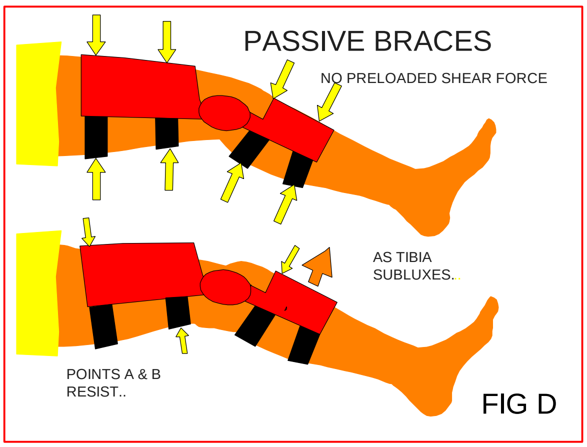
The greatest factor that limits control of abnormal movements by any external support device, including braces, is soft tissue movement and compression. Figure A shows a typical soft tissue compression curve of a 5cm wide strap on the posterior hamstrings. Using traditional orthotic principles, optimization of control involves increasing brace length to increase leverage, and increasing surface contact area of the straps and shells to reduce tissue compression for a given force level (Fig B). There is an upper limit to this approach in terms of the



permissible placement of straps and shells to achieve movement of the leg. Figure C shows that it is possible to achieve 20 mm of tibial subluxation with only 10 mm of hamstrings compression using typical design limitations. It is very easy to achieve this amount of compression during leg extension because the hamstrings are acting only as antagonists. This explains why traditional orthoses have

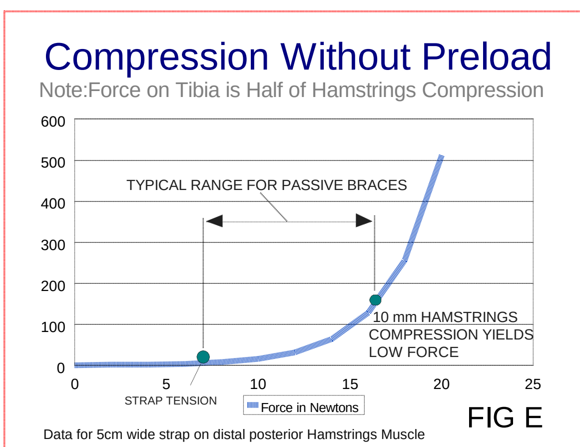


difficulty in limiting tibial movement at

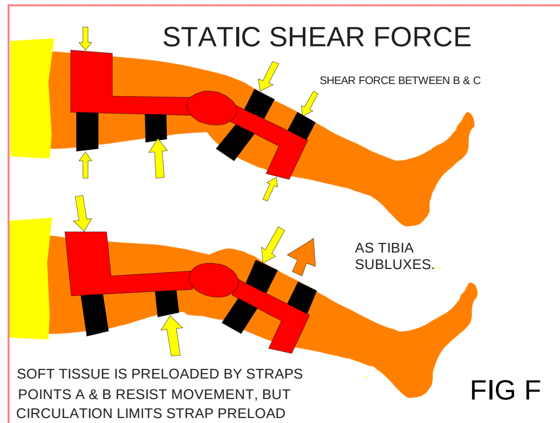


forces experienced during sports play.

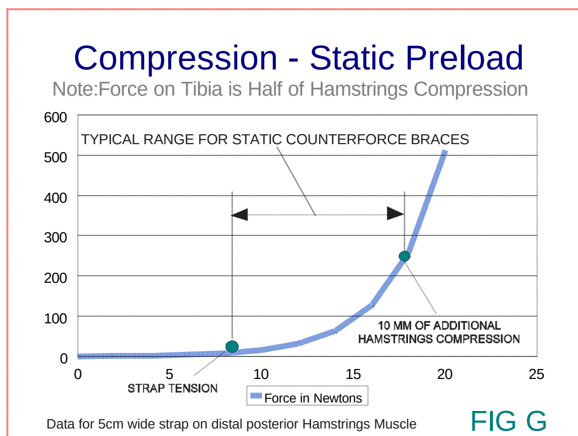
Braces with no net shear force can be termed passive braces (Fig D). Large subluxations



are possible before soft tissue is compressed enough to provide high resistance (Fig E).
It is possible in some brace designs to adjust strap tension to precompress soft tissue by placing a preloaded shear force against the knee. These braces can be termed static



counter force braces (Fig F). Although some increase in control force is possible, circulation places a limit on the amount of



preload possible in a static tensioned strap (Fig G).

Dynamic bracing uses the act of leg extension to place an increasing shear force across the knee as the leg is extended (Fig H). This effectively precompresses the soft tissues to

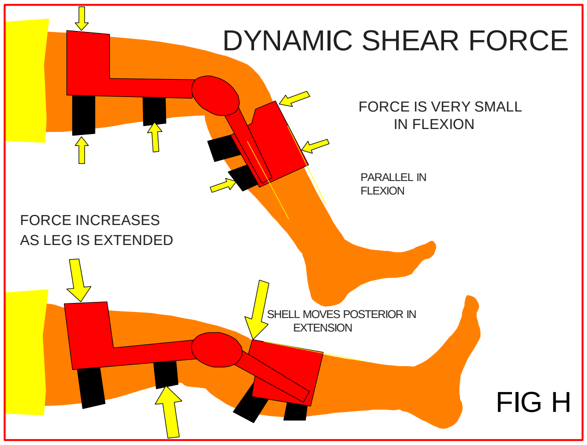


FIG H

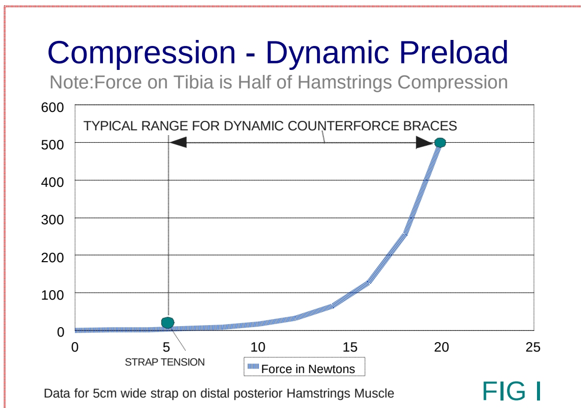


FIG I

very high levels dependent on design and patient tolerance (Fig I). The force is reduced as the leg is flexed so that circulation is not inhibited during sports play. This movement against the knee is readily apparent when the brace is seen in motion. Many braces may lack mechanical effectiveness but enhance the ability to sense abnormal movements in a symptomatic knee.

Dynamic braces provide varying compressive forces against the leg that the patient can correlate with angle to enhance joint position sense and restore quadriceps function in symptomatic knees. In two recent studies, Acierno et al [46,47], demonstrated the effect of dynamic braces on normal and ACL deficient knees using EMG during maximal effort isokinetic extension. It was shown that asymptomatic knees apparently compensate for the absence of the ACL and do not therefore exhibit quadriceps inhibition. The study also shows the effectiveness of a dynamic brace in stabilizing the tibia against subluxation thus reducing the hamstring's contraction, and permitting an increase in

EMG of Dynamic ACL Brace

The symptomatic subjects' mean EMG increased as much as 40% from 45-15 degrees of flexion during maximal effort isokinetic extension.

- Acierno S. et al - Orthopedics - Nov. 1995

Dynamic Bracing

...allowed an increase in Quadriceps activity in those subjects who frequently exhibited symptoms of ACL-deficiency. This increase was accompanied by a decrease in Hamstrings antagonist activity. The resulting knee extension force was higher with brace use.

- Acierno et al - Orthopedics - Nov. 1995

extension torque in symptomatic knees.[47]

Dynamic bracing is not just limited to the ACL deficient knee. It can be used on the reconstructed ACL to reduce stress on the reconstruction and permit earlier mobilization and quadriceps exercise[46]. The same principles can be used to reduce posterior subluxation for posterior cruciate problems by placing an anterior load on the tibia during knee flexion.

It is possible to use the principles of dynamic bracing to place varus or valgus loads on the knee for problems such as medial and lateral collateral ligaments, tibial plateau fractures, and osteoarthritis. In gonarthrosis it is particularly effective. When a dynamic brace is seen extending on the leg, it is easy to see the brace placing a large valgus load on a knee with medial gonarthrosis. As the leg is extended, the brace uses muscle power to

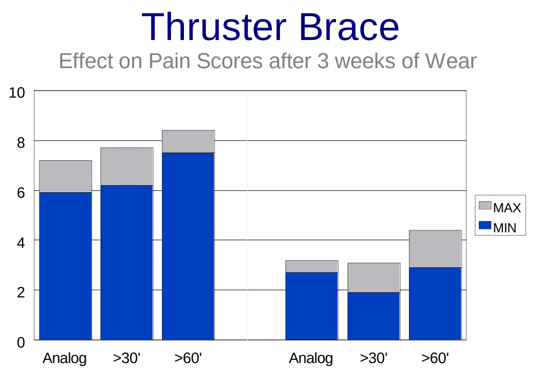


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FIG J

dynamically close the lateral compartment and open the medial compartment of a varus knee with osteoarthritis to control pain.

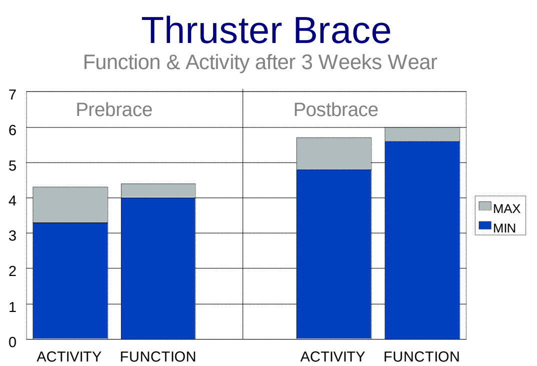

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FIG K

In a recent preliminary study by Noyes et al[49], patients that used the Bledsoe Thruster MA Brace for only 3 weeks were able to increase their walking time by a factor of five. They increased their function grade and activity level by 20%- 25%. At the same time, their average pain level during this increased activity and increased walking time was reduced from an

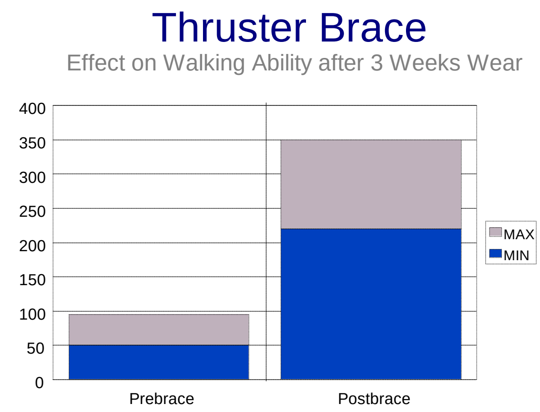

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FIG L

average analog score of 7 to less than 3 (Fig J, K, L).[49] Most of the patients were able to completely eliminate the need for pain and anti-inflammatory medications. The brace is very helpful in delaying the need for high tibial osteotomy or total knee replacement. The brace can also be used to test the effectiveness of an HTO, or to help hold the HTO closed after surgery thus permitting earlier motion and ambulation.

Summary

Dynamic bracing is capable of overcoming many of the obstacles that limit traditional passive orthoses, but it is not a cure-all. It is an interesting new tool that can be optimized to provide higher forces to control certain pathological conditions that are not possible to control with conventional designs. It expands the control that a brace can provide. There are many interesting possibilities as we search for ways to use these new principles for other joints and other pathological conditions.

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