Using an Indentation Measurement Device to Assess Foam Mattress Quality

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Foam mattress quality affects pressure ulcer risk but no reliable method to assess mattress fatigue and indentation is available. To ascertain Indentation Quality values of standard 14-cm (5-inch) foam mattresses after 15 years of use, a convenience sample of 50 visco-elastic foam mattresses from a total of 1,000 same-brand mattresses used in a Dutch University hospital was tested using a durometer. Indentation Quality values were obtained on the mattress cover at a relatively unloaded zone (corner), at the head and heel zones, the knee and shoulder areas, and in the middle (buttocks area). Indentation Quality values ranged from a mean of -11.91 mm (±2.58) in the unloaded zone to a mean of -26.96 mm (±4.31) in the middle zone (buttocks area, P <0.001 compared to all other mattress areas). The value at the relatively unloaded zone was significantly and positively related to the values at the head and the heel zones ($r = .70, P < .01$) and the knee and the shoulder zones ($r = .33, P < .05$). The value at the buttocks zone was positively related to the value at the knee and the shoulder zones ($r = .35, P < .05$). The study showed that mattresses that appeared similar had a wide range of indentation values (indicating a need for individual assessments to monitor their quality) and that Indentation Quality values, determined using the durometer, facilitate objective and quantifiable mattress assessments. Consideration of the consequences of foam mattress life span on quality of care, hospital management practices, and cost analysis is justified.

KEYWORDS: hospital management, material properties, durometer, visco-elastic, mattress fatigue


Foam mattresses with a thickness of 14 cm (5.5 inches) are used widely as standard supportive and pressure ulcer (PU) preventive devices in hospitals and nursing homes. Mattress quality is determined in terms of material or intrinsic factors such as density (kg/m$^3$) or indentation (mm, inches) and derived factors such as comfort and PU prevention capability.¹²

It is widely recognized that mattresses have a finite life span.¹ At first sight, foam mattresses of the same brand, delivered by one supplier and in use for the same period of time, may seem to be of comparable quality, although not every foam mattress would have been used the same way. Foam mattresses used for some years may exhibit visible wear and tear and “bot-toming” (mattress flattened down to hard structure below) may occur.¹ The bottoming phenomenon accelerates the risk of developing PUs because the mattress no longer reduces pressure.¹ Thus, maintaining foam
mattress quality is essential for reducing the incidence of PUs in hospitals and nursing homes.1

Foam mattress effectiveness (ie, ability to prevent or reduce incidence of pressure ulcers) should be examined and documented regularly. Most hospitals have a “need for a mattress audit-replacement” program. Chaloner5 prospectively studied the development of an audit tool to evaluate nurses’ knowledge and skills related to appropriate support surface use (results were not specified). Gebhardt6 performed a prospective study in a large teaching trust comprising 1,000 beds that included 200 foam mattresses to examine use of mattress overlays and replacements overseen by a mattress coordinator; the study found that intelligent management (described as replacement of old mattresses in due time to prevent pressure ulcers) helped reduce costs by a factor of five. Subsequent cost analyses7 performed in 11 hospitals in six UK NHS trusts (n = 1,971) demonstrated that alternating pressure mattresses are more cost effective and acceptable to patients than overlays and underscore the economic benefits of replacing ineffective and worn-out mattresses.

Defloor8 conducted a prospective, randomized comparison of the pressure-reducing capacity of two mattresses (pressure ulcer and standard cold foam) involving 62 patients and 10 mattress positions. Researchers found that 30-degree semi-Fowler provided better interface values than prone position and 30-degree lateral values were better than 90-degree lateral values in supine position. The pressure ulcer mattress provided 20% to 30% more reduction of pressure than 12-cm cold foam. Using a retrospective questionnaire, Weststrate and Heule9 studied the interface pressure on a foam mattress and compared it with interface pressures on other types of mattresses among 299 patients in ICUs in four European countries. They found a 27% prevalence of Stage II through Stage IV pressure ulcers; 80% of patients had been placed on a special mattress; 71% of the ICUs had a pressure ulcer prevention protocol; 41% of the units had a specialist nurse; and 27% did not use a risk scale. The authors concluded that standardization of intervention and policies was needed. In a prospective comparison, Gray et al10 assessed the pressure-reducing capabilities of 20 replacement foam mattresses 4 years after purchase (durability). Participants included 33 patients 65 years or older with intact skin and Waterlow ≥15, who were inpatients for at least 7 days. The skin of study participants was examined before starting the study and after 7 days of mattress use. Most skin areas remained intact; six patients exhibited erythema and two had pressure ulcers. In addition, participants were asked to rate mattress comfort on a scale from very uncomfortable to very comfortable; 87% qualified the mattress as adequate or very comfortable. The results indicate that the foam mattresses studied functioned satisfactorily after 4 years of clinical use. However, additional information is required to demonstrate the long-term pressure-reducing capacity of foam mattresses.

Assessing intrinsic quality. To date, little is known about the intrinsic quality of foam after several years of use. A foam mattress’ intrinsic quality can be quantified in various ways. Bain et al11 developed the Quince mattress tester and the Quince score (from 0 — no interface material or the mattress has bottomed out — to 100 — the support expected from a new mattress) to assess the condition of a mattress in a clinical setting. According to manufacturer standards, most commercially available mattresses have a score in excess of 80 when brand new. To use the Quince tester, the person pushes the handles down with both hands until a predetermined force is reached.11 Because this rather large instrument depends on the force exerted by the operator, results are

KEY POINTS

- Information about the quality of standard hospital foam mattresses is limited and clinicians are generally encouraged to press down to evaluate whether a mattress is “bottoming out”.
- Utilizing a device to measure indentation, the authors of this study evaluated 50 seemingly similar mattresses after 15 years of hospital use.
- The ability of these mattresses to provide patient support varied widely by body area and by mattress.
- The authors conclude that mattress evaluation standards and programs are needed.
not objective; hence, Bain’s method has not been widely used. No evaluations of the instrument or score have been reported since 2001.

The hand compression test (described at http://www.lpct.nhs.uk) assesses foam mattress quality by having the tester lean forward and press body weight into clenched fists against the mattress to determine 1) if the base of the bed can be felt through the foam or 2) if <4.5 cm (1.8 inch) of foam is present between the fist and the base of the bed, indicating that the quality of the mattress is insufficient. This method also is subjective because of tester strength variability.

Mattress surveillance (ie, inspection for wear-and-tear (cigarette holes, tears, hollows, dirty wet spots, and the like) and the hand compression test) are subjective and not used routinely for quality surveillance in hospitals and nursing homes.

Patient position. Earlier research summarized the effect on different parts of the body of the way people recline on a mattress (eg, backrest 0 degrees, 30 degrees, 30 degrees with 22-degree Fowler). In accordance with reported findings, four mattress measuring points were defined for the authors’ mattress study (see Figure 1). Point 1 is a relatively unloaded zone (corner) of the mattress to be used in comparison with the other three points — ie, a reference point. Point 2 comprises the head and the heel zones of the mattress. Point 3 of the mattress corresponds with areas of the knees and shoulders. Point 4 is the buttocks zone. All measurements are read as minus values.

The purpose of this study was to measure the indentation quality (IQ) — a factor of intrinsic quality — of visco-elastic foam mattresses at four points after 15 years of daily use. Three study questions were considered:

1. Will Point 1 (unloaded zone) have the lowest average IQ values compared to the other points?
2. How will the pressure exerted on mattress Point 2 (head and heel zone) affect IQ values and how will Point 2 values compare to those at Point 3 (knees and shoulders) and Point 4 (buttocks)?
3. Will the average IQ value at Point 4 be higher than at Point 3?

To secure more objective data, a durometer (a portable electronic indentation hardness measurement device) was used as a measurement tool to quantify mattress aging. Studying the IQ values of the four points measured provides the means to map the IQ relationships in an extensively used, visco-elastic foam mattress and subsequently to assess long-used mattress ability to reduce risk of PU formation.

Methods

Materials. The study mattresses had been purchased over a 1-year period and were used as standard mattresses for 15 years in a Dutch University hospital.

They were comprised of visco-elastic foam, 14 cm (5.5 inches) thick, with a 10-cm (4-inch) layer of high resilience foam (HR-foam) at the bottom. A 4-cm (1.6-inch) layer of visco-elastic foam was glued to the top of the mattress. The mattresses were only used with the visco-elastic layer side up. Material properties such as density, indentation, and pressure resistance were considered irrelevant in this study because all mattresses were of the same type and the same brand. Each mattress is wrapped in a polyurethane cover that provides moisture vapor transmission and moisture resistance.

Randomization. Of the 1,000 foam mattresses at the study facility, 50 were selected for measurement using a convenience sampling procedure to represent all the mattresses.

Equipment (durometer). The durometer (IMPRESSor, developed by Doove Medical BV, Zevenhuizen, The Netherlands, in cooperation with Erasmus MC, University Medical Center Rotterdam, The Netherlands, and Delft University, The Netherlands) (see Figures 2a, b) consists of a hard plastic cylinder containing a central heavy core that
can move freely. The change of downward movement of the heavy core into the foam — indentation — is measured electronically (note the black box in the Figures). The parameter of quality — the IQ value — is provided in mm of indentation on a small LED screen at the top (see Figure 2a). The downward direction of the core is displayed with a minus sign before the outcome of the measurement on the display. The less the core indents, the stiffer the mattress. The test procedure showed that the durometer has an range of accuracy of 0.5 mm. The durometer’s heavy core, with a diameter of 75 mm (3.0 inches), produced a pressure of 4.4 kPa. This pressure corresponds approximately to the pressure an 80-kg person exerts on a foam mattress. The maximum sacral area pressure a person exerts is between 3.4 and 5.5 kPa (ie, an average of 4.4 kPa — authors’ data). Disk diameter measures 50 cm (20.0 inches) (see Figure 2).

Measuring points. To ensure every mattress was tested at exactly the same four points, a transparent mat of 900 mm x 2,000 mm was placed on each mattress. The mat had an opening at the site of the four measuring points (see Figure 1) to mark the measuring points on the mattress. The durometer was calibrated periodically according to international standard ISA norm 3386.

Procedure. All 50 mattresses were measured after cleaning and drying. Cleaning took place in a semi-automatic manner: the foam mattresses were placed on a conveyor belt and hand-wiped with water and soap (the seams cannot withstand high-pressure cleaning) and robotically dried. Each mattress was put on the clean metal surface of a bed frame with the visco-elastic foam side up, the four points were marked on the mattress, and measurements were obtained when the mattress was dry to the touch (approximately 3 to 5 minutes after drying). The IQ values of the mattress at the four points were determined with the durometer and entered into in a database.

Measuring all 50 mattresses took approximately 8 hours and involved two of the authors.

Statistical analysis. Descriptive statistics (means, standard deviations, and ranges) were calculated for the IQ values of all points on the mattress. To compare IQ values between the different points on the mattress, a one-way repeated-measures analysis of variance (ANOVA) was used; the repeated variable was the four different points. A Bonferroni post-hoc
test was performed to compare the IQ values for each possible pair of points on the mattress separately. Pearson correlation coefficients were calculated to examine the relationship between the IQ values at the different points on the mattress. All statistical analyses were performed using SPSS, version 12.0.1. (SPSS Inc, Chicago, Ill). Significance was expected at $P < .05$.

### Results

**Variation in IQ values.** The mean scores, standard deviations (SDs), and ranges of the IQ measures for all points on the mattress show a large range of variation in IQ values among the 50 investigated mattresses (see Table 1). Both the standard deviations and the ranges indicated the investigated points differed considerably from each other in the level of indentation. For example, at the buttocks zone (Point 4), the IQ value fluctuated between (minus) 20.5 mm and (minus) 44.0 mm (8.2 to 17.6 inches). Considering that the average thickness of a foam mattress is 14 cm (5.5 inches), the indentation varied at this point between a minimum indentation of 15% to a maximum of 31% of the total thickness. The mean IQ values for each point on the mattress and the interval to which 95% of the mattresses belong were calculated (see Figure 3).

**IQ values for different points on the mattress.** The one-way repeated-measures ANOVA test showed that the different points on the mattress differed significantly with respect to their IQ values ($F_{3,147} = 309.07, P < .001, n^2 = .86$). As expected, Bonferroni post-hoc comparisons showed that the highest IQ value was found for the relatively unloaded zone (Point 1; $M_1 = -11.91$). At this point, indentation was significantly less than at the other points on the mattress (all $Ps < .001$). Moreover, IQ value at the head and the heel zones (Point 2) was significantly higher than at the knee and the shoulder zones (Point 3; $P < .001$) and at the buttocks zone (Point 4; $P < .001$). Finally, the greatest indentation was found for the buttocks zone (Point 4; $M_4 = -26.96$). At this point, the IQ value was significantly lower than that of all other points on the mattress (all $Ps < .001$).

**Relationships between different IQ values.** The IQ values at the relatively unloaded zone (Point 1) were significantly and positively related to the IQ values at the head and the heel zones (Point 2; $r = .70, P < .01$) and the knee and the shoulder zones (Point 3; $r = .33, P < .05$). However, a marginally significant, negative relationship was found between the IQ values at the relatively unloaded zone (Point 1) and at the buttocks zone (Point 4; $r = -.26, P < .08$), indicating that a smaller indentation at the relatively unloaded zone (Point 1) may be accompanied by a higher indentation at the buttocks zone (Point 4). Moreover, the IQ value at the most heavily loaded buttocks zone (Point 4) was positively related to the IQ value at the knee and the shoulder zone (Point 3; $r = .35, P < .05$) (see Table 2).

### Discussion

This study was conducted to test the quality of foam mattresses after a certain life span using a practical, objective method. Using a new durometer to test a random sample of 50 mattresses out of a series of 1,000 used for 15 years, it was found that the average IQ value at Point 1 is, as expected, lower than the average IQ value at the other points. To answer the second

<table>
<thead>
<tr>
<th>Mattress Point</th>
<th>Mean ± SD*</th>
<th>Range</th>
</tr>
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<tbody>
<tr>
<td>1 = relatively unloaded zone</td>
<td>$-11.91±2.58$</td>
<td>$-7.5−-21.5$</td>
</tr>
<tr>
<td>2 = head and heel zone</td>
<td>$-13.25±2.36$</td>
<td>$-8.5−-22.5$</td>
</tr>
<tr>
<td>3 = knee and shoulder zone</td>
<td>$-16.68±2.24$</td>
<td>$-11.5−-21.5$</td>
</tr>
<tr>
<td>4 = buttocks zone</td>
<td>$-26.96±4.31$</td>
<td>$-20.5−-44.0$</td>
</tr>
</tbody>
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*Note: all IQ values are given as minus values $P < .001$.

### Table 2

**Pearson correlation coefficients between indentation quality (IQ) values at different points on the mattress (N = 50)**

<table>
<thead>
<tr>
<th>IQ value Point 1</th>
<th>IQ value Point 2</th>
<th>IQ value Point 3</th>
<th>IQ value Point 4</th>
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<tbody>
<tr>
<td>IQ value Point 1</td>
<td>--</td>
<td>.70*</td>
<td>.33*</td>
</tr>
<tr>
<td>IQ value Point 2</td>
<td>--</td>
<td>--</td>
<td>.27†</td>
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<tr>
<td>IQ value Point 3</td>
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<td>IQ value Point 4</td>
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* $P < .01$, † $P < .05$, ‡ $P < .10$
and third study questions, data analysis showed that the average IQ value of Point 2 (head and heel zone) is lower than the average IQ value at Points 3 (knees and shoulder) and 4 (buttocks) and that the IQ value at Point 4 is higher than the IQ value at Point 3. Thus, the hypothesis that after many years of use, mattress areas not generally subjected to pressure such as the top corners do not exhibit the same signs of wear and tear as areas that are generally subjected to higher pressure, especially the buttocks area, was confirmed.

The observed range at the relatively unloaded zone (Point 1) also suggests that factors other than pressure from body weight influence wear. These factors and their influence on mattress quality over time require further detailed investigations.

The highest value is critical when quantifying the quality of foam mattresses. In assessing the quality of a foam mattress, one may suggest that it is sufficient to measure Points 3 and 4, considering their strong relationship, and the highest mean score at the buttocks zone. The outcomes showed that the highest measured IQ value at Point 4 even passes the visco-elastic layer — i.e., the indentation at point 4 (~44 mm) is greater than the thickness of the upper transfoam layer of the mattress (40 mm [1.6 inches]). The effect after many years of use of this upper layer on pressure ulcers should be evaluated to determine whether a more aging-resistant, thicker, or firmer upper layer would be better.

The significant range of measurements indicates the validity of measuring the quality of foam mattresses using this type of durometer. Mattresses that appeared identical in quality using the subjective method (visual, then manual judgment) were proven dissimilar using objective measuring.

To apply the IQ value in practice requires the definition of a standard that provides a norm for critical evaluation of foam mattresses — i.e., a baseline value for the new mattress should be provided by the manufacturer, such as an IQ of 5% after 1 year and 10% after 5 years. If an IQ value is higher than the standard, the mattress should be replaced because a compromised pressure-reducing capacity may enhance the risk for PU development. A marginal value must be calculated that reflects the foam properties of the mattress. Defining a standard IQ value for (new) foam mattresses should be part of further additional research. Organizations like the European Pressure Ulcer Advisory Panel and the National Pressure Ulcer Advisory Panel may want to adopt and advise implementation of related protocols among the organizations’ extensive network of healthcare professionals.

For now, careful monitoring of mattress material during use in the clinic is advised. Quality mattress material should be purchased and properly used, stored, cleaned, and maintained. Damaged products should be replaced and the use of an objective method to assess mattress quality (i.e., the durometer) should be used.

The results of this study justify pursuing a larger project involving a cost analysis for situations in which hospital foam mattresses were either replaced or not replaced after passing a quality norm and hospital foam mattress audits and management systems should be analyzed.

**Conclusion**

Seemingly similar mattresses differed greatly in their ability to withstand pressure at four points on foam mattresses after 15 years of use, indicating that mattresses should be measured individually for wear and tear to ensure that they are effective in providing support and redistributing pressure. The results confirmed that the lowest (minus) IQ value is at a relatively unloaded zone (top corner) of the mattress and the highest (minus) IQ value is in the middle of the mattress. Measuring indentation using a durometer provides an objective and a quantifiable assessment of a mattress. Study outcomes justify further examination of foam mattress management practices and cost analysis.

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References

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