

## RATIONALE FOR ORTHOTIC THERAPY IN POSTURAL RESTORATION

The ideal foot and lower extremity would have the following characteristics to function in a world made up of mostly flat surfaces:

PAIRED structures that are equal in size and shape  
VERTICAL structures that are maximally vertical  
MOTIONS that are neither limited nor excessive.

STRAIGHT structures that are maximally straight  
HORIZONTAL structures that are maximally horizontal  
FORWARD FACING structures that are maximally forward facing.

Unfortunately, no human foot meets these criteria, and in fact, the foot developed for bipedal gait on uneven surfaces. Fortunately, appropriately-made orthotics adapt the foot that is better suited to uneven surfaces to function on hard flat surfaces. To complicate the process, the structure and characteristics of each foot is as individual as fingerprints. In order to make useful orthotics, it becomes necessary to customize each orthotic to each unique foot and then match the orthotic to the shoe and the horizontal surface.

An orthotic that will help in postural restoration should try to stop the abnormal pronation before it starts -- early in the weight bearing phase of the gait cycle. It makes no sense to allow the foot to pronate excessively, causing subluxation of the joints of the foot, and then try to improve the biomechanical efficiency of these subluxed joints by putting wedges underneath the pronated foot. Continual subluxation and dislocation of the joints will lead to degenerative changes of the joints causing arthritis. The joints should be aligned in the mid range of motion allowing pronation and supination to take place without subluxation. Neutral position should be defined as that position in which the joints are in their mid range of motion with maximum cartilage to cartilage contact.

Most biomechanical experts are in agreement that stability of the foot is created by compression across the joints, and instability of the joints is created by rotational motions around the joints. The appropriate relative position of the bones creates compression across the joints stabilizing the foot. Ground reactive force at heel strike creates rotational motions in the subtalar joint which destabilizes the foot. The ligamentous structures are responsible for preventing dislocation and subluxation of the joints and do not actively create compression across the joints. When the ligaments are too loose, they allow for excessive range of motion and subluxation of the joints of the foot. This leads to excessive pronation and significant compensations throughout the lower extremity. If the ligaments are too tight they will create a different problem with the lack of range of motion of the joints and a lack of natural shock absorption.

The primary purpose of muscles and tendons is to create rotational motions of the joints and not necessarily to provide support. When the subtalar joint is excessively pronated, the muscles and tendons cannot pull appropriately around the subtalar joint which creates instability. In an excessively pronated position, the mechanical advantage of the peroneus longus and brevis tendons will actually cause excessive pronation. When the subtalar joint is realigned with the calcaneus underneath the talus it allows the peroneus longus and brevis muscles along with the posterior tibial muscle and long flexors to the toes to provide compression across the subtalar joint helping to stabilize it. Muscles and tendons do provide stability but only when two antagonistic muscles pull at the same time creating compression across the joint as opposed to rotational motion but only if the joints are in appropriate alignment.

In a foot with normal pronation the midtarsal and Lisfranc joints unlock at heel strike when the subtalar joint pronates, making the foot a flexible shock absorber. During mid-stance, the weight bearing leg and talus, which is locked between the maleoli, is externally rotated by the opposite leg and pelvis swinging forward. This external rotation of the talus on top of the calcaneus resupinates the subtalar joint locking the midtarsal joint and Lisfranc joint without the use of significant muscular activity. Elfman described the parallel position of the axis of motion of the talar navicular and the calcaneal cuboid joints which allows for flexibility at the midtarsal joint while in a pronated position. In a supinated position, the obliquity of the axis of motion of the talar navicular and calcaneal cuboid joints creates stability. In addition, the Lisfranc's joint becomes stable because of the locking of the wedge-shaped cuneiforms and cuboid when the subtalar joint is supinated and flexible when the subtalar joint is pronated-- "The Keystone Effect." (Some biomechanics experts state this as the forefoot is supinated on the pronated rearfoot and vice versa.) For these two stabilizing effects to take place in the foot, it needs to be in a relatively perpendicular position with regard to the direction the individual is moving.

When the foot is allowed to excessively pronate early in the gait cycle, it causes compensatory internal rotation of the lower extremity leaving the axis of motion of the knee off of the frontal plane. Since the knee is basically a hinge joint, it will not work well unless it is realigned approximately on the frontal plane. Motor learning will cause the patient to externally rotate the lower extremity at the femoral acetabular joint to place the axis of motion of the knee back on the frontal plane leaving the foot in an abducted position. In this abducted position of the foot the talus cannot be externally rotated on top of the calcaneus and the subtalar joint cannot be resupinated leaving the joints of the foot subluxed and dislocated. From a postural restoration point of view, when the femoral acetabular joint is in an externally rotated position,

it allows for a forward tilt of the pelvis and increased lordosis of the low back. This also will affect the motor learning process of the rest of the skeletal system.

The central nervous system recruits muscles during the gait cycle in a learned pattern. This pattern is dependent upon the function of the lower extremity, and the relative position of the bony structures. The recruitment of muscles will be different in a foot that is excessively pronated throughout the gait cycle than in a foot that is more appropriately aligned. The axis of motion at the knee, the ankle, and the first MTPJ should be perpendicular to the direction the individual is going -- "The Plane of Progression". This position of the joints should provide for the most energy-efficient mode of forward progression and the most stable alignment of the joints. The PRI orthotic should be designed in such a manner as to realign the axis of motion at the knee, ankle, and first MTPJ perpendicular to the plane of progression while still allowing for normal motion. This position will allow for greater stability of the pelvis and spine.

The PRI orthotic is designed to be made of materials that can be highly conformed to the individual's foot, adapting the curved shape of the foot to the hard flat surfaces. The cast on which the orthotic is made is taken in a neutral position with the joints in their mid range of motion. The joints are not pronated or supinated and the joints are not allowed to sublux during the casting process. The orthotics are made of non-compressible, flexible materials that can move within normal motion of the foot during the gait cycle while still providing support. The orthotic is designed to make the foot, the shoe, and the orthotic all function as one unit adapting the lower extremity to the hard flat surfaces. In addition, construction of the PRI orthotic will include consideration for neuromotor facilitation of the left adductor at early midstance and inhibition of the right adductor by making the patient more comfortable proprioceptively at midstance.

The neutral position for casting is based on our original considerations of what a perfect foot would look like to function in a flat surfaced world. To evaluate this, the patient should lay face down in a prone position with the feet hanging off of the end of the table. The foot will generally fall into a neutral position, with no stress on the ligamentous structures and the muscles and tendons relaxed. Evaluating the foot in this position allows us to see the varus of the rearfoot and forefoot and to evaluate the contour of longitudinal arch. This is the shape of the foot that the practitioner needs to capture in a neutral position cast.

To take a neutral position cast for PRI orthotics, the patient should be in a sitting position with the knee flexed and at 90° and ankle at 90°. The subtalar joint can be palpated to neutral and checked for the varus relationship that was noted when the patient was lying prone. The foot should be placed on the foam and the heel pressed into the foam as far as possible. This will leave the forefoot in a supinated position with relationship to the rearfoot. The forefoot can then be pushed into the foam to the level that will allow the practitioner to capture rearfoot and forefoot varus in the impression material. One small trick that seems to work well is to take the impression in a slightly supinated position, remove the foot and evaluate the impression for accuracy, and then place the foot back in the impression material and slowly pronate the foot to its appropriate position. This technique allows the practitioner to pronate the foot in the impression material to improve the quality of the impression since once too much pronation is placed in the impression material, it cannot be re-supinated.

PRI orthotics are different than most orthotics. There are a number of orthotics built on the theory that the subtalar joint will pronate until the foot is stable against the ground. Once the foot is in a stable position against the ground, wedges are placed under the orthotic to try and provide a biomechanical change to make the foot function more efficiently. This concept is based on rotating the foot around the axis of motion of the subtalar joint by the use of the wedges underneath the medial aspect of the foot. This approach will make the patient more comfortable by changing function, but does nothing to stop the subluxation of the joints in the foot, nor does it provide for realignment of the lower extremity with the foot, the ankle, and the knee going the same direction. The patient with an abducted forefoot gait continues to walk with an out toe gait.

Many types of orthotics will work to some degree because they change function. It does not matter whether we make the individual function better or worse, the problem will probably disappear because we've changed the overall function of the lower extremity. Regardless of what type of orthotic we use, the patient will see improvement. The question becomes whether we are making the patient function better or worse. The goal of the orthotic, of course, is to make the patient function better.

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