Comparison of Plantar Pressures Distribution Patterns between Foot Orthoses Provided by CAD-CAM and Foam Impression Methods

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Introduction

• Normal Values
• Factors influence in plantar pressure pattern
• Foot Orthotics in Plantar Pressure Measurement
Introduction - Normal Values

- evaluate foot deformities: flatfoot, clubfoot, hallux valgus, plantar fasciitis, callus formation and foot ulcers (diabetes mellitus)
- normative data is needed to provide a basic knowledge on plantar pressure.
- comparison with for the abnormal conditions of plantar pressure
Introduction – Normal Values

- 30 healthy subjects
- EMED-SF measuring system with a two-step recording technique
- smallest standard deviations of pressure values
  - heel and the second and third metatarsal
  - → heel, central forefoot regions were functionally the most stable areas of the foot during the stance
- greatest variations of pressure values
  - the mid-foot, the fifth metatarsal and the lesser toes

(Bryant et al. 2000)
Introduction- Normal Values

- 74 healthy volunteers
- walk with a cadence of 100 steps/min
- using Musgrave Footprint
- foot image was divided into 6 plantar regions
- greatest pressure
  - second to fourth Metatarsal Heads (greater structure stability, act as main loading area)
  - hallux
- lowest pressure
  - fifth metatarsal Head

(Bennett and Duplock 1993)
Introduction

Factors influence plantar pressure pattern:
1. Walking speed
2. Gender
3. Type of foot and type of shoes
Introduction – walking speed

- Effects of different walking speed on plantar pressure
- Subjects: 20 normal subjects
- walking on treadmill at 6 different speeds
- Specific regions: hallux, the medial, central and lateral forefoot and the heel
- Conclusion:
  - hallux and heel regions - highest pressures (increased linearly with faster speeds)
  - central and medial forefoot pressure (initially increased then become steady plateaued at faster speeds)
  - lateral forefoot had the lowest peak pressure (decreased at faster speeds)

(Segal et al. 2004)
Introduction - Gender, foot types and types of shoes

- **no gender differences** plantar pressure or contact area - Men and women → subject group
  
  (Murphy DF et al. 2005)
  
  (Soames RW, 1985)

- high arch, normal and low arch groups - **high arch group** result in least loading in mid-foot region and compensated by increasing loadings in the heel and forefoot regions.
  
  (Rosenbaum et al. 1994)

- peak pressure, central metatarsals pressure and heel pressure - **bare feet significant higher pressure then wearing shoes**
  
  (Burnfield JM et al. 2004)
  
  (Praet FE et al. 2003)
Introduction - Effect of Orthotics in Plantar Pressure measurement

- Four casting methods
  - foam box techniques in full weight-bearing and Semi weight-bearing
  - suspension plaster casting techniques in full weight-bearing and Semi weight-bearing
- Concluded: the effects of different casting methods on peak pressure and gait lines for accommodative and functional orthoses are almost the same

(Guldemond et al. 2006)
Introduction - Effect of Orthotics in Plantar Pressure Measurement

• Three Dimensional finite element analysis
• Custom-moulded soft insole reduced the peak pressure on the metatarsal and heel regions and increased the contact area
• Concluded: custom-moulded shape is more important in reducing the peak pressure rather than the material stiffness of insole

(Cheung et al. 2005)
Introduction

• Aim:
  1. compare the plantar pressure distribution pattern between foot orthoses generated by CAD-CAM and foam impression methods
  2. provide additional reference on indication of appropriate orthotic intervention for different foot conditions
Methodology

• Subjects: 5 males and 25 females
  • Age 31.6 (22-55)
  • Height: 1.6m (1.5m-1.76m)
  • Weight: 56.4kg (44.0kg-71.8kg)

• Inclusion criteria:
  • No static foot deformity
  • No painful foot condition
  • Arch index within normal ( arch index= 0.21 <AI<0.26 )

(Cavanagh PR et al. 1987)
Methodology

Instruments:

• Novel PEDAR-mobile (Novel Gmbh, Munich, Germany) in-shoe plantar pressure measuring system
  • Four different size insole sensors 2.6mm, 99 sensors using capacitance transducer
  • Frequency: 50 Hz
  • Calibration was done before data capture
Methodology

• The Swiss Comfort CAD-CAM foot orthotics system

- Assessment stand
- Vacuum system
- Comfortspline software
- Analyzer
- Former
# Methodology

## Materials
- Foam box
- Insole materials
  - Multiform
  - Multikork

### Insoles materials:

<table>
<thead>
<tr>
<th>Insoles materials:</th>
<th>Flat insole</th>
<th>Foam impression</th>
<th>CAD-CAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>3mm multiform+ 2mm multikork</td>
<td>3mm multiform + 2mm, 8mm multikork</td>
<td>3mm multiform + 20mm multikork</td>
<td></td>
</tr>
</tbody>
</table>

### Thickness
- ~5mm Even thinkness
- ~5mm At the points of the heel centre and the toes
- ~5mm At the points of the heel centre and the toes
Methodology

• Procedures
  • Foot shape collection
  • Shape rectification
  • Insole fabrication
  • Measurement of plantar pressure
  • Data analysis
Methodology

• Foot shape collection
  • Weight and height of subjects were measured and recorded
  • Footprints were taken by using Harris-Mat footprint and arch index were calculated (Cavanagh PR et al. 1987)
  • Foot shape were taken by
    • Foam impression method
    • CAD-CAM method
      • Partial weight-bearing
      • Sit on firm chair with hip and knee flex in 90°
      • Subtalar joint in neutral position
Methodology

Shape rectification

• Foam impression method
  • Impressed foam impression box kit was filled with Plaster of Paris → positive model
  • Modification of toe piece → flatten toe platform
  • Smoothed by sand paper and allowed to dried up

• CAD-CAM method
  • Toes section was modified to become a flat platform
  • The foot shape adjusted shallower through the ComfortSpline software on in order to prepare rooms for the covering
Methodology

• Insole Fabrication
  • Foam impression method - vacuum moulding
  • CAD-CAM method - former
  • Flat Insole
Methodology

- Foam Impression method
- CAD-CAM method
- Flat insole
Methodology

• Plantar pressure measurement
  • Foot orthoses fitted with 1cm heel height and laced sport shoes
  • Pedar insole sensor with correct size was select
  • zero setting
  • Walked along 10m pathway with his/her walking speed
  • Each trial- more then 10 steps
  • 3 successful trial taken in each condition
  • Conditions were taken in randomly
Methodology

• Data Analysis
  • Pedar multi-mask evaluation was used
  • Divided into 8 regions

1. Heel region
2. Medial mid-foot region
3. Lateral mid-foot region
4. Medial forefoot region
5. Mid-forefoot region
6. Lateral forefoot region
7. Hallux
8. Other toes
Methodology

- Parameters
  - Peak Pressure
  - Maximum force
  - Pressure time integral
  - Contact area
- SPSS statistical software (version 11.0)
  - One-way ANOVA tests
  - post hoc Tukey
Result

- **Peak Pressure**

![Peak Pressure in Eight Foot Regions](image)

- Flat Insole
- CAD-CAM provided orthosis
- Foam Impression provided orthosis
Result

• Peak Pressure - flat insole
Result

• Peak Pressure- CAD-CAM provided orthosis
Result

- Peak Pressure- Foam impression provided orthosis
Result

- Peak Pressure

Flat insole | CAD-CAM | Form impression
Result

- **Maximum force**

![Bar chart showing maximum force in eight foot regions.](chart.png)
Result

• Maximum force
**Result**

- **Pressure-time integral**

![Pressure-time Integral in Eight Foot Regions](image)

- **Flat Insole**
- **CAD-CAM provided orthosis**
- **Foam Impression provided orthosis**
Result

• Contact Area

Contact Area in Eight Foot Regions

<table>
<thead>
<tr>
<th></th>
<th>Flat insole</th>
<th>CAD-CAM provided orthosis</th>
<th>Foam Impression provided orthosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medial arch</td>
<td></td>
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<td></td>
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<tr>
<td>Lateral arch</td>
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<tr>
<td>Medial forefoot</td>
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<td>Mid forefoot</td>
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<td>Lateral forefoot</td>
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<tr>
<td>Big toe</td>
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<tr>
<td>Toe</td>
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</tbody>
</table>
Discussion

• Comparing among flat insole and total contact insole (CAD-CAM and foam impression)
  • Medial arch support in total contact insole contributed in
    • ↓ Peak pressure and maximum force in heel
    • ↑ peak pressure and maximum force in medial arch region
    • ↑ pressure-time integral in medial arch region
    • ↑ total contact area and area in medial arch region
Discussion

• Comparing among insoles provided by CAD-CAM and foam impression method
  • ↓ peak pressure and pressure-time integral in mid forefoot region in CAD-CAM provided orthosis
    • compression force was applied on the dorsum of mid foot in foam impression method
    • → transverse arch collapsed
    • Not in CAD-CAM → neutral metatarsal support during scanning
Discussion

- Comparing among insoles provided by CAD-CAM and foam impression method
  - ↑ contact area in medial arch region in CAD-CAM
- Foam impression method
  - Difficult to control subject’s foot
    - Applied force
    - Keep foot in subtalar neutral
Discussion

• Casting method and technique
  • Casting method and technique affected the outcome of the insoles
  • semi-weight bearing condition are different
    • percentages of weight-bearing in foam impression method were higher than CAD-CAM method
  • contact area of CAD-CAM insole was significant higher than the foam impressed insole
Discussion

• Suggested Guideline by selection of CAD-CAM and Foam Impression Methods
  • both methods can decrease heel pressure and increase medial arch support
  =>plantar fasciitis
Discussion

• Suggested Guideline by selection of CAD-CAM (Swiss Comfort) and Foam Impression Methods
  • CAD-CAM provided orthosis: reduced peak pressure and pressure-time integral in mid forefoot → callus or pain in 2nd and 3rd MTH
  • CAD-CAM provided orthosis: hallux valgus which associated with flatfeet / forefoot varus and flatfeet which associated forefoot / hindfoot structural disorder => foot alignment is easily control
Conclusion

• Total contact insole provided by both methods can redistribute peak pressure and maximum force from heel to medial mid foot area
• Swiss Comfort CAD-CAM System could provide similar result as the foam impression method did
References

References

• Murphy, D.F., Beynnon, B.D., Michelson, J.D., Vacek, P.M. Efficacy of plantar loading parameters during gait in terms of reliability, variability effect of gender and relationship between contact area and plantar pressure. Foot Ankle International, 2005, 26(2), 171-179.
Acknowledgements

• Dr. Aaron Leung, my supervisor
• Mr. Daniel Lo, my Hospital Department Manager
• Mr. Denis Wong, my service in-charge
• Mr. Noel Kwong, my colleagues
• All my subjects
Thank you