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A comparison of trial shoe and shell shoe fitting techniques

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Abstract

In Europe, bespoke orthopaedic shoes are usually sent for a trial fitting in order to check the fit and indicate any modifications required before final finishing. The use of shell shoes at the fit assessment stage, rather than the traditional alternative of partially or fully finished shoes, can offer service advantages, and is widely used for example in the Netherlands. However the comparability of shell fit assessment with the traditional method of trial shoe fit assessment has not been evaluated, either to assess its sensitivity or to elucidate any difference in assessment technique required of the orthotist. In this work, the results of fit assessments by both methods are compared. The trial involved a group of normal subjects wearing high street shoes of styles similar to those used for orthopaedic footwear. The results indicate that the shell fit assessments were in the main comparable to those for trial shoe fit. The only consistent area of deviation noted, in the heel at the topline, is attributable to a construction factor in shoe making. Apart from this area, the orthotist need not adjust his technique to make use of the shell method.

Introduction

In the orthopaedic shoe trade in the UK, bespoke shoes are made to measure or from casts, and usually sent for fitting at the stage of rough finishing, i.e. with the uppers tacked in place and a temporary sole attached. However in continental Europe fit assessment is often made on the basis of a shell shoe, made by vacuum moulding PVC materials over the shoe last (the model over which the shoe is constructed) to form a temporary shoe (Fig.1). This has the advantage that the shoe need not be constructed before fit assessment is made, which reduces both the time to the first fit and materials wastage in achieving the final shoe. Because the shoe last shape is adjusted before patterns and shoe uppers are cut, more complex styles can be attempted with confidence.

Questions remain as to the comparability of fit assessments made using these two techniques. Does the person performing the fitting have to make allowances for the two methods? To what extent does an assessment made with a shell accurately indicate the fit of the final shoe? The process of fit assessment by either method is a skill rather than a science, which reflects the basic lack of quantification of what constitutes a good fit (Rossi, 1983). Fit assessment is an area of considerable impact on the volume shoe trade, and one where increased effort has been expended recently in view of the trend towards more quantitative descriptions needed for computer aided design systems (Browne, 1993; van der Zande *et al.*, 1995).

There are two groups of factors which affect

Fig. 1. One of the shell shoes made for this trial.

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the perceived fit of a pair of shoes on any individual. The most obvious group are attributable solely to the shoe, and relate to its dimensions and material properties — the shoe related factors. The last shape and shoe construction are two of the most important factors in this group. Shell fitting differs from trial shoe fitting in that the last shape factor may be identical but the construction factor is not. Also important to fit however are a group of factors relating to an individual's requirements — the subject related factors. These encompass the degree of flexibility of the foot, subjective preference for tightness, and pathology giving special problems such as hypersensitivity. The perceived fit of shell shoes may be affected by the different and unfamiliar feel compared to ordinary shoes.

In this investigations the authors set out to study the shoe related factors in making a fit assessment. This was done mainly by noting the fitter's assessment. The specific objectives of the study, part of a doctoral thesis (Chen, 1993) were:

- to document a procedure for assessing shell shoe fitting
- to compare assessment of fit by shell shoes and normal shoes for normal subjects
- to identify limitations of shell shoes fitting
- to separate fit factors due to last shaping from those due to shoe construction.

Fit assessment procedure

The assessment of fit is of its nature subjective. However, extensive fit assessments are routinely made in the volume trade before a new model of last and shoe is approved for production. Therefore considerable experience resides in the fitting departments at shoe manufacturing companies (as opposed to the limited skill in shoe shops). This expertise was tapped for the study. The protocol described below was derived from the fit assessment procedure used at C & J Clark International, Street, Somerset, UK. The method is also compatible with the British Standard 5943 (1980) Methods for Measurement and Recording for Orthopaedic Footwear.

The foot is first placed into the shoe and the shoe is then firmly fastened. Fit is assessed in the following areas during partial weight bearing as defined in British Standard 5943 i.e. with the subject seated, the shin vertical and the weight of the limbs applied through the feet.

Forepart

Length allowance – Assess the effective length in front of the toes by pressing (shoes) or viewing (shells) and compare with the standard of around 8 mm for fashion shoes, or up to 15 mm for orthopaedic shoes. The effective length extends to where the shoe is still deep enough to accommodate the toes, which may exclude the end part in pointed or shallow toe boxes.

Forepart width – Check the width of the shoe across the joint. First locate the joint of the foot by palpation; this is the widest part of the forepart, running from the first to fifth metatarsal heads. The width in the forepart is correct if there is no excessive pressure across the joint or empty space to the sides of the foot.

Alignment – Check that the foot shape is aligned correctly in plan view in the forepart of the shoe and there is no centrally directed pressure on the big toe and the smallest toe.

Forepart depth – Squeeze the vamp area of the shoe across the joint inward from the medial and lateral side walls. If there are too many creases at the vamp of the upper, the forepart is too deep. Check that the forepart is not too tight (may also be the result of insufficient width). Check that there is sufficient clearance on the toes by palpation (shoes) or visually (shells).

Heel-to-ball length – Ensure that the ball of the foot is correctly positioned in the shoe. In this position, the joint of the foot should be aligned from the medial side to the widest part of the shoe. If the heel-to-ball measure of the shoe is too long, there will be a gap between the heel and the backseam of the shoe. If it is too short, the heel will be forced uncomfortably back in the shoe or the ball of the foot will be forced too far forward in the shoe.

Midfoot

Waist fit – Assess the fit of the waist especially checking the arch area. Check both the medial or lateral areas by pressing on the shoe/shell.

Instep fit – Record the facing gap or overlap and check it with the original design (shoes). For shells, the cut line at the facings should just meet.

Quarters

Topline – Observe the topline, i.e. the opening around the ankle. Feel with fingers along the front section of the topline to make sure it fits neatly against the foot.

Under ankle height – Observe any pressure on the medial and lateral malleoli. The malleoli must be clear of the topline, although this may not be necessary if the topline is padded.

Backpart

Seat width – Assess whether the width of the heel seat is adequate. If the heel can be rocked in the shoe, the seat may be too wide – if the foot is too wide for the seat, it will tend to flatten the sides and cause gaping at the topline under the ankle.

Heel curve – Observe any excessive pressure or gaping at the top of the back seam (or in the case of a shell, the notional position of the back seam).

Heel grip – This final assessment is done initially during walking. First observe any heel slip which occurs during walking. Then ask the subject to sit down, lift the foot, and pull firmly down on the shoe heel which should not slip. Note if there appears to be excessive grip pressure from indentation of the skin.

It is not deemed possible to categorise fit more accurately than to a five-point scale. Each feature was put into one of these categories:

UA– too tight/small
AO– adequate: on the tight/small side
OK good fit
AO+ adequate: on the loose/large side
UA+ to loose/large

Shell shoe making

Shell shoes were made over the production shoe lasts for each of the models of shoe selected. These were made of a transparent material using a fairly stiff 500 μ PVC for the heel area and side walls, and more flexible 200 μ PVC over the top of the vamp. The shoe last was mounted bottom up in a vacuum moulding machine with the shoe insole already in place. The thinner stiff PVC was vacuum moulded over the bottom and sides, Figure 2.

Fig. 2. The first part of the PVC shell is formed by moulding over the bottom of the last: an example sole unit is also shown.

The sides were then trimmed *in situ* to leave the heel area and the side walls extending down the quarter and vamp right to the toe. Small 'v' notches were cut into the side wall to facilitate flexing at the metatarsal break during walking. Glue was applied around the edge of the walls, the last was turned upright, and the softer thicker PVC was vacuum moulded over the top of the last. This forms a closed shell. The same sole unit as used on the trial shoe was then attached, and the production insole inserted.

The top line of the uppers was trimmed consistently according to a set of geometric construction rules used by Dutch orthopaedic shoe-makers, which results in a standardised backseam height, under-ankle height and vamp point (the point corresponding to the base of the lace panel in standard Gibson style shoes). The vamp was split to allow for foot entry, and small holes were punched into the PVC to form a mock lace panel.

Trial protocol

Shoes: Four styles of Clarks shoes were chosen, representative of typical styles which could be used for orthopaedic footwear, i.e. low heeled shoes (heel height lower than 4 mm) with lace fastening over the instep (Fig. 3). These styles were named 2nd Nature, Nocturne, Ohio and Pop-life. The lasts on which these styles were made were all different shapes: the 2nd Nature has a 'natureform' shape with a straight medial border and wide round toe box, the Ohio style is a moccasin, while the other two were more traditional designs. Standard last measures were taken to give evidence of the differences in designs and for further studies of

Fig. 3. This shows the natureform trial shoe and its matching shell.

the allowances between foot and last measures, although these are not discussed further here.

Subjects: Asymptomatic female subjects were used in the study. These were drawn from the usual staff volunteer panel used for assessment of new models of shoes at a large UK volume shoe manufacturers, C & J Clark International, Street, Somerset. The subjects are all deemed to represent average customers having no reported foot problems. There were ten subjects of nominal size UK 5D, continental 38, seven of whom tested each of three styles (2nd Nature, Nocturne and Ohio); the three remaining subjects tested only two styles because one style was not available at the time. A further eight subjects of nominal size UK 4E, continental 37, tested a single different style (Pop-life). Eight subjects were in the age group 16-25, five subjects in the age group 26-35, three subjects in the age group 36-45 and one subject each in the age groups 46-55 and 56-65. No further selection criteria were used.

Procedure: Each subject was brought to the fitting room, the trial procedure was explained and verbal consent gained. The feet were then measured by one of the authors, RCC, according to BS 5943. Assessments of shoes or shells, and different styles where applicable, were carried out in a random order. Although it would have been preferable to separate the two assessments in time, this was not feasible because of the time constraints on the subjects. All assessments were made by the senior fitter at Clarks (JT), with RCC recording the results. Additionally, spontaneous subjective comments regarding fit were noted.

Results

Foot measurements

The foot measurements are shown in Table 1. In the first section on foot length, the difference in foot length measures between the nominal UK sizes 4 and 5 subjects is as expected: an increase of approximately 10 mm (4.4%) in the average foot length corresponds to the standard shoe length increment of 8.5 mm ($^1/_3$ inch) per size. The average joint girth differed by 3 mm (1.3%) compared to a full width size of 6.5 mm; in the UK sizing system, the 5D and 4E shoes nominally have the same girth. Other girth averages are comparable between the two sizes i.e. less than a full width difference, and no consistent differences in the heights taken were noted.

The wide ranges in the measures may appear large for subjects nominally the same size, representing for example ±3% of stick length,

Table 1. Foot measurements in the groups 4E and 5D in millimetres.

Foot measurements	4E Subjects, n = 8		5E Subjects, n = 10	
	Average	Range	Average	Range
Foot (stick) length	228	220 - 233	238	232 - 242
Medial heel to ball	169	165 - 173	178	171 - 189
Joint girth	227	219 - 239	230	221 - 238
Waist girth	218	211 - 227	222	212 - 228
Instep girth	230	221 - 242	234	228 - 237
Short heel girth	302	285 - 317	309	300 - 320
Height over 1st metatarsal head	36	32 - 37	35	30 - 38
Instep height	57	50 - 62	58	49 - 64
Joint width	90	86 - 96	91	86 - 94

and ±4% of joint girth. These ranges however are of the order of one full size or width fitting, and, due to the complex combination of measures and foot shape that produce a given nominal size, the ranges are not dissimilar to other (internal) survey data from Clarks.

Fit assessment

An example chart collating the results for all forefoot width fit assessment is shown in Table 2; this demonstrates the closeness of the assessments for shell and sample shoe fit. In all except two cases the fit is in the same category, and then these two cases are in adjacent categories.

Note that the majority of fit is in the central categories, which is expected since these subjects were fitted with shoes of their own nominal size. Some of the shoes were deemed too tight for the subjects, but none too loose. It is also apparent that the Nature form design was looser in the forepart on average, which corresponds to its wider design.

A summary chart for all assessments of all features (Table 3) indicates that the majority of the fits were adequate, and for most features, a good fit was seen at both shell and trial shoe assessments. Again, the number of assessments in each category comparing shoe or shell fit are remarkably similar, differing by only one except for a trend in the heel area where the shells were assessed to be looser.

General observations

Most of the subjects reported that the shell shoes felt slightly bigger than the trial shoes.

Table 2. Example of chart for forefoot width fit, all assessments

Subject	Shoe Style	UA-	AO-	OK	AO+	UA+
4E01	Pop-life		*#			
4E02	Pop-life		*#			
4E03	Pop-life	*#				
4E04	Pop-life			*#		
4E05	Pop-life			*#		
4E06	Pop-life		*#			
4E07	Pop-life		*#			
4E08	Pop-life	*#				
5D01	Nocturne		*#			
	Ohio			*#		
	2nd Nature			*#		
5D02	Nocturne		*	#		
	Ohio			*#		
	2nd Nature			*#		
5D03	Nocturne		#	*		
	2nd Nature				*#	
5D04	Nocturne		*#			
	2nd Nature				*#	
5D05	Nocturne		*#			
	2nd Nature			*#		
5D06	Nocturne		*#			
	Ohio		*#			
	2nd Nature			*#		
5D07	Nocturne			*#		
	Ohio			*#		
	2nd Nature			*#		
5D08	Nocturne			*#		
	Ohio			*#		
	2nd Nature				*#	
5D09	Nocturne		*#			
	Ohio		*#			
	2nd Nature			*#		
5D10	Nocturne			*#		
	Ohio				*#	
	2nd Nature				*#	

* indicates trial shoe fit, #indicates shell shoe fit.

Table 3. For all assessments of all features, the number occurring in a given fit category

Features		Number of assessments (n = 35)				
		UA-	AO-	OK	AO+	UA+
Length allowance	Shoes	2	2	26	4	1
	Shells	2	1	27	4	1
Forepart width	Shoes	2	12	16	5	–
	Shells	2	11	17	5	–
Alignment	Shoes	–	–	29*	–	–
	Shells	–	–	29*	–	–
Forepart depth	Shoes	3	8	16	8	–
	Shells	3	8	16	8	–
Heel-to-ball length	Shoes	1	6	28	–	–
	Shells	1	6	28	–	–
Waist fit	Shoes	1	6	25	3	–
	Shells	1	5	26	3	–
Instep fit	Shoes	3	8	21	3	–
	Shells	3	7	22	3	–
Top line	Shoes	1	2	30	2	–
	Shells	1	2	30	2	–
Under ankle height	Shoes	–	–	35	–	–
	Shells	–	–	35	–	–
Heel seat width	Shoes	–	5	30	–	–
	Shells	–	5	30	–	–
Heel curve	Shoes	–	1	32	2	–
	Shells	–	1	28	4	2
Heel grip	Shoes	–	3	30	2	–
	Shells	–	1	10	20	4

* it was not possible to assess this feature in six cases where the foot was too wide for the shoe and caused distortion of the forepart.

With shell shoes, white patches on skin were seen on almost every subject, even where fit was satisfactory to the experienced shoe-fitters and subjects. At the topline point on mid-line of the forepart cone, the shells exhibited pressure to one side, at the medial (instep) dorsum of the foot. Pressure was also seen in the heel area and around the joint.

Discussion

The main purpose of this trial was to compare the results of shell shoe fitting with those of trial shoe fitting. The results indicate that, for these subjects and shoes, the outcome of the two methods is very similar.

Only in the region of the heel were there any differences of note. The majority of the shell assessments were one category looser than the trial shoe assessments. This was not unexpected: it is normal practice to apply a 'heel clip', or removal of material, to the shoe upper patterns at the topline in the region of the heel backseam so that an adequate heel grip is obtained. A shell shoe obviously cannot incorporate this feature.

On the whole the subjects reported that the shoes were tighter than the shells. This phenomenon might be attributed to any of the following possibilities:

- Where a shoe is formed by machine pulling the leather upper over the last, shrinkage occurs after the last is pulled out of the shoe; all the assessed shoes were made by machine lasting methods, and hence they would be slightly smaller than the last. In contract, bespoke orthopaedic shoes are infrequently machine lasted.
- Different materials caused different sensations to subjects. Although shells are made from soft PVC material, it is not soft enough to mould to the foot closely. In addition the surface of PVC is too smooth to grasp the foot. This may cause some feelings of looseness for the subjects.

Many orthopaedic companies have experimented with, or use, alternative materials for making shells which more closely resemble both the feel and compliance of leather. These may be superior in respect of sensation although they are not transparent and do not allow visual inspection.

The shells allowed the fitter to observe the regions in which pressure is applied to the dorsum, thereby causing the skin to whiten by occluding blood supply. It appears that such pressure on skin is tolerable to the normal foot. It would be instructive to define what level of pressure causes whitening vs. tolerable pressures on tissues, coupled to the limits of sustainable pressure and duration. Although this type of data is available for tissues involved in pressure sore formation, they are not known for the foot as yet. It is also noted that pressure levels tolerated on a normal foot might not be permissible in pathological conditions. This is an area in shell shoe fitting where only experience can at the moment be applied.

From the results, it would appear that of the shoe related fit factors, the construction factors are secondary to the last shape in determining initial fit. However, the shell cannot give any indication of problems which might arise due to poorly located seams, stitching or leather stressing. Normally, unlike fashion shoe styles, orthopaedic shoe styles are carefully controlled to avoid any possibility of these problems arising in any case.

The objective of this research is to provide information of use to the orthopaedic service. It is valid therefore to query whether a trial of normal shoes on normal subjects reflects the potential of shell shoe fitting for orthopaedic cases. It is already known, however, that the method is used successfully in European countries for fitting of bespoke orthopaedic shoes. The research primarily indicates that the fitting with shell shoes needs little modification to the orthotist's technique, since both shell and trial methods gave the same result. That is to say, the only compensation needed in interpretation of the fit is in the area of the heel grip.

Conclusion

In the process of supply of bespoke orthopaedic shoes, assessment of fit by shell shoes offers a method to improve service delivery. This research indicates that fit assessment by shell shoes provides very similar results to that by trial shoes, except in the area of heel grip where the fit of the shell shoes is one category looser. The orthotist need not otherwise adjust his fitting procedure to take advantage of this technique.

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