

Position Paper

AN INNOVATIVE MECHANICAL APPROACH TO TREATING CHRONIC KNEE PAIN: A BIO-IMPLOSION MODEL

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Abstract. *Chronic knee pain syndrome in excessive pronators is a mechanical phenomenon. However, when it is treated in a nonmechanical way, the results can be baffling and frustrating to both patient and practitioner. The theoretical construct of Bio-Implosion is the basis of an innovative, mechanical treatment model presented in this paper, the efficacy of which has only recently been clinically observed. Current treatment modalities include postural control orthotic therapy, manual medicine, and home stretch programs.*

Descriptors. *bio-implosion, chronic pain, excessive pronation, fibromyalgia, knee pain, postural control orthotics*

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INTRODUCTION

At the Bellevue Foot and Ankle Center (BFAC), patients are seen with a variety of postural complaints. The most common complaints are arthritic in nature involving the knee, hip, mid-back, and neck. Most of these patients have been treated by a number of practitioners. By the time they reach BFAC, their pain has become chronic and, in many cases, unrelenting. Past histories are inconclusive. Rarely are chief complaints related to specific injuries. Typically, their symptoms develop insidiously, progressing from mild in early life to debilitating in later life. And although multiple joint symptoms are common, the patients view these symptoms as separate and unrelated.

So how is the contemporary pain management clinician to help these patients? At times, clinicians tend to focalize on the primary complaint almost to the exclusion of all other subjective symptoms. Podiatrists treat the plethora of foot and ankle complaints with a variety of approaches ranging from orthoses to medication and surgery. Sometimes the patients' foot complaints improve and sometimes they do not. But rarely do podiatrist-clinicians make an impact on resolving symptoms above the ankle of the patient.

The purpose of this paper is to present a new approach in treating chronic joint pain using orthoses—serial posting (vertical lift). In serial posting, gravitational forces through the

foot are methodically and serially altered to reduce excessive subtalar joint pronation patterns. In a closed kinetic chain, wedging the foot towards neutral retroactively fosters joint surface congruity along the entire weight-bearing axis. Stabilizing the foundation of a building, stabilizes the entire superstructure. By maximizing joint surface fit, articular compressive forces are dissipated over a larger surface area. Clinical observations suggest that it is this mechanism that allows articular caps to regenerate resulting in reduced arthritic symptoms. Orthoses used in this manner are termed Postural Control Orthotics (PCOs)¹. Intolerance to PCOs can occur if the incremental changes in posting are too aggressive. It is this same precaution that an orthodontist follows when straightening teeth.

DISCUSSION

Postural control orthotic (PCO) therapy. Orthotics, by definition, refer to any device or plate worn in the shoe and not attached to the foot directly. The most common type of orthotic used by all health and allied health professionals are arch supports, which are mechanically effective from heel contact to mid-stance of stance phase. These orthotics are designed to support the arch primarily and decrease foot-related symptoms. Postural Control Orthotics (PCOs) are mechanically effective from heel contact to toe off. They change body mechanics via the judicious application of vertical lift, referred to as *posting*. To understand the concept of PCOs, however, one must first understand the concept of bio-implosion.

Bio-implosion is defined as a gravity-induced skeletal collapse due to an underlying congenital structural anomaly in the foot. Five elements contribute to this model including

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¹ PCO is a trademark of PCO, Inc of Bellevue, Washington

excessive pronation of the foot and ankle, genu valgum of the knees, anterior asymmetrical rotation of the pelvis (commonly known as pelvic tilt with an articular torsion component), protraction of the shoulder girdle, and forward thrusting of the head. Etiologically, bio-implosion is theorized to originate in the ontogenetic retention (phenotype) of forefoot supinatus, defined as forefoot varum deformity in the fully-formed foot at birth. Interestingly, concurrent retention of forefoot and rearfoot supinatus is defined as a clubfoot deformity. Those children who do not manifest any varum deformities are said to be mechanically efficient and, thus, do not manifest bio-implosion. Mechanical inefficiency may be observed later in a person's life for other reasons (e.g., injury, CNS/PNS lesions, polio), but forefoot varum must be suspected as the primary etiology when all of the elements of bio-implosion are present.

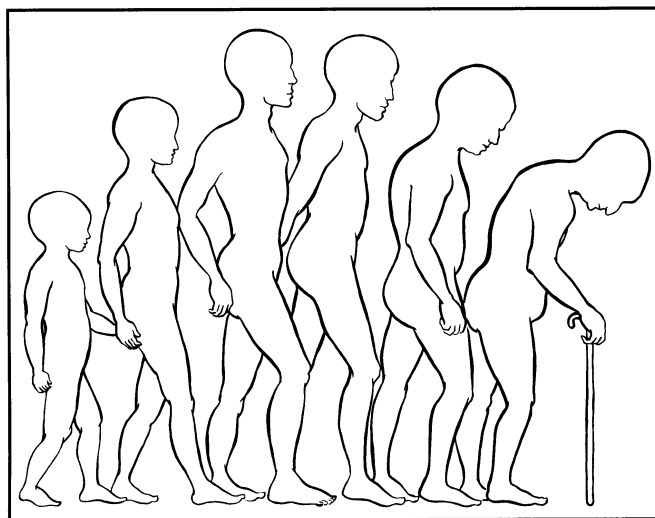


Figure 1. Bio-implosion: Gravity induced skeletal collapse.

To treat forefoot varum deformity effectively, a fundamental bioengineering principle is applied—achieve foundational stability (*i.e.*, full foot-to-ground contact), so that the structure does not collapse. PCO therapy accomplishes this by maximizing foot-to-ground contact.

The mechanics by which PCO therapy works can be understood by evaluating the kinetics of motion in general and of bio-implosion in particular. Because the body is connected from head to toe, what affects one part of the body affects every other part. This is a compensatory concept of motion. Because human beings exist on a planet with gravity, this fundamental principle of physics cannot be overlooked. In every moment, with every movement, the body makes every attempt to balance itself from top to bottom, side to side, and front to back. When forefoot varum is present, at midstance, the forefoot must roll inward and downward (pronate excessively) to attain full foot-to-ground contact (foundational stability). As the body's center of gravity is shifted to the inside of the foot, the knees are forced to roll inward and closer together, producing an oblique patellar tracking pattern and genu valgum (knock knees). The sacroiliac joints then rotate inward, downward, usually asymmetrically, producing a pelvic tilt with an articular torsional component secondary to

excessive pronation which is usually asymmetrical. The collapsing foot drives the pelvis forward because the body's center of gravity is anterior to the sacraliliac joints. This asymmetrical pelvic tilt carries the lumbar spine with it, producing lumbar lordosis with a compensatory thoracic kyphosis, seen visually as "sway-back" and "hunched" shoulders. When the shoulders protract, the cervical spine loses its normal curvature, and the head is thrust forward.

The goal of PCO therapy is to prevent bio-implosion at the mechanical level of dysfunction in order to restore the body as close to maximum biomechanical efficiency as possible. This is done in a series of incremental changes to give the body an opportunity to adapt to these changes with as little untoward reaction as possible. This technique is termed *shimming* or *posting*, building the ground up to the foot using vertical lift in the PCO to accommodate for the varum torsion in the forefoot (see Figure 2). By increasing the foot-to-ground contact, excessive pronation is decreased and bio-implosion is reversed to the degree the body will tolerate in the direction of increased mechanical efficiency, *i.e.*, increased postural stability. PCO therapy does not correct torsional anomalies in much the same way glasses do not correct vision. When PCOs or glasses are not worn, the maladies of bio-implosion or myopia remain.

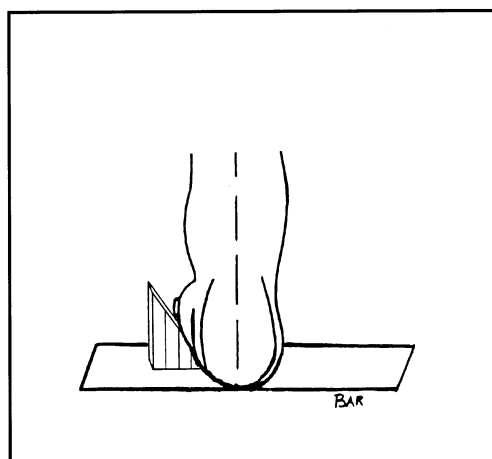


Figure 2. Biovector positioned under first metatarsal head. Vertical height is increased until subtalar joint remains congruous through knee flexion extension.

Much as implosion causes a building to collapse, bio-implosion causes skeletal collapse and produces muscle bracing. This is seen as increased muscular activity. In other words, the body overuses muscles across those joints that are structurally unstable in order to stabilize the framework and maintain an upright posture. This constant muscle bracing is very wearing on the system, producing generalized fatigue and, probably, fibromyalgia. Early electromyographic studies have supported this concept of muscle bracing in biomechanically unstable models. In addition, muscle bracing is greater in the upper body because of the lever arm effect, *i.e.*, increasing muscle bracing is directly proportional to increasing lever arm length (distance from muscle to foot), given an equal degree of excessive pronation in the structure. In this way, muscle bracing caused by excessive pronation is a major contributing

factor to mechanical problems in the head and neck, *e.g.*, tension-type neckaches. Hence, attenuating excessive pronation decreases muscle bracing and its concomitant effects in all areas of the body.

Finally, visceral components have been noted in some patients in the treatment of bio-implosion and chronic pain. In theory, because the internal organs “hang” on the skeletal framework in the body, torsion of the skeleton, from the biomechanical dysfunction, may produce compression/torsion on the viscera. To use another example from engineering, if a building collapses or severely settles, the furniture inside the building is definitely, and, sometimes, dramatically, affected. Thus, it is not surprising for patients with pelvic tilts to have a “tipped” uterus or, for those with a severe forward head thrust, to have sinus problems. Gastrointestinal symptoms have been reported during PCO therapy by some patients, which is consistent with the concept of somatovisceral reflex in osteopathic medicine. For example, a somatic dysfunction can precipitate a visceral dysfunction via the nerves that innervate the viscera which are at or near the skeletal segments most significantly affected biomechanically in the bio-implosion model.

CASE STUDY: PATELLAR FEMORAL STRESS SYNDROME

DJL is a 25 year old male, 5'10", 150 pounds. His chief complaint is a chronic sharp-to-dull ache along the medial compartment of both knees, left more than right. Subjective symptoms increase with activity; however, sitting with his knees bent produces stiffness (positive movie sign). No history of injury was given. X-rays were negative for bony involvement; however, medial joint line narrowing is noted, left more than right. Anterior Draw Sign² and McMurray Test³ were negative for anterior cruciate or meniscus involvement. Careful questioning divulged the following symptoms: (i) chronic tiredness in both feet at the end of the day, (ii) chronic ankle instability with tendency to invert his right ankle playing basketball, (iii) episodic clicking in his right hip, outside compartment, (iv) chronic mid-back aching, increasing with prolonged sitting or standing, and (v) chronic tightness in his right shoulder and neck, increasing during the day.

Examination. Palpation of the medial joint line elicits subjective 1+ sensitivity right, 3+ sensitivity left (0-5 scale). Pes anserinus⁴ sensitivity is noted bilaterally. The right ilio-tibial

² *Anterior draw sign:* Torn anterior cruciate ligament. Patient supine on table, knees flexed at 90 degrees. Examiner positioned on edge of table, stabilizing the patient's foot by sitting on it. The tibia is drawn towards examiner. If it slides forward under the femur, a torn anterior cruciate ligament is suspected.

³ *McMurray Test:* With the knee flexed, leg externally rotated and knee in valgus stress, the knee is slowly extended. If a click is palpable or audible, the test is considered positive for a torn meniscus.

⁴ *The flare of medial tibial plateau.* Common insertion point of the sartorius, gracilis, and semitendinosus tendons.

band is tight with 1+ sensitivity at Gerdy's Tubercle⁵, right leg. The adductor tubercles⁶ are inflamed bilaterally. The sacral-iliac joints are sensitive to palpation, 5+ left, 2+ right. Sitting, the patient leans back on his hands or arcs his low back, a maneuver pathognomonic of SI Joint inflammation (positive Rothbart sign). Prone, the left leg appears 1/2" longer than the right leg. Supine, both legs appear the same length. The scapula levator and sternocleidomastoides muscles are tight, right side > left side. Thomas Test is positive, left side > right (tight hip flexors). Hamstrings are tight, 3+ bilaterally. In a standing position, with the knees flexed, genu valgum and collapse of the inner longitudinal arch is noted bilaterally (see Figure 3a). No positional correction was noted in the knees with the patient standing on his arch supports (see Figure 3b).

Incremental Vertical Lift Therapy: All pictures taken with knee flexed at 15-20 degrees. By flexing the knees, the static load patterns in the foot approximate the dynamic load patterns in the foot at midstance of gait.

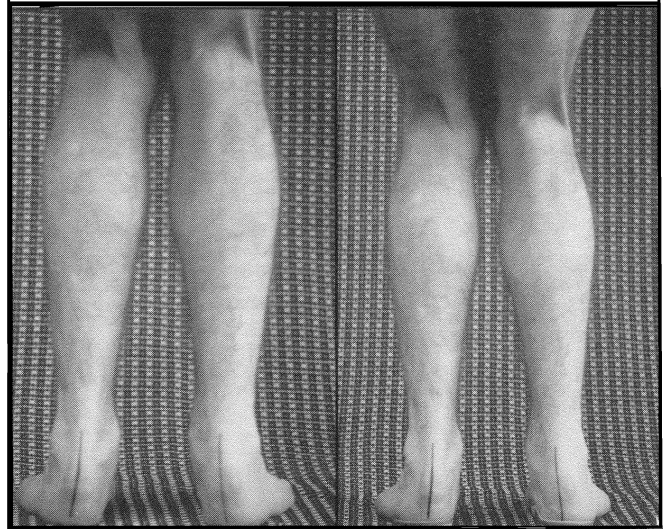


Figure 3a. No orthotic, note the valgus position of the heel and knee.

Figure 3b. Arch supports. The valgus position of the heel bone has decreased; however, the knees appear closer together.

Measurements. Forefoot varum 13 mm left, 17 mm right (measured standing on biovector). Tibial varum 4 mm bilaterally (using rearfoot shims). The first ray is plantarflexed, left more than right, and could not be totally reduced manually. Ankle joint dorsiflexion is greater than 15° bilaterally. Active range of motion at the first metatarsal-phalangeal articulation was greater than 20° bilaterally. Passive range of motion at the first MPJ was less than 10° and 15°, right and left foot respectively. Off weight bearing neutral position casts taken with the plantarflexed first ray reduced to resistance, demonstrate a

⁵ *The flare of the lateral tibial plateau just below the knee joint.* Insertion point of the iliotibial tract.

⁶ *Adductor tubercle:* The posterior medial portion of the femoral epicondyle just above knee joint. The insertion point of the adductor longus tendon.

forefoot varum pattern right > left. A significant plantar deflected first ray is noted in the left cast.

Gait evaluation (visual analysis). The calcaneus is overpronated at heel contact, right > left. The right foot is more abducted than the left. At midstance, excessive pronation is observed through the subtalar joint, left > right. Genu Valgum is noted, left > right. A pelvic tilt is present with a compensatory kyphotic curve (swayback). The right shoulder drops during swing phase of the right leg. The right arm swing is tenuous. Both hands are pronated. Recurrently, a lateral lurch to the right is observed. The patient drifts to his right when his attention is diverted. From heel contact to midstance, weight transfer is maintained on the lateral border of the right foot—a compensatory reaction to the dropped right shoulder. The head is thrust forward and side-bent right.

TREATMENT

Day 1. Postural control orthotics were fitted with an extrinsic forefoot vertical lift: 5 mm left, 7 mm right (see *Figure 3c*). The patient stated, “My balance is off.” Concomitantly, pressure awareness—not discomfort—was described along the distal medial margin of the PCOs. A slow break-in period was stressed: increasing/decreasing wear-time one hour per day as tolerance permits.



Figure 3c.



Figure 3d.



Figure 3e.

Figure 3c, 3d, 3e. PCO #1 through PCO #3. Note the increased verticality of the heel bone and increased distance between the knees. Both arch supports and PCOs are Class IIs levers at heel contact. PCOs maintain a Class II lever effect until heel raise. Arch supports become Class III levers at midstance losing their mechanical efficiency.

Week 2. DJL was able to wear the PCOs full-time, forgetting the PCOs are in his shoes (referred to as transparency). Initial postural reactions are noted as follows: (i) Day 2: increased aching along the medial joint line, bilaterally, (ii) Day 4: increased mid-back pain associated with standing or bending, and (iii) Day 3-7: increased tiredness and fatigue in both legs and feet. All of these postural reactions subsided by Day 10. No subjective improvement was noted in his knees or shoulders. However, all foot symptoms abated and he felt he

could stand longer before his mid-back aches.

Week 9. The medial knee symptoms were dramatically improved. For the first time in five years, the patient was able to hike all day without debilitating knee pain; however, his knees tired by the end of the hike. His mid-back was improved. He could sit and stand for longer periods of time before experiencing back discomfort. His feet continued to be asymptomatic. He felt his balance to be improved, and he was not drifting to the right as before. He felt as if he were standing straighter.

Week 23. Medial compartment pain in the left knee reoccurred (referred to as *storming*)—onset approximately two weeks prior to the visit. Concurrently his mid-back started to ache and his balance deteriorated to the point of drifting to his right again. His feet were still asymptomatic. Forefoot measurements were retaken and recorded as follows: 14.5 mm left, 17.5 mm right. Vertical lift on the forefoot increased as follows: 3 mm left, 4 mm right using temporary elevation of medial posts (TEMPS). This placed the forefoot posting at 8 mm left, 11 mm right.

Week 24. Subjective pain in the left medial knee compartment was dramatically improved. The patient was recasted. The negatives demonstrated more varum in the right cast.

Week 26. A second pair of PCOs were dispensed with the following forefoot varum prescription: 08 mm left, 11 mm right (see *Figure 3d*).

Week 32. Knees were continuing to improve. Patient was able to run three times per week, two miles per run, without significant knee pain. Prior to orthotic therapy he had not been able to run comfortably for 10 years. His mid-back no longer ached when he were to stand or bend and is only mildly symptomatic when he would sit for more than two consecutive hours. Surprising to the patient, his neck and right shoulder symptoms were abating. He experienced as many as 3-4 days straight without any upper body stiffness. Once again his

balance continued to improve; he no longer drifted to the right.

Week 50. Stiffness in the right shoulder was reoccurring—onset approximately one week prior to the visit. However, his knees and mid-back were no longer a problem. Forefoot varum measurements were retaken with the BioVector and recorded as follows: left 14.5 mm, right 18.5 mm. Using TEMPs, varum prescription was increased to 12 mm left, 15 mm right.

Week 51. Within 24 hours post-TEMPs, stiffness in the neck was attenuated. The patient was recasted. The right negative demonstrated more varum.

Week 53. A third set of PCOs were dispensed with a vertical forefoot lift of 12 mm left, 15 mm right. A 1-mm rearfoot lift was added to the left PCO. A 3-mm rearfoot lift was added to the right PCO (see *Figure 3e*).

Week 59. Patient was able to run 40 miles per week with no knee pain. All mid-back symptoms subsided and, for the first time in his life, his neck was not tight even under stress.

Week 83. The patient was asymptomatic if he did not exceed structural limitations. The patient stated his foot was 100% improved, knees 75% improved, mid-back 80% improved, and neck 70% improved.

RESULTS

Statistical evaluation. Over a span of four years (1989-92), 128 chronic knee pain patients have participated in a study at the Bellevue Foot and Ankle Center. All these patients had been treated prior to the present study with various modalities (e.g., NSAIDs, aggressive physical therapy, surgery). Results were disappointing; attenuation of pain and disability had not met patient expectations. All of these patients were professionally advised that “nothing else could be done.” Many were referred to pain management facilities to learn how to cope with their pain and live with their disability, a process termed *body hardening*.

One year after PCO therapy was concluded, questionnaires were sent to each of the 128 patients (see *Figure 4*). The participants were asked to evaluate the percentage of knee improvement since wearing PCOs. Of 128 respondents, 8 reported an improved range of improvement of 10-40%, 14 improved 50-60%, and 78 reported improvement of 70% or greater. Twenty-five respondents reported improvement with no range given. One reported no improvement, and two reported their knee symptoms increased.

Subtalar joint articular efficiency ratios (SJAER). In a standing position, the degree of subtalar joint pronation, can be defined in terms of the Subtalar Joint Articular Efficiency Ratio (SJAER). A SJAER of 1.0 indicates complete joint congruity (i.e., neutral position) of the subtalar joint. A SJAER of 0 indicates a maximally pronated subtalar joint. A biovector is used to measure the amount of vertical lift required to maintain the subtalar JAER at 1.0 as the weight of the body is transferred forward through the foot. The patient stands on a biovector, a triangular wedge with an integrated millimeter scale. Using motion/palpation, the knee is flexed and extended

as the subtalar joint is palpated. Using the biovector, vertical lift is slowly increased under the surgical neck of the first metatarsal until the subtalar joint no longer pronates (i.e., maintains joint congruity). This measurement is recorded. In theory, when the subtalar joint is maintained near its neutral position in stance phase (SJAER = 1), the knees will track linearly, the sacral iliac joints maintain joint congruity, the spinal cord is loaded concentrically, and the head is centered over the cervical spine. Arch supports and postural control orthotics are defined in terms of SJAERs. Any device with a SJAER of 0.25 or greater is defined as a PCO. Any device with a SJAER of less than 0.25 is defined as an arch support. Arch supports are mechanically too inefficient to affect the hips, pelvis, and neck. PCOs with an SJAER > 0.70 can affect every joint from the ankle to the jaw.

Using PCOs is a time-orientated process. Healing is cyclical. The SJAER must be adjusted carefully. If adjustments are too severe, inflammatory reactions may occur in the ankles, knees, pelvis (sacral-iliac articulation), back, and neck. If adjusted judiciously, beneficial effects are noted in the knee, hip, back, and neck. SJAERs are regulated relative to subjective profiles and clinical data. When initial symptoms return (storms), SJAERs are increased. If the SJAER is increased past tolerance, atypical reactions can occur.

Using PCOs requires evaluation of all major weight-bearing joints. Overall structural integrity determines the aggressiveness of treatment. In the absence of significant osteodegenerative arthritis, an SJAER of 0.3-0.5 should be prescribed in the first pair of PCOs. The patient's tolerance to subsequent PCOs with increased SJAER is determined by a temporary elevation of the medial posts (TEMPs). Premeasured 2 or 4 mm wedges are applied to the superior medial margin of the PCO as determined by the physician. These wedges compress and must be replaced every two days, hence the term TEMPorary. Adverse reactions to TEMPs suggest an endpoint in treatment has been reached.

CONCLUSION

The authors have presented a new approach to the use of orthoses—serial posting (vertical lift). Treatment is based on bioengineering principles. With judicious posting, reactive ground forces through the foot are methodically and serially altered to reduce subtalar joint surface incongruity. In a closed kinetic chain, wedging the forefoot and, indirectly, the subtalar joint towards neutral retroactively fosters joint surface congruity along the entire weight-bearing axis, much as stabilizing the foundation of a building, stabilizes the entire superstructure. By maximizing joint surface fit, articular compressive forces are dissipated over a larger surface area. Clinical evidence from the 1989-1992 knee study of 128 patients suggests that it is this mechanism that allows articular caps to regenerate resulting in reduced arthritic symptoms. Orthoses used in this manner are termed Postural Control Orthotics (PCOs). This paper has been an attempt only to share the authors' clinical observations and theoretical model. Responses are welcome.

Bellevue Foot and Ankle Center
A Sports Medicine Facility
Orthotic Questionnaire

Chief complaint or reason for seeking care _____

How were you referred to the Bellevue Foot & Ankle Center (Physician/Friends or Relatives/Yellow Pages/Other) _____

Have you had (Check where appropriate)

Surgery or Orthopedic Care	<input type="checkbox"/>
Osteopathic Manipulation	<input type="checkbox"/>
TMJ Work	<input type="checkbox"/>
Chiropractic Care	<input type="checkbox"/>
Physical Therapy	<input type="checkbox"/>

In Box A, Check your location of Symptoms

	A	B
Neck	<input type="checkbox"/>	<input type="checkbox"/>
Back	<input type="checkbox"/>	<input type="checkbox"/>
Knee	<input type="checkbox"/>	<input type="checkbox"/>
Legs	<input type="checkbox"/>	<input type="checkbox"/>
Ankle	<input type="checkbox"/>	<input type="checkbox"/>
Feet	<input type="checkbox"/>	<input type="checkbox"/>

In Box B, Estimate your percentage of Improvement since wearing Orthotics

Have you had prior experience with orthotics? _____ (Yes/No)

If Yes: Type (Hard/Soft/Leather/Plastic/AD/PCO) _____

Dispensed by : Physician _____ Physical Therapist _____ Other _____

Are you pleased with the results since wearing our Orthotics (Yes/No) _____

What Percentage of time are you wearing your Orthotics (Circle where appropriate)

80-100%
60- 80%
40- 60%
<40%

What suggestions do you have to improve our care of service _____

Date

C #