An Overview of Polyurethane Foams in Higher Specification Foam Mattresses

Esa Soppi, MD, PhD; Juha Lehtiö; and Hannu Saarinen, MSc (Tech), BSc

Abstract
Soft polyurethane foams exist in thousands of grades and constitute essential components of hospital mattresses. For pressure ulcer prevention, the ability of foams to control the immersion and envelopment of patients is essential. Higher specification foam mattresses (ie, foam mattresses that relieve pressure via optimum patient immersion and envelopment while enabling patient position changes) are claimed to be more effective for preventing pressure ulcers than standard mattresses. Foam grade evaluations should include resiliency, density, hardness, indentation force/load deflection, progressive hardness, tensile strength, and elongation along with essential criteria for higher specification foam mattresses. Patient-specific requirements may include optimal control of patient immersion and envelopment. Mattress cover characteristics should include breathability, impermeability to fluids, and fire safety and not affect mattress function. Additional determinations such as hardness are assessed according to the guidelines of the American Society for Testing and Materials and the International Organization for Standardization. At this time, no single foam grade provides an optimal combination of the above key requirements, but the literature suggests a combination of at least 2 foams may create an optimal higher specification foam mattress for pressure ulcer prevention. Future research and the development of product specification accuracy standards are needed to help clinicians make evidence-based decisions about mattress use.

Keywords: review, mattresses, polyurethanes, pressure ulcer, beds

Guideline and Literature Review
To complement currently available review articles and guidelines on polyurethane-based support surfaces, the terms polyurethane or foam or flexible or density or resilience or mattress or support or surface were used in database searches of the Web of Science, Scopus, Medline/Ovid, and PubMed, which yielded 1,301 unique hits of material published since 1970. Among the search results were 547 English abstracts, from which 85 full-text articles (most previously...
familiar) were reviewed in more detail, yielding 2 studies that contributed new data to this study. Altogether, 41 of the retrieved references are cited in this study; the remainder did not add meaningful information.

**Polyurethane foams.** Soft polyurethane foams are complex, plastic-like materials that result from chemical reactions of 2 main components, polyol(s) and isocyanate(s), with water. Polyurethane also contains a number of other components that act as catalysts in the manufacturing process, as well as surfactants, fillers, and fire retardants. Once the components are mixed, the reaction starts immediately: foam and bubbles are formed and the mixture expands. The properties of polyurethanes also depend on external conditions such as temperature and humidity of the ambient air during manufacture, although no clear scientific understanding exists of how the properties of foams are affected by changes in the formulation process. Therefore, and due to numerous compounds involved, experimental studies have shown it is difficult to reproduce identical polyurethane foams from batch to batch and (based on the experience of foam manufacturers) a production tolerance of ± 10% is an extremely demanding requirement for any foam manufacturer.

Variations in these multiple ingredients generate an enormous number of different soft polyurethane foam grades. The soft polyurethane foams are composed of an internal cell/bubble structure that is usually “broken” or open. These foams are made up of a network of cellular shapes comprised of tiny struts and cell windows (see Figure 1). The size of the bubbles, the wall thickness, and the bubble structure affect the density and other properties of the foam. The open cells allow air to move slowly through the foam (to “breathe”), the amount of which is expressed in cubic feet per minute and measured as the volume that can be drawn through a 2- x 2- x 1-inch polyurethane foam sample at a 0.5-inch water pressure differential. An industrial standard for adequate airflow in soft polyurethane foams is at least 2.0 cubic feet (55 L) per minute.

**Main properties of flexible polyurethane foams.** The methods and measures to classify polyurethane foams differ from continent to continent. Industrial standards and guidelines are written by the American Society for Testing and Materials (ASTM) and the International Organization for Standardization (ISO).

**Resilience.** Resilience is an indicator of the surface elasticity or “springiness” of foams. Resilience is typically measured by dropping a standardized steel ball onto a specific sized foam sample and measuring how high the ball rebounds. Foam resilience ranges from about 30% ball rebound to >60% rebound in high resilience (HR) foams. Conventional resilience in soft, open cell foam by industry standards corresponds to a ball rebound of 20%/30%/60%.

**Density.** Density (kg/m$^3$) is one of the most important properties of foams. Density is a function of the chemistry used to produce the foam and of the additives used during synthesis. The density of the foam affects not only its physical properties in a complex fashion, but also the foam’s durability and support. Typically, the higher the polymer density, the better the foam will retain its original properties; it will last longer and provide the support it was originally designed to produce. The densities of HR foams, viscoelastic foams, and conventional foams are typically >40 kg/m$^3$, 30 to 100 kg/m$^3$, and 25 to 65 kg/m$^3$, respectively.

**Hardness.** Compression load deflection (CLD, recorded in kPa) — the technical reference to “hardness” — is measured as the force required to compress a defined piece of foam a defined percent of the original with a compression plate that is larger than the piece of foam (see Figure 2). The foam is compressed 3 times to 70% and after the third compression readings are taken at 60%, 40%, or 25% of compression. Foam hardness can be controlled during production by varying the chemical formulations and processing techniques. CLD hardness is independent of density. A high-density foam can be produced in such a way that it may have a low or high CLD value. The CLD hardness reflects how deep the patient sinks into the foam; the higher the immersion, the lower the CLD value and vice versa. Furthermore, higher
CLD hardness values reflect the foam’s ability to support the body and to prevent the bottoming out.

*Indentation force/load deflection and progressive hardness:* Indentation force/load deflection (IFD or ILD, recorded in Newtons) — referred to as “firmness” or “stiffness” — is defined as the force required to compress a defined piece of foam with a compression plate that is smaller than the piece of foam.\(^ {18,26,27}\) IFD/ILD is independent of foam density, although it is often thought higher density foams are firmer than low density foams,\(^ {18,26}\) and it is possible to produce high-density foams that are less firm and lower density foams that are firm.\(^ {1,2,27,28}\) IFD reflects the surface feel of the foam and is a measure of the immersion and envelopment characteristics of the foam (see Figure 3).

Progressive hardness (support factor, or the SAG-index [from the verb *sag*]) is measured by dividing the force needed to indent the foam 65% of its original height by the force needed to indent the foam 25% of its original height (see Figure 4).\(^ {20,27,29}\) In high-resilience foams, the SAG-index is >2.4.\(^ {18,21}\) The SAG-index reflects how well the foam envelops the body contours; the better envelopment, the lower the SAG index and vice versa. Furthermore, higher SAG index values reflect the foam’s ability to support the body and to prevent the bottoming out.

*Tensile strength.* Tensile strength describes the durability of the foam and is defined as the maximum force at the point of rupture when a piece of foam is subjected to the pull of opposite forces. The result is usually expressed in PSI, kg/cm\(^2\), or kPa.\(^ {20,28,39}\) German reimbursement standards require a tensile strength of all types of mattress foams of >80 kPa.\(^ {18,31}\)

*Elongation.* Elongation describes the durability of the foam and is defined as the length of elongation at the break point recorded as a percent of the original length.\(^ {18,20,30}\) The elongation at the breaking point of all types of medical use mattress foams must be >115%.\(^ {18,31}\)

For the clinician, these characteristics reflect the high quality and durability of the foam in mattress.

*Viscoelastic foam (ie, differentiating viscoelastic foam from other foams).* When the human body is positioned on viscoelastic foam, the foam progressively conforms to the shape of the body, and after the weight is removed, the foam usually slowly reassumes its initial shape; this is a type of “slow recovery” foam.\(^ {26}\) The physical properties of viscoelastic foam can be greatly influenced by temperature. In testing viscoelastic foam performance characteristics, it is also important to make notation of the ambient temperature and be certain all comparison testing is performed under like conditions. The sample must be conditioned at specified temperature and humidity before testing.\(^ {18}\) Even slight changes in room temperature can affect the measured

---

**Figure 2.** Compression load deflection (CLD). CLD is used to measure hardness by compressing a defined piece of foam with a compression plate that is larger than the piece of foam.\(^ {18,24,26}\)

**Figure 3.** Schematic representation of immersion: a) no immersion of the body with high compression load deflection (CLD) hardness mattress; b) immersion and envelopment with typical of medium density foam and low CLD hardness mattress; c) limited envelopment capability typical of a standard/conventional foam mattress; d) more optimized envelopment, immersion, and support capability typical of a 2-layer higher specification foam mattress.
firmness and recovery rates. Depending on the formulation, some viscoelastic foams maintain their “memory” feature at temperatures as low as 30˚F (0˚C), but the optimum range for the best “memory” action is between 55˚F (13˚C) and 85˚F (30˚C).\(^{18}\)

Viscoelastic foam is characterized by a ball rebound of <20% (ie, this type of foam exhibits low resilience [LR]). In fact, certain viscoelastic foams can absorb approximately 90% of the ball impact.

The optimal combination is defined by the application, but for high-resiliency and viscoelastic foams the densities vary from >40 kg/m\(^3\) to >50 kg/m\(^3\) and CLD hardness from 4–5 kPa to 1–3 kPa, respectively.

Due to its conforming aspect and low resilience, viscoelastic material provides a comfortable yet supportive mattress. People with impaired mobility can benefit from the foam’s capacity to redistribute weight and surface pressure, potentially reducing PU development risk.\(^{4-6,13,14}\) Unfortunately, production economics often restrict end-use applications. Unlike traditional foam processing, viscoelastic formulation flexibility is more restrictive. Raw materials must be carefully altered to generate foam with varying properties. Cutting, profiling, and other fabrication techniques also may require more care due to the slow recovery aspect of the foam.\(^{2,22}\) These considerations affect product economics.

**Patient issues with pressure and physiological change.** Pressure causes stress in the tissues and deforms the skin, fat, and muscle. It affects blood flow and metabolism of the tissues subjected to pressure\(^{3,34}\); the latter have different elastic modulus characteristics: resistance of tissues to become deformed elastically (ie, nonpermanently when a force is applied to it), and pressure causes shear between and within the tissues. The magnitude of the shear depends on the person’s characteristics, such as the anatomical configuration of the bony prominences and the elasticity of the skin and tissues.\(^{3,34}\) These concerns have been examined in experimental and clinical studies.\(^{3,32-34}\)

Support surfaces should be designed to manage tissue loads and stress reactions to pressure, shear force, temperature, and microclimate by redistributing the pressure and managing the interactions between the tissues and support surface combined immersion and envelopment properties. When a person lays or sits on a support surface, his/her weight deforms both the support surface (typical property of viscoelastic foam) and his/her soft tissues.\(^{32}\) As a patient sinks (immerses) into the support surface, equalization of pressure off bony prominences should occur. Bottoming out needs to be prevented; this can be achieved by increasing the CLD hardness, but equalization properties of the foam will be lost (see Figure 3a). Increasing the density and height may help to some extent, but also increases the weight of the mattress. Furthermore, the height of the mattress can be increased or multiple layers of different types of support surface need to be introduced. However, as the patient sinks deeply into a very deep mattress, the property of deep immersion of the mattress (a disadvantage of viscoelastic foam) may make it difficult to change positions (see Figure 3). Furthermore, the “memory” function (ie, the slow recovery of original conformation of viscoelastic foams) is hypothesized to cause shear forces in the tissues when the patient is repositioned by the nursing staff because the original immersion configuration in the mattress will remain long after repositioning.

The support surface’s envelopment capability (ie, capability to conform to the shape of the person) describes its ability to deform around irregularities of the body without causing any substantial pressure increase (see Figure 5). Furthermore, the pressure of the individual’s body will be more evenly distributed and the strain on bony prominences, where PUs typically develop, alleviated.\(^{3,12,22,35}\) This may reduce internal tissue pressure, strain, and stress to a great extent.\(^{32}\) The extent to which small areas of the body are subjected to high pressure will determine the degree of damaging deformation and physiological changes.\(^{16,32,35}\)

Circulatory and metabolic changes result from the pressure exerted on the tissues.\(^{3,23,36}\) As shown in clinical experimental studies,\(^{3,36}\) pressure-induced stress in the tissues will change the blood flow in the microvasculature and decrease tissue oxygen tension, irrespective of the type of mattress the patient is using. Interindividual variation in this change in oxygen supply is enormous.\(^{33,36,38}\) The counterbalancing physiological effects aim to maintain tissue oxygen levels, and these effects are markedly influenced by the support surface (see Figures 5 and 6).\(^{37,38}\) In one randomized controlled study,\(^{37}\) 10 healthy volunteers were placed on a conventional, nonviscoelastic foam (35 kg/m\(^3\)) or dynamic (the microchip-guided control unit with pumps, functioning for approximately 1 hour/day). This nonalternating air mattress [Carital\(^{36}\) Optima, Carital Ltd, Helsinki, Finland] adjusts automatically to the
pressure values of the air within it to predefined levels irrespective of patient’s weight, body shape, or position). Mean tissue oxygen tension (see Figure 6a), capillary flow using Doppler (see Figure 6b), and skin temperature (see Figure 6c) were measured. Although the mean tissue oxygen tensions were similar on both mattresses, the standard mattress caused the capillary flow to increase throughout the whole 2 hours of exposure to pressure. This increase was due to the following mechanism: As the oxygen consumption and temperature rose in the tissue exposed to pressure, the tissue reacted by increasing blood flow in an effort to uphold a stable oxygen pressure in the tissue. Naturally, this compensatory effect cannot continue indefinitely on a standard mattress, because the capillary flow must even out, at some point in time, and this will result in a drop in tissue oxygen tension. The dynamic, nonalternating air mattress has shown optimized immersion and envelopment capabilities and to be highly effective for prevention of pressure ulcers among extremely sick intensive care patients in a randomized, controlled trial.

These findings suggest tissues exposed to sufficiently high local pressures exhaust their compensatory blood flow reserves and this may lead to ischemic tissue injury and PU formation. However, this did not occur in healthy volunteers (the ethical committee had limited the test period for 2 hours). This effect will take place even in healthy individuals if the pressure or exposure time is sufficiently long. These concerns become even more crucial in severely ill people who have fever and compromised blood flow. Taken together, the results suggest that optimal control of patient immersion and envelopment on any mattresses are crucial for optimal tissue perfusion and oxygenation.

Figure 5. Sacral area tissue oxygen tension in healthy volunteer placed on conventional, non-viscoelastic, polyurethane foam (35 kg/m³) mattress. Footnote: Change in position after 120 minutes. Reprinted with permission of the Finnish Medical Journal Duodecim.

Figure 6. Physiological changes due to pressure exerted on the tissues. Skin temperature from 30 minutes onwards, P <0.01 to <0.001 (Figure 6c). Footnote: Reprinted with permission.
Higher Specification Foam Mattresses

Currently, the distinguishing characteristics of HSFMs are not well described. Outcomes of patients placed on standard hospital foam mattresses and other foam mattresses are compared in a Cochrane review covering 7 studies, of which are randomized trials. The studies included in the Cochrane review are detailed in Table 1. The studies that compared standard and alternative foam mattresses varied in quality and all failed to adequately define standard hospital and higher specification foam mattresses. Furthermore, in some of the studies higher specification mattresses were used as standard mattresses in other studies (see Table 1). Still, the meta-analysis concluded HSFM reduced the incidence of PU-related events for individuals at risk to less than half of the incidence among standard mattress users (risk ratio = 0.41, P = 0.021).

The key randomized, controlled study by Russell et al involved elderly patients requiring acute care in orthopedic and medical wards with a Spenco or Propad mattress (N=604) versus HSFM (N=90). The researchers found that HSFM reduced the incidence of nonblanching erythema among standard mattress users (risk ratio = 0.54, P = 0.004 for all patients and P = 0.005 for those without nonblanching erythema on trial admission).

Table 1: Summary of trials investigating the performance of standard and higher specification foam mattresses (HSFM)

<table>
<thead>
<tr>
<th>Patient characteristics</th>
<th>Risk scale (risk score)</th>
<th>Standard foam mattress properties (N)</th>
<th>Higher specification foam mattress, HSFM (N)</th>
<th>Primary outcome</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hofman et al 1994⁴⁻⁵</td>
<td>Patients with femoral neck fracture</td>
<td>Dutch consensus scale (score &gt;8)</td>
<td>Standard SG40 hospital mattress² (N=23)</td>
<td>Comfortex DeCube mattress² (N=21)</td>
<td>Pressure ulcer incidence. Standard: 68% (13/19) versus HSFM 24% (4/17)</td>
</tr>
<tr>
<td>Gray and Campbell 1994⁴⁻⁵</td>
<td>Orthopedic trauma, vascular and medical oncology patients without breaks in the skin</td>
<td>Waterlow (score &gt;15)</td>
<td>Standard NHS foam mattress³ (thickness 130 mm) (N=80)</td>
<td>Soft foam mattress³ (N=90)</td>
<td>Pressure ulcer incidence. Standard 33.8% versus HSFM 6.7%</td>
</tr>
<tr>
<td>Santy et al 1994⁴⁻⁵</td>
<td>Patients &gt;55 years of age with hip fracture, with or without pressure ulcers</td>
<td>Standard foam⁴ (NHS contract surface) (N=64)</td>
<td>Clinifloat⁴, Transfoam⁴, Therarest⁴, Vaperm⁴ mattresses (N=441)</td>
<td>Pressure ulcer incidence. Standard 26.5% versus HSFM 9.5%</td>
<td>P = 0.002</td>
</tr>
<tr>
<td>Collier 1996⁴⁻⁵</td>
<td>Patients attending at a general medical ward</td>
<td>Standard hospital mattress (Re-lyon)⁵ (thickness 130 mm) (N=9)</td>
<td>Clinifloat⁵, Omni-foam⁵, Softfoam⁵, STM5⁵, Therarest⁵, Transfoam⁵, Vapourlux⁵ mattresses (N=81)</td>
<td>Pressure ulcer incidence. No pressure ulcers in any of the mattresses</td>
<td>Not significant</td>
</tr>
<tr>
<td>Gray and Smith 2000⁴⁻⁵</td>
<td>Surgical, orthopedic, and medical patients</td>
<td>Waterlow (mean score 14 for standard; score for 13 HSFM)</td>
<td>Transfoam⁶ (N=50)</td>
<td>Pressure ulcer incidence. 2% in both groups. In addition, nonblanching erythema 2% in both groups</td>
<td>Not significant</td>
</tr>
<tr>
<td>Russell et al 2003⁴</td>
<td>Elderly acute care, rehabilitation, and orthopedic patients</td>
<td>Waterlow (score 15-20)</td>
<td>Numerous standard foam mattresses (King’s Fund⁷, Softfoam⁷, Transfoam⁷, Linknurse⁷, or a King’s Fund mattress with a Spenco or Propad mattress overlay) (N=604)</td>
<td>CONFOR-Med: 3 inch (7.5cm) viscoelastic foam on the top and 3 inch (7.5cm) standard polyurethane foam on the bottom⁷ (N=562)</td>
<td>Incidence of nonblanching erythema or worse Intact skin with blanching erythema: standard (N=161) 26.6% versus HSFM (N=110/19.6%). Intact skin with nonblanching erythema: standard (N=66) 19.6% versus HSFM (N=48) 9.5%</td>
</tr>
<tr>
<td>Berthe et al 2007²</td>
<td>Medical and surgical patients</td>
<td>Modified Ek’s scale on Kliniplot (7.5cm) standard polyurethane foam on the bottom⁷ (N=562)</td>
<td>Numerous standard mattresses. No specifications available (N=1072)</td>
<td>Kliniplot: Foam (Bultex) mattress with block structure⁷ (height 18 cm) (N=657)</td>
<td>Pressure ulcer incidence. Standard 1.9% versus Kliniplot 3.2%. Time to pressure ulcer 31 days for Kliniplot versus 18 days for conventional foam mattress</td>
</tr>
</tbody>
</table>

*Not known to be in production any more. No other specifications, as shown in the table, are available.*
rehabilitation wards. The support surfaces included standard foam hospital mattresses (see Table 1) and a HSFM composed of a 3-inch (7.5 cm) layer of standard foam on the bottom and a 3-inch (7.5 cm) layer of viscoelastic foam on the top. Use of the HSFM was associated with a significant reduction \((P = 0.004)\) in the incidence of blanching erythema (primary outcome measure) and a nonsignificant decrease in the incidence of nonblanching erythema (10.9% versus 8.5%, \(P = 0.17\)). A statistically significant decrease was noted in all nonblanching erythema groups in favor of HSFM at day 7 \((P = 0.0015\) and \(P = 0.042\), respectively).\(^4\)

Thus, currently no consensus based on published studies and reviews has been reached on the requirements of HS-FMs.\(^1^2\) A HSFM needs to fulfill 3 essential functional specifications: 1) it must possess optimum immersion and envelopment properties; 2) the patient must be able to change position; and 3) it must be easy for the patient to change position or for the nursing staff to move the patient. At present, there is no evidence a single foam grade provides an optimal combination of these key specifications. The specifications may be achieved only by combining at least 2 layers of different types of foams, as suggested by the results reported by Russell et al.\(^4\) Table 2 summarizes the main features of higher specification foam mattress requirements as based on this review. The minimum requirements of polyurethane foam qualifications rely on the properties of different grades of polyurethane foams and on expert experience on the behavior of different grades of foams used in support surfaces. A thin layer of viscoelastic foam on the top utilizes its beneficial properties and simultaneously eliminates its disadvantages (deep immersion and slow recovery) when thick support surfaces are used alone. The essential properties of high resilience (on the bottom) and viscoelastic foams are characterized by ball rebound, density, CLD hardness, and SAG-index.

**Mattress Covers**

Mattress covers are also important and may modify the functionality of the mattress, especially microclimate management.\(^1^2\) A cover can ruin the functionality of a HSFM, but a good cover, as defined below, cannot transform a conventional foam mattress into a HSFM. Thus, a HSFM needs a cover with clearly specified properties. Studies on mattress covers are lacking, but generally used minimum requirements include the following: The cover needs to be breathable (ie, the microclimate control and enough elasticity that it does not impair the functionality of mattress or cause a

### Table 2. Key properties of higher specification foam mattresses (HSFM)

<table>
<thead>
<tr>
<th>Specification</th>
<th>Foam layer, bottom</th>
<th>Foam layer, top</th>
<th>Middle layer(s)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main functionalities of foams</td>
<td>Immersion control; supports body and prevents bottoming out</td>
<td>Envelopment; capability to deform around and encompass the contour of the body</td>
<td>Improves immersion control and prevents bottoming out in heavy patients. Reduces point pressures</td>
<td>Middle layer is needed for patients weighing &gt;100 kg</td>
</tr>
<tr>
<td>Type of foam</td>
<td>High resiliency (HR) foam</td>
<td>Viscoelastic foam</td>
<td>HR/Viscoelastic/Other</td>
<td>A huge number of various soft foams are available</td>
</tr>
<tr>
<td>Ball rebound (%)</td>
<td>≥60</td>
<td>&lt;20</td>
<td>According to the desired function</td>
<td>A measure of resilience</td>
</tr>
<tr>
<td>Density (kg/m(^3))</td>
<td>≥40</td>
<td>&gt;50</td>
<td>≥40</td>
<td>The dense, the more durable</td>
</tr>
<tr>
<td>CLD hardness at 40% (kPa)</td>
<td>4–5</td>
<td>1–2.5</td>
<td>HR: 4–5 Viscoelastic: 2–3</td>
<td>Main measure of immersion control</td>
</tr>
<tr>
<td>Progressive hardness (SAG-index)</td>
<td>2.7–3.1</td>
<td>&lt;2.4</td>
<td>According to desired function</td>
<td>SAG-index = IFD at 65% / IFD at 25%</td>
</tr>
<tr>
<td>Tensile strength (kPa)</td>
<td>&gt;80</td>
<td>&gt;80</td>
<td>&gt;80</td>
<td>Describes durability of foam</td>
</tr>
<tr>
<td>Elongation at break (%)</td>
<td>&gt;115</td>
<td>&gt;115</td>
<td>&gt;115</td>
<td>Describes durability of foam</td>
</tr>
<tr>
<td>Layer thickness (cm)</td>
<td>Minimum 8 (at least 3.2 inches)</td>
<td>Minimum 4–5 (at least 1.6–2.0 inches)</td>
<td>According to desired function(^a)</td>
<td>Layers must be glued together since it enhances the durability</td>
</tr>
<tr>
<td>Production tolerance (%)</td>
<td>±10</td>
<td>±10</td>
<td>±10</td>
<td>±10% is today an extremely demanding quality requirement</td>
</tr>
</tbody>
</table>

\(^a\) can reduce the thickness of top and bottom layers


hammocking effect). For hygiene reasons, the cover also must be impermeable to biological fluids; the cover materials should be resistant to urea in urine and sweat and organic acids as well as disinfectant antimicrobial agents. Both the cover and the mattress need to be fire safe according to the local regulations.

Discussion

A large number of soft polyurethane foam grades are suitable for mattress use. In the health care setting, mattresses are used continuously, and the durability of the foams and mattresses needs to be better than in home use. Measures of durability (eg, density, tensile strength, and elongation capability) and the construction of the mattress layers are important. The cells within the foams resemble microscopic mechanical springs and gradually lose their functionality and thickness because of fatigue. Foam mattress manufacturers claim a 3-year to 5-year lifespan for conventional mattresses in continuous use. Over time, the comfort and capability of standard foam mattresses to prevent PUs becomes impaired, although the mattress may look intact. Profiling or scoring the top layer of the foam may improve its immersion and envelopment properties, but profiling and use by patients weighing >100 kg causes extra stress to the foam and mattress structures, and this may reduce the mattress’ life expectancy. The foams used in HSFM should have a life span of at least 5 years. To prevent bottoming out of patients weighing >100 kg, a third, middle layer is needed if the aim is to maintain the mattress thickness at a level that fulfills the distance requirement from the mattress to the top of the side rail to reduce the possibility of a patient accidentally falling from the bed.

When the mattress contacts the body surface, pressure is generated and causes physiological changes in the tissues. The main changes is reduced tissue oxygen tension (to approximately 30 mm Hg), with marked individual variations. The values can be extremely low, but it is not known whether this affects the individual’s susceptibility to PU development. The tissue oxygen tensions are similar in low-end and high-end mattresses and are a function of the internal tissue pressures created, temperature and capillary flow profiles, and other circumstances. The skin-mattress contact raises the local temperature and modifies capillary flow; this phenomenon is exacerbated by any general infection the patient may have, because proinflammatory cytokines and free radicals are released. A rise in body temperature of 0.5°C increases oxygen consumption by the tissues by 6% to 7% and increases the susceptibility of the skin and subcutaneous tissues to PU.

Immersion and envelopment, on the other hand, are essential user specifications and crucial for the functionality of any mattress. Optimal control of immersion and envelopment is still extremely difficult to achieve with only 1 foam type without profiling (cutting blocks, waves, or holes into the foam) or using a thick layer of a single foam (>6 inches/15 cm). However, to ensure patient safety, the top of the side rail should be more than 8.7 inches (22 cm) above the mattress; this limits the height of the mattress. Even if the required immersion and envelopment characteristics probably were fulfilled, the 2 other essential user specifications (the patient must be able to change his/her position without help and it must be easy for the nursing staff to change the patient’s position and to move the patient) cannot be achieved.

From the available data, the best combination to reach all essential user specifications appears to be a 2-layer construction (as a minimum): a viscoelastic foam on the top and a high resilience foam on the bottom as discussed by Russell et al. The foams also should have a low production variation tolerance; otherwise, the mattress specifications will vary too much from one foam batch to another, and the quality specifications will no longer be reached.

Conclusion

Based on the literature, definitive meanings and characteristics/qualifications designating standard/conventional foam mattresses and HSFM are yet to be determined. The data reviewed provide a basis for further research. In the future, product specification accuracy will be a factor of the key properties of each foam type used in mattresses. The authors hope their findings improve the essential requirements of mattresses in the implementation of patient care globally.

Acknowledgment

The language of the article was reviewed by Robert Paul, MD, PhD, certified translator.

References


43. Sancy JE, Butler MK, Whymann JD. A comparison study of 6 types of hospital mattress to determine which most effectively reduces the incidence of pressure sores in elderly patients with hip fractures in a District General Hospital. Report to Northern and Yorkshire Regional Health Authority. 1994. Available through special libraries.


