CAN FLOORING AND UNDERLAY MATERIALS REDUCE THE NUMBER OF HIP FRACTURES IN THE ELDERLY?

Professor R J Minns, Regional Medical Physics Department, Newcastle General Hospital, Westgate Rd, Newcastle Upon Tyne, NE4 6BE.
Email: **julian.minns@nuth.northy.nhs.uk** Tel:0191 273 8811 ext 22658
F Nabhani, J Bamford, Department Mech Engineering, Univ Teesside
J Rich, PolarSeal, Farnham, Surrey.

INTRODUCTION

Falls resulting in the fracture of the hip in elderly people are a major health problem worldwide. In England and Wales, 20 percent of Orthopaedic beds were occupied by patients undergoing treatment for the repair of a fracture of the hip. Women in the home are 2 ½ times more likely to fracture their hips than men, this figure rises to 4 times in women over 65 yrs old [Myers et al ,1991]. In 1989, 43,220 patients were treated in England and Wales, 60,000 in the UK in 1994 at a cost then of £742 million, predicted to rise to 70,000 plus in 2001. The average hospital stay in 1989 was 30 days at a cost of £160 million, An estimate is these figures will rise to 94,000 in 2006 and 117,000 by 2016. The rate of fractures varies from the US at 100 plus per 100,000 to less than 5 for the South African Bantu, the value in the UK is 63/100,000 [Nevitt et al, 1991]. This may be because of the place fractures from falls occur in the developed world are in Institutions and the home with hard floors and stairs [Tinetti et al, 1994]. The people at high risk of a fracture are more likely to be over 75 years old, unwell with multiple pathology, fall indoors, and have fallen before. Patients between 65 to 74 years old are more likely to fall from external environmental hazards, and overall over 50 percent of fractures are due to falls from tripping at home, rising for patients older than 75 years old [Nevitt et al, 1993].

Poor flooring which is slippery and unsuitable footwear are other major factors contributing to the onset of fractures in the home, and the design of buildings should incorporate measures to minimise the risk of falls [R Coll Physicians, 1989]. This report stressed that even a small percentage reduction in the incidence of hip fractures would save several £million in health care costs. The type of floor can be modified using a honeycomb structure under the surface to reduce the peak impact forces on the femur such as that developed at Penn State University [Casalena et al, 1998], but this requires major structural changes to be incorporated at the building stage and is an impractical solution in homes or Hospitals already built.

The floor covering is a significant factor in the likelihood of a patient falling down and sustaining a fracture of the hip [Healy, 1994], and the type of floor covering in a very small trial [Booth et al, 1996] indicates that thicker carpet (7mm) gave a fourfold decrease in fracture incidence over a Vinyl floor covering although no information on Underlays were given in this study. The peak force from an object dropping onto a hard surface may be substantially reduced by selecting an appropriate floor covering [Maki and Fermie, 1990], no work has been performed on the effect of the underlays underneath floor coverings and this could have a major effect on the number of hip fractures.

MATERIALS AND METHODS

RIG DESIGN

It consists of a framework that allows a plunger to be loaded with up to 40Kg and be dropped onto the hip from heights of up to 0.51 m. A drop height of 0.51 m has been chosen in this study to obtain a typical impact velocity in a fall. The impact velocity is 3.16 ms^{-1} and this is within the typical impact velocity range of 3.19 ± 0.45 ms^{-1} [Van der Kroonenberg et al, 1993]. In all experiments, the effective mass of the plunger was 24 Kg. Thus the striker mass had a kinetic energy value of 120J on impact. This energy value has been chosen because it is a typical impact energy from simulated falls in laboratory studies [Robinovitch et al, 1991].

At the centre of the aluminium base there is a pin that transmits the impact force to a load cell. The central pin has a curved surface that has a radius of 50 mm in both planes and has a 5mm fillet to prevent sharp edges when raised. It can be raised upward in 1mm steps using washers above the load cell. In this study, the pin was raised 1mm to give a realistic profile. Skin was simulated using a 5 mm layer of silicone elastomer with a fabric base layer (Silipos (UK) Ltd. Middlesex, UK) on the aluminium base.

The test rig is clamped within a metal cabinet frame to give it stability. It also gave a solid fixing point for the release mechanism to be attached at the predetermined height. The cabinet was sited on a concrete floor and the base was packed with a metal block to ensure that it was solid. To ensure low friction as the pulley falls, a linear bearing was used. Flooring materials such as carpets with or without underlay could be attached to the underneath of the weight carrier. A quick release mechanism was used to drop the pulley from the predetermined height.

The carpet material was a conventional fabric backed luxury pile carpet made with open tufted polyester fibres.

The test materials are shown in Figure 1.

The Vinyls were either 3mm Rhinofloor™ Aristocrat manufactured by Armstrong with a wear layer of 0.35mm and a 2.65 mm foam backing or a 1.5mm thick vinyl with no foam backing.

The tested Underlays were:

Conventional 7mm thick Rubber Latex foam moulded into a “Waffle” type structure with a textiled fabric backing. The latex foam is actually 3mm thick.

7mm Treadaire™ Festival Latex sponge moulded with a fine ribbed pattern and with a polyester reinforced backing.

7mm Duralay Treadmore™ Rubber crumb underlay with a polyester fabric backing. Both these two Underlays are produced by Interfloor Ltd (Dumfries, Scotland).

6mm Sorbotec™ 2070 (Sorbothane, Leyland, Lancs) is a viscoelastic polymeric compound used in the Orthotic trade as a shock-absorbing material within insoles and for industrial anti-vibration applications such as the damping of oscillating machinery.

12.5mm PVC closed cell foam samples were also tested as a potential shock absorbing material, this material was produced by PolarSeal Ltd (Farnham, Surrey).

Polyurethane foams such as Poron™ (Rogers Corporation) were also considered but these were shown to not withstand repeated loading and had undesirable absorbent properties.

RESULTS

With no floor covering the peak force recorded was 7kN and this value was used to determine the percentage reduction in peak force for the materials tested. The thin noise reducing foam used under vinyl and wooden flooring offers no impact reduction.

Carpet

12mm PVC foam produced the best energy absorbance and minimum peak force over any other underlay materials, followed by 2 thicknesses of Treadmore. The other combinations were all above 2kN, the rubber foam and the Treadaire material provided little protection and reduction in the peak forces (Fig 2).

Vinyl

The variation of peak force with material has a similar trend to the carpet results. The Rubber underlay has very little effect on the peak force reduction and consequently provides little protection to the risk of fracture. There is only a slight reduction in the peak force for all the materials for the thicker Vinyl as expected since 2 mm of foam backing is not substantial enough to contribute to the overall energy and force reduction when impacted (Fig 3).
Fabrication of the PVC foam into a flexible workable form may be difficult as it is a rigid form that does not stretch or bend easily during laying and positioning. A quicker immediate solution to provide protection with existing materials could be to use two or even three layers of the Treadmore™ underlay as the reduction of peak force under the carpet may be below the level that may be expected to fracture the hip.

The summary results of the energy absorption and the reduction in peak force is shown in Table 1.

DISCUSSION

Impact testing on current conventional underlays under carpets regardless of the composition and construction of the carpet suggest they offer poor energy absorption when the elderly fall, and thin and thick vinyl floors are even poorer at reducing the energy that may fracture a hip in an elderly person.

There are many solid and foam materials which provide energy absorption and can be fabricated to provide underlay protection under floor covering materials but are expensive and can be rigid and difficult to roll and lay. Retrospective measures such as floor mats, could be put in areas where the elderly are known to fall and break their hip, next to the bed is a common site. However, floor mats present another potential source of tripping and are only transient measures[Wolf-Klein et al, 1988]. The underlay, and its role as reducing the energy and peak forces transmitted to the hip from a lateral fall onto the greater trochanter, provides a more permanent solution and because it is hidden from view, aspects of texture and colour are not considerations for purchasers of floor coverings.

We have clearly shown that the impact resistance of conventional floor coverings such as the common Vinyls and carpets are not necessarily improved to levels that would reduce the energy levels and peak forces to safe levels with the pressed rubber foam underlays that are commonly used. The Compound rubbers and rubber crumb underlays can offer a large reduction in energy absorption, but we have found that Sorbothane and PVC foam offer the best reduction although they have to be at least 12 mm thick to reduce the values to below those likely to fracture the hip from a fall. Thick underlays greater than 15mm may present other problems such as traction of wheeled devices (Hoists/wheelchairs) and we are currently evaluating this effect with these new materials. The other aspect to consider is the compression set of these materials, that is the ability to recover to their original thickness after local loading such as a chair or bed leg. By modifying the cellular structure of many of the foams this effect can be dramatically reduced. The best current commercial underlay that provides a degree of effective energy and peak force reduction is the rubber crumb structures such as the Duralay Treadmore^{TM} and System Ten underlays, but this would be expensive when two or more layers are considered. Underlays are not commonly used with the Vinyl overlays as these tend to have a thin foam backing to add a "comfort" factor, but all the Vinyls tested were very poor at energy and peak force reduction and need firm underlays to offer any such protection against fracture. The PVC foam appears to be very effective at energy absorbance and was the only material that reduces the peak force to below 2 kN

The ideal underlay/floor covering should have the following features:

- Firm enough to reduce the energy level experienced at the hip to fracture the hip (<20J). 20J is considered the maximum that would fracture most hips in the osteoporotic elderly (i.e. at least a 50 % reduction in impact energy). Most foam rubber underlays only provide 10-30 % reduction in energy.
- Reduce the peak force to below 2kN which is the minimum threshold that most osteoporotic patients are unlikely to fracture their hips.
- Not too thick and soft to cause possible rucking or tripping on the carpet/vinyl that will be lying over the underlay, a maximum thickness of the floor covering materials including the underlay of 20 mm.
- Have good compression set properties, return to original thickness after both short term(<1 sec) and long term loading(>5 weeks)
- Must have anti-static characteristics to reduce attraction for dirt and minimise static build-up on the carpet/vinyl overlay due to relative movement between the two.
- Moisture resistant on both the upper and lower surfaces.
- Be suitably flexible for ease of laying down and fixing. Some of the firm PU foams are difficult to roll and lay flat during cutting and shaping.
- Ageing effects minimum, must not shrink with time and temperature.
- Easy to cut by knife/scissors and lay for the carpetfitters.

- Comparable costs to say Duralay Treadmore and Treadaire Festival (c £7-8/square metre).
- Comply with building regulation pertinent to flooring covers (Noise reduction etc)

CONCLUSIONS

1. Many nursing homes and Hospitals have totally inappropriate flooring and their coverings that would reduce the risk of patients fracturing their hips on falling on these surfaces.

2. Vinyl floors offer only a negligible reduction in the peak force and energy attenuated and the thin foam backings under these Vinyls contribute very little to further attenuation.

3. Carpets without underlays are only marginally better than foam-backed Vinyls

4. The commonly used “waffle” moulded rubber foam underlays double the small reduction in this attenuation effect under a carpet, but is still well short of reducing the peak force and energy that could fracture a hip in the elderly.

5. The firmer rubber crumb underlays do further reduce the energy absorption and force attenuation , but a single layer only halves the values if it is not present.

6. A double layer of the “Treadmore” rubber crumb underlays offers a significant reduction in the energy and force on the hip but three layers under a conventional pile type carpet is likely to reduce the force and energy sufficiently to prevent the hip from fracture, and may offer a similar impact protection as a hip protector.

7. At least 30mm of the rubber crumb material (i.e. four layers) is needed under the Vinyls to produce the same low values (<2 kN) to fracture the hip. However, this thickness may produce walking and traction problems of wheeled devices over the floor.

8. Some of the new rigid foams such as PVC, and the expensive Sorbothane rubbers could also provide a protective layer under floor coverings, but are still undergoing development to be a suitable underlay.

9. The features are described of the ideal underlay in areas where patients who are at risk of fracturing their hip if they fall onto the floor without other means of protection.

10. Consideration should be made of the floor covering and underlay when conducting a risk assessment of the areas where patients walk, who are at risk of hip fracture.

Fig 1

TABLE 1

Material	Energy absorbed (%)	Reduction in Fmax compared with no underlay (%)
Carpet: rubber underlay	25	25
2x7mm Treadmore	51	70
12.5 mm PVC foam	65	73
3mm Vinyl: Rubber underlay	19	11
2x7mm Treadmore	55	31
12.5 mm PVC foam	63	57
1.5mm Vinyl: Rubber underlay	11	8
2x7mm Treadmore	38	51
12.5 mm PVC foam	40	56

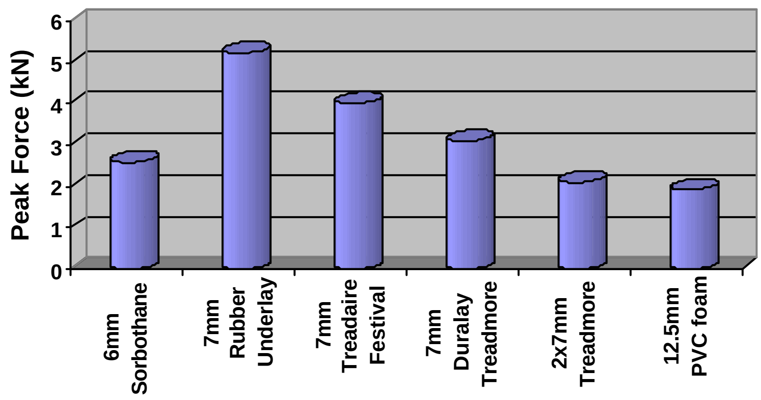

Fig 2

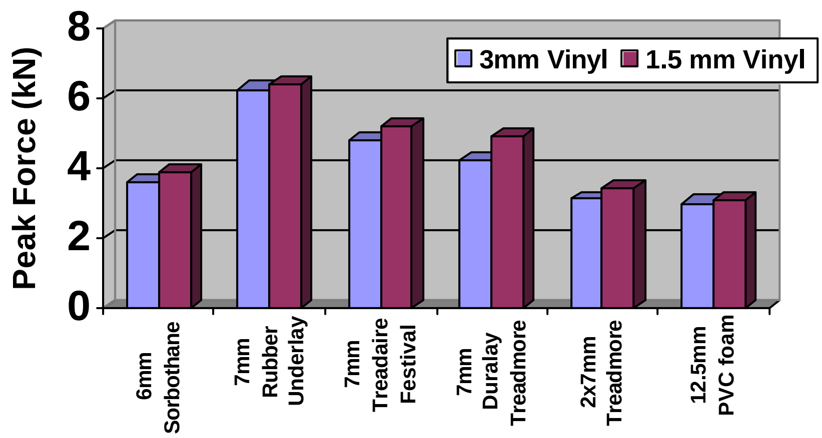

Fig 3

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