Effect of Custom Foot Orthosis on Dynamic Plantar Pressure Distribution

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Abstract:
Background: Foot Orthosis has been used from last 2 decades for treatment of flexible flat feet, however there is limited understanding of its effect on kinetics during gait.
Objective: To evaluate the effect of plantar pressure distribution using custom made functional foot Orthosis in adult flexible flat feet
Methods: In this single group pre-test post-test experimental design, CDG Gait analyser was used to measure plantar pressure distribution with shoe only and foot Orthosis with shoe in patients with flexible flat feet
Result: significant redistribution of plantar pressure was seen in patient with flexible flat feet while using customised functional foot Orthosis
Conclusion: customise functional foot Orthosis is effective method of treatment as per the kinetic analysis but to get more clear picture kinematic analysis is equally important.

1. Introduction

The human foot is a masterpiece of engineering and a work of art. The foot and ankle serve as the primary interface between the ground and the body during ambulation. This requires that the foot and ankle complex be able to absorb impact loading forces, adapt to uneven ground, and allow efficient propulsion. To accomplish this task, the foot and ankle are usually composed of 26 primary bones, 19 muscles, and 107 ligaments [1].Great work has been done to develop an understanding and standards of practice regarding the foot biomechanics & its orthotic management, but it is hardly surprising that the foots working cannot be captured in one or two statements or even a single, compact theory. Custom foot orthoses have been a treatment method for foot deformities for well over two centuries.

In 1781, Petrus Camper, a Dutch physician, published one of the first books on foot deformities, On the Best Form of Shoe, which stimulated interest in placing arch supporting orthoses into shoes for children’s flatfoot[2] Queen Victoria’s chiropodist, Lewis Durlacher, developed a leather foot orthosis to correct for “plantar pressure lesions” and “foot imbalances” in 1845[3]. In 1889, Royal Whitman, MD, developed an orthosis constructed of 18-20 gauge sheet steel made over a plaster cast of a foot in order to raise the medial longitudinal arch of the foot and make it less pronated.[4] Edward Reed, MD, an orthopedic surgeon from Santa Monica, Calif., was the first to describe, within the medical literature, plaster splint impression casting for foot orthoses in 1933[5].

Starting from their simple origin as leather, cork, and/or metallic in-shoe arch support, foot orthoses have gradually evolved into a complex assortment of in-shoe devices that may be fabricated from a multitude of synthetic and natural materials to accomplish the intended therapeutic goals for the injured patient. The use of foot orthoses as an effective treatment tool for biomechanical dysfunction of the feet has evolved during 20th century [6]. The foot orthoses generally prescribed clinically consists of flat insoles, arch support, wedges etc or may be fabricated using negative cast of affected foot[7].Irrespective of methods and material used from now and then the goal is to support or balance the foot in order to eliminate the need for the foot to compensate for the structural deformity or misalignment., their use may also be indicated for plantar pressure reduction through total contact fit and non yielding relief under sites of high pressure[8]. As a frequently reported condition it has significant implications. These are not only for the individual, where pain or the appearance of the foot is outside normal around functionality, where the clinician is requested to align the foot back to within normal foot functioning parameters [9].

Many biomechanical theories has been developed for the orthotic management of foot deformities. One of the most common is Then in 1958, Merton Root, DPM, a 1952 graduate from the California College of Chiropody, revolutionized foot orthosis
...technology by experimenting with new materials called thermoplastics and began developing his Root Functional Orthosis[10]. In 1971, Root and colleagues proposed their ideal “eight biophysical criteria for normalcy” and developed a foot and lower extremity classification system that was based on the subtalar joint neutral position [11]. They also proposed that all feet and lower extremities that did not meet their criteria for “normal” had structural defects and one should therefore consider these feet “abnormal” [11].

In 1971, Root and colleagues also developed the “neutral suspension casting technique” for custom foot orthoses in which they used plaster splints to capture the non-weight bearing contours of the plantar foot while the subtalar joint was in the neutral position and the fourth and fifth metatarsals were dorsiflexed on the rearfoot[12]. Finally, in 1977, Root and coworkers published Normal and Abnormal Function of the Foot, their definitive textbook on foot biomechanics and mechanically-based pedal pathologies [13]. Anthony Redmond in 2000[15], studied the effect of cast and non cast foot orthosis on plantar pressure and forces during gait and found that cast foot orthosis with root modification were more effective in controlling pronation and plantar pressure and forces during gait. It could be argued however that while the theory has contributed positively to the development of the current understanding of the mechanics of foot function and, by extension, the intervention based on foot function- there has been little emphasis testing of that theory through rigorous scientific experiment work. Studies has been done to find out the effect of different orthosis on development of arch support but very less data is available to address the functional performance of foot orthosis with respect to flexible flat foot. Hence this study is a small attempt to quantify the functional performance of root functional foot Orthosis in patients with flexible flat feet by quantifying plantar pressure distribution pattern.

2. Methods

Subjects

A Convenient sample of participants with Age group: 11-40 years Both male and female having Bilateral flexible flat foot with Calcaneal eversion angle of 5 degree or more in resting calcaneal stance position & Navicular drop of 10mm or more. were recruited for the study from OPD of N.I.O.H, Kolkata. Informed consent were taken from all patients. Participants were clinically assessed as per above criteria. Exclusion criteria includes: Any pathology at hip, knee and ankle joint. Any history of surgery of lower limb, any neuromuscular disorder, rigid flat foot, Mental retardation.

Instrumentation:

CDG gait analyzer was used to measure plantar pressure distribution: For plantar pressure distribution recording in CDG gait analyzer: 1. CDG shoes containing 8 pressure sensors (Fig 3.1) of appropriate sizes were fitted to the patient at the sole of the normal shoe with or without orthosis according to the above mentioned procedure. 2. Shoes were tied with the help of auxiliary straps 3. Stretch bandages were used once the shoes are connected properly to the cables along the legs of the patient and the cables were connected to the microcontroller which was tied to the trunk of the patient. 4. Once the instrument was applied to the patient the patient was asked to walk for 20 sec on level ground surface. 5. Three trail data were taken and average of three was taken for final data analysis.

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In order to meet the purpose of the study a planned and careful procedure was chosen before proceeding further. The individuals with flexible flat foot reporting to OPD were screened through the inclusion and exclusion criteria. After screening detailed description and purpose of the study was mentioned verbally to each patient and those patients who agreed to give their voluntary consent in written. After that baseline data was taken with patient wearing shoes only. Then measurement was done for selected all participants using root neutral suspension casting technique Fabrication and fitting of the orthosis was done. The final check out of foot orthosis was performed and post data was taken after two weeks. Data was analyzed to compare the shoe only and shoe with custom foot orthosis in terms of plantar pressure distribution during gait.

3. Data analysis

Raw data were exported from CDG gait analyser into Microsoft excel, and final data. Analysis was performed in SPSS for windows, version 16.0(SPSS Inc, Chicago, Illinios). The data were explored using appropriate descriptive and graphic techniques and each data set was examined for a normal distribution prior to conducting any inferential analysis. Paired t test was used to analyze difference between shoe only and shoe with orthosis conditions. An alpha level of p<0.05 was fixed. Prior to full analysis, data for left and right foot were analyzed for differences. Data were analysed for following parameters:

- Plantar pressure was analyzed by dividing the foot into 5 anatomical regions and finding the percentage of pressure in all regions including (figure 3):
  - Heel
  - Midfoot
  - Medial forefoot
  - Lateral forefoot
  - Toes
4. Results:

a. Plantar pressure distribution: between left and right feet

Student t test was used to analyze the differences in plantar pressure distribution pattern of left and right foot of all subjects with and without orthosis for both groups with a value set at 0.05. The results of left and right foot did not show any significant difference hence were pooled together which generated a sample size of 30 for each group which was used for further analysis of result.

Table 1: data analysis between left and right foot in shoe only condition

<table>
<thead>
<tr>
<th>Anatomical area</th>
<th>Mean ± standard deviation (shoe only left)</th>
<th>Mean ± standard deviation (shoe only right)</th>
<th>t value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heel</td>
<td>42.90 ± 2.55</td>
<td>43.87 ± 1.90</td>
<td>1.18</td>
<td>0.12</td>
</tr>
<tr>
<td>Mid foot</td>
<td>26.53 ± 3.13</td>
<td>25.40 ± 2.40</td>
<td>1.09</td>
<td>0.14</td>
</tr>
<tr>
<td>Lateral forefoot</td>
<td>11.28 ± 3.29</td>
<td>10.50 ± 1.98</td>
<td>0.78</td>
<td>0.21</td>
</tr>
<tr>
<td>Medial forefoot</td>
<td>11.07 ± 3.11</td>
<td>10.70 ± 2.41</td>
<td>0.35</td>
<td>0.36</td>
</tr>
<tr>
<td>Toes</td>
<td>8.0107 ± 3.11</td>
<td>9.44 ± 2.40</td>
<td>-0.34</td>
<td>0.36</td>
</tr>
</tbody>
</table>

b. Plantar pressure distribution: pre and post data analysis.

- Significant change in pressure distribution was seen in all anatomical regions of foot. In heel region reduction of pressure was seen between shoe only (43.39 ± 2.26) and shoe with cast orthosis condition (41.45 ± 1.72) with p = 0.01.
- In midfoot area also reduction in pressure was seen between shoe only condition (25.96 ± 2.82) and cast orthosis (23.55 ± 1.58) with p = 0.00.
- Similarly in lateral forefoot area reduction in pressure was seen between shoe only (10.8 ± 2.70) and shoe with cast orthosis (9.87 ± 1.67) with p = 0.05.
- However in medial forefoot and toe region significant increase in pressure was seen.
- In medial forefoot region pressure increased from shoe only (10.89 ± 2.83) to shoe with cast orthosis (12.77 ± 1.72) with p = 0.00.
- In toe area significant increase was seen from shoe only condition (8.727 ± 2.83) to shoe with cast orthosis (12.34 ± 1.74) with p = 0.00.

Table 2: data analysis between left and right foot in shoe with orthosis condition

<table>
<thead>
<tr>
<th>Anatomical area</th>
<th>Mean ± standard deviation (orthosis left)</th>
<th>Mean ± standard deviation (orthosis right)</th>
<th>t value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heel</td>
<td>41.46 ± 1.94</td>
<td>41.43 ± 1.54</td>
<td>0.48</td>
<td>0.48</td>
</tr>
<tr>
<td>Mid foot</td>
<td>23.57 ± 1.54</td>
<td>23.53 ± 1.67</td>
<td>0.76</td>
<td>0.47</td>
</tr>
<tr>
<td>Lateral forefoot</td>
<td>9.88 ± 1.366</td>
<td>9.86 ± 1.98</td>
<td>0.034</td>
<td>0.486</td>
</tr>
<tr>
<td>Medial forefoot</td>
<td>13.19 ± 1.992</td>
<td>12.35 ± 1.335</td>
<td>1.352</td>
<td>0.093</td>
</tr>
<tr>
<td>Toes</td>
<td>11.87 ± 1.16</td>
<td>12.80 ± 2.11</td>
<td>-1.504</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Table 3: data analysis between shoe only with orthosis plus shoe condition

<table>
<thead>
<tr>
<th>Anatomical area</th>
<th>Mean ± standard deviation (shoe only)</th>
<th>Mean ± standard deviation (custom orthosis)</th>
<th>t value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heel</td>
<td>43.39 ± 2.26</td>
<td>41.45 ± 1.72</td>
<td>3.838</td>
<td>0.01</td>
</tr>
<tr>
<td>Mid foot</td>
<td>25.96 ± 2.82</td>
<td>23.55 ± 1.58</td>
<td>4.196</td>
<td>0.00</td>
</tr>
<tr>
<td>Lateral forefoot</td>
<td>10.8 ± 2.70</td>
<td>9.87 ± 1.67</td>
<td>1.63</td>
<td>0.05</td>
</tr>
<tr>
<td>Medial forefoot</td>
<td>10.89 ± 2.83</td>
<td>12.77 ± 1.72</td>
<td>-3.978</td>
<td>0.00</td>
</tr>
<tr>
<td>Toes</td>
<td>8.727 ± 2.83</td>
<td>12.34 ± 1.74</td>
<td>-5.938</td>
<td>0.00</td>
</tr>
</tbody>
</table>

5. Discussion

The purpose of the study was to study the effect of custom foot orthosis on plantar pressure distribution during gait in patient with flexible flat feet. The study included bilateral flexible flat feet with no consideration of gender. Plantar pressure was quantified in percentage by dividing the foot into five regions namely: heel, midfoot, lateral forefoot, medial forefoot and toes. The results of plantar pressure distribution shoe only are in agreement with many studies. PAUK et al in 2010[14]. Analyzed of
the plantar pressure distribution in children with foot deformities and found that the highest mean pressure in typical subjects was found under the heel and the metatarsal heads. The lowest pressure distribution was under the cuboid bone. In the planovalgus subjects, a higher pressure distribution was found under cuboid bone compared to typical one, which suggested that pressure under the midfoot area of foot increases in flat feet patients. Similarly timothy 2005[16] and redmond et al 2000[15] reported increased pressure in heel area in patients with flexible flat feet without orthosis however, in forefoot region pressure gets shifted laterally due to supination twist to maintain the foot on ground[17].This result is also in agreement with myoung- kwong, kim 2013[18] and chang reyol lee 20128. Another pathological implication of seen in flat feet is that the subtalar joint remains pronated after footflat[19]. The midtarsal joint is not locked and forefoot remains a mobile adapter instead of a rigid lever for propulsion, this could be reason of lesser pressure on toes in shoe only condition of this study. The results of planter pressure distribution show significant improvement with custom orthosis in all areas of foot as comparison to shoe only. In heel region cast orthosis has shown 1.94% decrease in pressure as compare to shoe only condition, this may be due to contoured shape of cast orthosis. Similar results have been found by timothy 2005[16]. Who did study on cadaveric flat feet using UCBL. This may suggest that contoured orthosis may also be preferable in conditions where reduction of forces or pressures in heel is required especially in plantar fasciitis which may also be a complication of flat feet.

In midfoot region custom orthosis has shown 2.4% of decrease in pressure than shoe only condition. This reduction may be due to contoured arch support function of custom orthosis which supported the highly mobile joints of foot and reduces the navicular drop and hence excessive pressure. The closely fitted contours of the custom device result in those forces being spread evenly over the area. These results are in agreement with Anthony Redmond et al 2000[15].

In forefoot region, both orthosis has shown significant results. There has been seen significant decrease in plantar pressure in lateral forefoot with cast orthosis showing 0.93% of decrease from shoe only condition and 0.84% more decrease than non cast orthosis, however non cast orthosis shows 1.09% decrease in pressure. On the other hand significant increase in pressure has been seen in medial forefoot area in both type of orthosis. cast orthosis has shown 1.88% increase in plantar pressure and non cast orthosis has shown 1.37% of increase of pressure. Similarly in toe region increased pressure has been seen with 2.5 % increase with no cast orthosis and 3.6% with cast orthosis i.e. 1.48% more increment is seen with cast orthosis than non cast orthosis and this redistribution of pressure in forefoot area may be due to realignment of subtalar joint which further realigned the midtarsal joint hence realigning forefoot and reducing compensatory forefoot varus which resulted in shifting of pressure from lateral forefoot to medial forefoot, this supination moment at terminal stance which locks the midfoot and creates a rigid lever from calcaneus through metatarsals. This rigid lever will then rotate around the MTP axis and hence will assist in toe off phase of gait[20].

Nevertheless, the results clearly demonstrate that orthoses have the ability to alter foot function selectively. There remains a great deal more to learn about the mechanism by which orthoses may exert that effect, but the results in this instance appear clear.

6. References:


