

## Initial experiences with clinical assessment of plantar tissue hardness in diabetes: A brief case series

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Plantar tissue assessment is important in the management of diabetic foot problems. As clinical assessment of plantar tissue hardness typically relies on palpation and observation only, durometer assessment is a potentially useful and feasible addition. This brief case series reports on initial experiences with the use of plantar tissue hardness measurement in 5 patients, together with plantar pressure measurement data. The results suggest some relationship between tissue hardness and peak plantar pressures (PPPs) at the forefoot. The data may suggest cut-off values, with forefoot tissue hardness <40 predicting safe PPPs and tissue hardness 60+ predicting dangerous PPP. However further research would be required to clarify these initial findings. Use of a durometer was found to be feasible within a clinical setting, and some initial data for comparison is provided. While assessment of plantar tissue hardness alone is unlikely to be a singular value which can guide treatment, it may offer a helpful addition to existing clinical assessments.

**Keywords:** diabetes, tissue hardness, durometer, tissue assessment, pressure

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Foot ulcers are a major source of morbidity in diabetes [1]. Risk factors for the development of foot ulcers include peripheral arterial disease, neuropathy and foot deformity [2,3]. Limited joint mobility and altered plantar tissue characteristics have also been shown to increase risk of ulceration [3, 4]. Plantar tissues in diabetes may become thinner, stiffer and harder [5, 6 ,4].

Plantar tissue hardness can be measured relatively easily using a durometer and this has been explored in experimental studies, including studies of people with diabetes [4,7,8]. Given that clinical assessment of plantar tissues typically relies on palpation, observation and subjective judgement only, the addition of durometer assessment is potentially helpful. This brief case series reports on initial

experiences with the clinical use of plantar tissue hardness measurement, together with plantar pressure measurement data.

### Methods

Skin hardness was measured with a durometer using the Shore O scale. The patient was positioned in supine and the durometer was applied perpendicularly to the foot for 3 seconds before taking the reading. Selected peak plantar pressures (PPP) were also recorded as part of the assessment, using the Pressure Guardian system (Tillges technologies, USA). Plantar pressures were recorded during walking at self-selected pace, with the subject wearing their usual shoes with a 3.2mm grey poron 4000 polyurethane inlay (Algeos, UK) only inside the shoe, in line with

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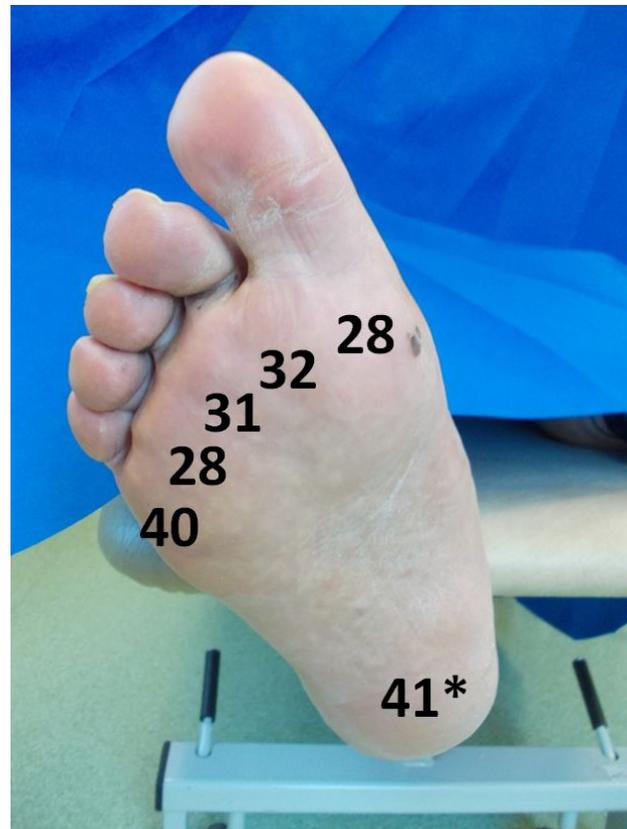
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the department's protocol. Recorded PPP were compared to the 200kPa threshold, which has been tentatively proposed as a dangerous level of pressure [9]. Patients gave written informed consent for use of the information in this article.

Case 1

Subject 1 is a 60-year old male with type 2 diabetes and a left sided trans-tibial amputation. The remaining right foot has a history of ulceration at the interphalangeal joint of the hallux only, and the foot has been intact for over 1 year. The plantar tissues appeared in good condition except a small area of discolouration at the 1<sup>st</sup> metatarsal-phalangeal joint (MPJ), representing a small 'blood blister'. Plantar tissue hardness was tested at the heel and all MPJs (Figure 1) and ranged between 28 – 41 shore O. PPP were measured at MPJs 1 and 3 in addition to the heel. Only the heel exceeded 200kPa (Table 1).



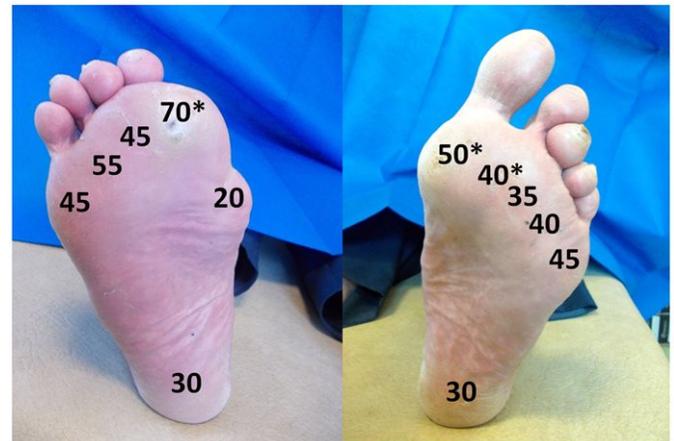
**Figure 1** View of plantar tissues with shore hardness values (peak plantar pressures exceeding 200kPa indicated by '\*') - Subject 1.

Location	Hardness (Shore O) of skin – Right foot [kPa with 3mm poron]
1 <sup>st</sup> MPJ	191 [191.26]
3 <sup>rd</sup> MPJ	80 [80.19]
Heel	236* [235.73]

**Table 1** Plantar tissue hardness and peak plantar pressures – subject 1.

Case 2

Subject 1 is a 70-year old male with type 2 diabetes and a right amputation through the first metatarsal. There is a history of ulceration at the right 2<sup>nd</sup> MPJ and distal aspect of the left 3<sup>rd</sup> toe and the right 2<sup>nd</sup> MPJ ulcer has been open within the prior 3 months. The plantar tissues appeared thin and dry, with reduced padding under the MPJs. Callus was visible particularly at the right 2<sup>nd</sup> MPJ and left 1<sup>st</sup> and 2<sup>nd</sup> MPJ. Plantar tissue hardness was tested at the heel, all MPJs and the cut end of the right 1<sup>st</sup> metatarsal (Figure 2) and ranged between 20 – 70 shore O. PPP were measured at MPJs 1 (cut end of metatarsal on right), 2 and 5 in addition to the heel. The right 2<sup>nd</sup> MPJ and left MPJs 1-2 exceeded 200kPa (Table 2).



**Figure 2** View of plantar tissues with shore hardness values (peak plantar pressures exceeding 200kPa indicated by '\*') - Subject 2.

Location	Hardness (Shore O) of skin – Right foot (1 <sup>st</sup> ray amputation)	Hardness (Shore O) of skin – Left foot
1 <sup>st</sup> MPJ	20 (cut end of 1 <sup>st</sup> metatarsal) [118.52]	50* [423.34]
2 <sup>nd</sup> MPJ	70* [563.99]	40* [254.62]
3 <sup>rd</sup> MPJ	45	35
4 <sup>th</sup> MPJ	55	40
5 <sup>th</sup> MPJ	45 [78.74]	45 [74.46]
Heel	30 [108.11]	30 [123.35]

**Table 2** Plantar tissue hardness and peak plantar pressures – Subject 2 (\*location which exceeds 200kPa when walking on 3mm grey poron. Note sites tested for pressure = 1<sup>st</sup> MPJ, 2<sup>nd</sup> MPJ, 5<sup>th</sup> MPJ, heel).

Case 3

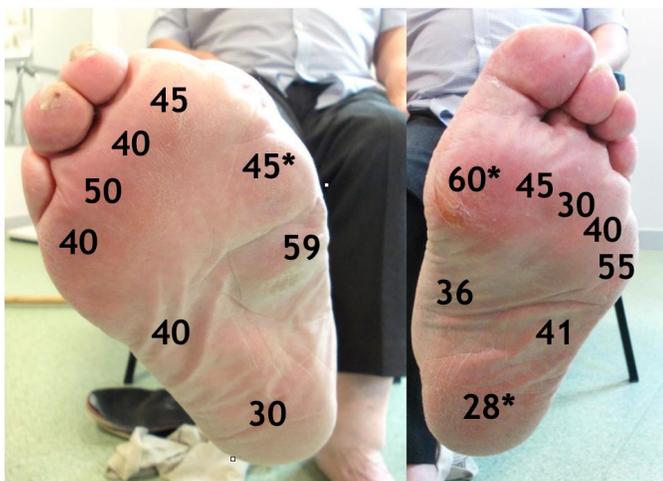
Subject 3 is a 70-year old male with type 2 diabetes. He has an amputation through the right first metatarsal in addition to removal of the right second toe. There is a history of ulceration at the left 1<sup>st</sup> MPJ and distal aspect of the right 4<sup>th</sup> toe but the feet have been ulcer free for over 12 months. The plantar tissues appeared generally good, with reasonable padding under most of the MPJs, but callus present at the left 1<sup>st</sup> MPJ and distal aspect of the right 4<sup>th</sup> toe. Plantar tissue hardness was tested at the heel, all MPJs, the cut end of the right 1<sup>st</sup> metatarsal and medial/lateral aspects of the plantar midfoot (Figure 3) and ranged between 28 – 60 shore O. PPPs were measured at MPJs 1 (cut end of metatarsal on right), 2 and 5 in addition to the heel. The right cut end of 1<sup>st</sup> metatarsal and left 1<sup>st</sup> MPJs exceeded 200kPa (Table 3).

Location	Hardness (Shore O) of skin – Right foot (1 <sup>st</sup> ray amputation) [peak plantar pressure on 3mm poron / custom foot orthosis - kPa]	Hardness (Shore O) of skin – Left foot [peak plantar pressure on 3mm poron / custom foot orthosis - kPa]
1 <sup>st</sup> MPJ	55 (cut end of 1 <sup>st</sup> metatarsal)* [234/177]	60* [330/306]
2 <sup>nd</sup> MPJ	45 [157/55]	45 [25/132]
3 <sup>rd</sup> MPJ	40	30
4 <sup>th</sup> MPJ	50	40
5 <sup>th</sup> MPJ	40 [113/39]	55 [18/26]
Medial arch	59	36
Lateral arch	40	41
Heel	30 [138/165]	28* [221/136]

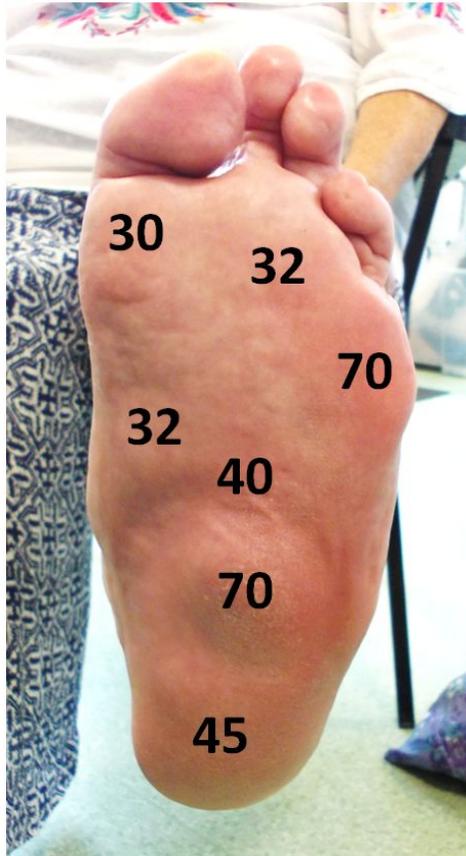
**Table 3** Plantar tissue hardness and peak plantar pressures – Subject 3 (\*location which exceeds 200kPa when walking on 3mm grey poron. Note sites tested for pressure= 1<sup>st</sup> MPJ, 2<sup>nd</sup> MPJ, 5<sup>th</sup> MPJ, heel).

Case 4

Subject 4 is a 60-year old female with type 2 diabetes. She has a right trans-tibial amputation and a history of Charcot foot on the left in addition to removal of the left 5<sup>th</sup> toe. There is a history of ulceration, most recently at the dorsal hallux but the feet have been ulcer free for over 12 months. The plantar tissues appear in generally good condition, with reduced padding under the MPJs, and a very prominent lateral plantar midfoot. Plantar tissue hardness was tested at the heel, MPJs 1,3 and 5, medial arch, lateral plantar Charcot midfoot prominence and the skin adjacent to the midfoot prominence (Figure 4) and ranged between 30-70 Shore O. PPPs were only measured at the lateral plantar Charcot midfoot prominence, and exceeded 200kPa (Table 4).



**Figure 3** View of plantar tissues with shore hardness values (peak plantar pressures exceeding 200kPa indicated by \*\*) - Subject 3.



**Figure 4** View of plantar tissues with shore hardness values - Subject 4.

Location	Hardness (Shore O) of skin
1 <sup>st</sup> MPJ	30
2 <sup>nd</sup> MPJ	32
3 <sup>rd</sup> MPJ	32
4 <sup>th</sup> MPJ	33
5 <sup>th</sup> MPJ	70
Medial arch	32
Lateral midfoot Charcot prominence under cuboid region	70* [509kPa]
Tissue adjacent to Charcot prominence	40
Heel	45

**Table 4** Plantar tissue hardness and peak plantar pressures – Subject 4. (\*location which exceeds 200kPa when walking on 3mm grey poron. Note site tested for pressure = Lateral midfoot Charcot prominence under cuboid region).

### Case 5

Subject 5 is a 75-year old male with type 2 diabetes. He has a history of Charcot foot on the right side, causing medial collapse around the talonavicular joint. There is a history of ulceration, and at the most recent assessment there were active ulcers at the right medial navicular/cuneiform region and right 5<sup>th</sup> toe. The plantar tissues appear dry, with reduced padding under the MPJs, and callus under the 1<sup>st</sup> and 2<sup>nd</sup> MPJs bilaterally (Figure 5). Plantar tissue hardness was tested at the heel, MPJs 1,2 and 3, and ranged between 40-78 Shore O. PPPs were measured at the heel, MPJs 1,2 and 3, and exceeded 200kPa at the 1<sup>st</sup> and 2<sup>nd</sup> MPJs bilaterally (Table 5).



**Figure 5** View of plantar tissues with shore hardness values (peak plantar pressures exceeding 200kPa indicated by “\*”) - Subject 5.

Location	Hardness (Shore O) of skin – Right (Charcot side) [peak plantar pressure on 3mm poron / custom foot orthosis - kPa]	Hardness (Shore O) of skin – Left [peak plantar pressure on 3mm poron / custom foot orthosis - kPa]
1 <sup>st</sup> MPJ	60* [307 / 91]	73* [291 / 94]
2 <sup>nd</sup> MPJ	78* [257 / 65]	50* [360 / 136]
3 <sup>rd</sup> MPJ	40 [32 / 27]	42 [152 / 71]
Heel	45 [61 / 26]	45 [169 / 111]

**Table 5** Plantar tissue hardness and peak plantar pressures – Subject 5 (\*location which exceeds 200kPa when walking on 3mm grey poron).

## Discussion

A wide range of tissue hardness values were recorded, ranging between 20-78 Shore O. PPP also varied widely, between 18-564kPa. Considering the plantar heel, a smaller range of hardness values was recorded, between 28-45 Shore O. This is similar to the 35-50 (Shore A) reported in a diabetic group by another author [8]. Two heels exceeded 200kPa when tested – their hardness values were 28 and 41 Shore O (mean 35). The remaining heels with both durometer and pressure data (n=5) had a mean hardness of 36 Shore O. This, combined with the fact that the two hardest heels (45 Shore O) did not exceed the pressure threshold, does not seem to show an obvious prediction of high pressures by testing tissue hardness at the heel. The forefoot included higher hardness values, ranging between 28-78 Shore O. This is a wider range than the 45-50 Shore A reported by Martinez Santos [8]. Eight MPJs tested exceeded 200kPa; the average tissue hardness of these sites was 60 Shore O. In comparison, the remaining MPJs with both durometer and pressure data (n=18) had a mean tissue hardness of 42 Shore O. Forefoot hardness values of 60 Shore O or higher always predicted PPPs exceeding 200kPa. However of 11 sites exceeding 200kPa, five (45%) had tissue hardness values below 60 Shore O. Forefoot hardness values below 40 were never associated with PPP exceeding 200kPa. While these observations seem to show some relationship between forefoot tissue hardness and dynamic PPP, which has been observed elsewhere, it would appear that other factors also influence PPP [10]. The data may suggest cut-off values, with all tissue hardness <40 predicting safe PPPs and all tissue hardness 60+ predicting dangerous PPP. This could suggest that durometer testing of forefoot tissues offers an alternative to instrumented pressure measurement, in contexts where this technology is unavailable. However further research would be required to clarify these initial findings.

## Conclusion

Use of a durometer was found to be feasible within a clinical setting, and some initial data for comparison is provided. Hardness testing offers quantification of more subjective assessment methods such as palpation. While plantar tissue hardness alone is unlikely to be a singular value which can guide

treatment, it may offer a helpful addition to existing clinical assessments.

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