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CHAPTER TWO

PACKAGING - A PROBLEM FOR PATIENTS WITH HAND DISORDERS?
A CROSS-SECTIONAL STUDY ON THE FORCES
APPLIED TO PACKAGING TEAR TABS


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ABSTRACT

Introduction  Patients with hand disorders frequently experience difficulties opening peelable packaging.

Purpose  To investigate the forces patients can apply to tear tabs and to compare the results with normative data to make recommendations for the industry and clinical practice.

Study design  Descriptive, cross-sectional.

Methods  One hundred patients with hand disorders were studied. The pinch pull force (PPF) applied to tear tabs of different lengths and materials (aluminum, plastic) was measured with a specially designed device. Key pinch was measured with a pinch gauge. Normative data were taken from another study on 402 healthy adults.

Results  Patients were able to apply most force to the longest aluminum tab, using the key grip, but this was only 53% of the force exerted by healthy people. Key pinch determines PPF ($R^2 = 0.548$, $p \leq 0.001$).

Conclusions  Manufacturers should provide long aluminum tear tabs. Health professionals are encouraged to measure key pinch to detect difficulties in opening packages.

Level of Evidence  Level IV.
INTRODUCTION
Many consumers experience difficulties in opening packaging but these are most apparent in elderly and disabled people. People older than 65 often suffer from hand disorders such as osteoarthritis, which is prevalent in up to 76% of this population. Taking symptoms such as pain, loss of grip strength, and reduced dexterity into account, it can be assumed that many consumers have difficulties in opening packaging.

Rahman et al. evaluated the forces healthy elderly people needed to open different household containers such as medicine bottles, an aerosol can of air freshener, a trigger pump spray bottle, and a dual-pinch safety squeeze bottle. Their results show that the last of these required the highest force to open it, although many participants commented on its ease of use. The Department of Trade and Industry (DTI) in the United Kingdom also investigated the forces people are able to generate onto peelable packaging such as cheese or ham containers. Using three different tab lengths, the researchers measured pull strength using either the key or the tip-to-tip pinch grip and determined that the force applied by people with dexterity problems was only about half that of healthy people.

Although there is awareness of the issue of package opening, there is a lack of information on how much force patients with hand disorders are actually able to apply to packaging. Data about grip strength for both healthy people and patients have been published in the medical literature, but these data are not much use to the industry because they do not consider different opening techniques, tab size, or tab material, which determine the friction force between the skin and the tear tab.

PURPOSE
The objectives of this study were to investigate the forces that patients with hand disorders are able to generate onto different tear tabs, to compare the results obtained with normative data, and to identify the difficulties in opening different types of packaging, to make recommendations on packaging design to the industry. A further aim was to study the correlation between forces applied to a 14mm long plastic tear tab and clinical measurements to suggest relevant outcome measures in clinical practice.

METHODS
Patients
Between September 2010 and November 2010, patients with hand problems who consulted a hand surgeon or an occupational therapist at the Schulthess Klinik in Zurich, Switzerland, were consecutively enrolled in this cross-sectional study. Inclusion criteria were a disorder of the dominant hand leading to meaningful restrictions in daily life, age ≥ 16 years, and written informed consent. Patients were excluded if they had undergone surgery within the last three months, had a cardiac pacemaker fitted, or were unable to understand German. The full study protocol was approved by the local ethics committee.
Assessments

Pinch Pull Force

To measure the forces people are able to generate onto different kind of tear tabs, the Fraunhofer Application Center for Processing Machinery and Packaging Technology (AVV, Dresden, Germany) developed the Pinch Pull Force Tester (PPF tester), a technical device containing a force gauge, which simulates packaging (Figure 1). Tear tabs of different sizes and materials were inserted into this device to measure the force with which the patient was able to pull these tabs, that is the pinch pull force (PPF). Tear tabs made of aluminum and plastic were available in three different lengths: 7, 14, and 21mm (Figure 2). The patients washed their hands to prevent the tear tabs slipping because of sweat or body lotion, and performed the following test procedure in a standardized sitting position. First, they pulled the 7mm plastic tab once with the tip-to-tip pinch, then once using the key (lateral) pinch grip on the same tab. Next, the 7mm aluminum tab was inserted and the patients were asked to pull again, first with the tip-to-tip and then with the key grip. The next tab in size was then inserted and the patients repeated the process. Because of the software calibration, all patients followed exactly the same sequence, resulting in a total of 12 measurements for each patient. There was a recovery time of about 30 seconds during the tab changes. Each tab was discarded after use and a new one provided for the next participant. Patients were instructed to pull the tear tab straight up with their dominant hand, as hard as they could. They were not allowed to support the tearing hand on the device, for example, by rolling it over the top of the tester while using the key grip. The other hand was used to hold the device in place. Patients who were not sure about their handedness used the hand normally used for opening packaging.

Difficulties in package opening

A questionnaire containing pictures of eight widely used packagings with different opening mechanisms was given to the patients. They were asked to indicate whether they experienced difficulties in daily life in opening the following: meat/cheese packaging (peelable packaging), a bottle (screw cap), a coffee packet (peelable), a jam jar (screw lid), cereals (peelable), a yoghurt cup (peelable), a beverage can with a ring pull, and a plastic-wrapped package to be opened with a pull strip (Figure 3). Difficulties were defined as discomfort during opening and/or needing an assistive device and/or being unable to open it at all.

Figure 1 Pinch Pull Force tester with a 7mm tear tab inserted. (A) Tip-to-tip grip. (B) Key grip.
**Figure 2** Tear tabs made of aluminum (above) and plastic (below). The shaded part of the tab is inserted into the Pinch Pull Force tester. Patients pull on the protruding end, which is 7, 14, or 21mm long.

**Figure 3** Pictures of the different packagings that were given to the patients. (A) Meat/cheese (peelable), (B) bottle (screw cap), (C) coffee (peelable), (D) jam jar (screw lid), (E) cereals (peelable), (F) yoghurt cup (peelable), (G) beverage can with a ring pull, and (H) plastic-wrapped package with a pull strip.
Clinical measurements

Key and tip-to-tip pinch maximal strengths were measured with the help of a digital pinch gauge (E-LINK, Biometrics Ltd, Gwent, UK) in a standardized sitting position. Three trials were conducted for each grip, and the average value was calculated.

The range of motion of thumb opposition was quantified according to the Kapandji index. This score ranges from 1 to 10, with a higher score indicating better opposition.

To assess subjective function, patients filled out the Patient Evaluation Measure (PEM), a simple, reliable, and validated questionnaire for assessing outcomes in patients with hand disorders. It has been translated into German according to the guidelines of Beaton et al. Only the second part, consisting of ten items about hand function, was used in this study. The total score ranges from 10 to 70, with lower scores indicating better hand function. Besides looking at the total PEM score, questions no. 3 (hand pain) and no. 6 (grip strength) were analyzed in more detail.

Patients filled out a German version of the EuroQoL 5D (EQ5D) to assess their quality of life.

Normative data

The AVV recorded normative data from 402 healthy adults aged between 20 and 80 years, with a mean age of 53.8 years (standard deviation [SD] 19.2), using the same PPF tester and test procedure. All raw data were made available for statistical analyses.

Statistics

Continuous data were analyzed using descriptive statistics with mean and SD. Normal distribution was confirmed by means of the Kolmogorov-Smirnov test and Q-Q plots. To achieve greater statistical power, nonparametric tests were used instead of parametric ones. The Friedmann test was used to test for significant differences between the different tear tab sizes and the Wilcoxon signed-rank test for differences between the two materials.

Guidelines for packaging manufacturers recommend that 95% of the consumer population should be able to handle the products effectively. Though the consumer population includes stronger males and weaker females, and younger and older people, use of the 95th percentile of the weakest target group is recommended. The threshold for healthy people was therefore calculated using the 95th percentile of elderly females (≥ 60 years). The threshold for the patient population was calculated using the 80th percentile of all females. This excluded patients with the most severe hand problems, as they cannot be expected to be able to open difficult kinds of packaging.

As there was good correlation between the forces exerted on the different kinds of tear tab (r = 0.57 - 0.92), the following analyses were performed only with the 14mm long plastic tear tab, using the key grip, as this tab is very commonly used for meat or cheese packaging in European countries. Differences between normative values and the patients’ data were analyzed with the help of the Mann-Whitney U test. Spearman’s correlation coefficient was used to test for correlation between the PPF and clinical outcomes. All variables showing a significant coefficient of correlation with PPF (r ≥ 0.5) were entered into a linear regression model with PPF using the key grip on the 14mm plastic tab as the dependent variable.

The analyses were done with SPSS 18.0 (www.spss.com) and R 2.12.0 (www.r-project.org). The level of significance was set at p ≤ 0.05.
RESULTS

One hundred one consecutive patients with different hand disorders were recruited and gave their informed consent. One patient withdrew because of pain during the measurements, leaving complete data from 100 patients. The mean age of the 71 female and 29 male patients was 61 years (SD ± 12.7). Patients with different diagnoses were included; osteoarthritis of the hand and carpal tunnel syndrome were the most common (Table 1, Figure 4).

Table 1 Characteristics of 100 patients with hand disorders

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Total number</th>
<th>Mean (Standard Deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Sex (females/males)</td>
<td>71/29</td>
<td></td>
</tr>
<tr>
<td>Age (yr)</td>
<td></td>
<td>61.0 (12.7)</td>
</tr>
<tr>
<td>&lt;20</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>20-30</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>31-40</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>41-50</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>51-60</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>61-70</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>71-80</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>&gt;80</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Key/lateral pinch strength (kg)</td>
<td></td>
<td>4.6 (2.2)</td>
</tr>
<tr>
<td>Tip-to-tip pinch strength (kg)</td>
<td></td>
<td>2.6 (1.4)</td>
</tr>
<tr>
<td>Kapandji Score (0-10)</td>
<td></td>
<td>8.7 (1.4)</td>
</tr>
<tr>
<td>EuroQoL SD (0-1)</td>
<td></td>
<td>0.7 (0.2)</td>
</tr>
<tr>
<td>Patient Evaluation Measure (10-70)</td>
<td></td>
<td>29.9 (13.8)</td>
</tr>
</tbody>
</table>

Pinch Pull Force

Comparisons between the different tear tab sizes and materials showed a number of significant differences: patients could apply more force to aluminum tear tabs than to plastic ones (p ≤ 0.001). The longer the tab, the larger the force applied (p ≤ 0.001). Furthermore, using the key grip rather than the tip-to-tip grip resulted in significantly higher force values for all tabs (p ≤ 0.05), except for the 7mm aluminum tab (p = 0.064). Data from healthy people followed the same pattern.

The threshold forces that 80% of female patients could apply to the different tear tabs are given in table 2. For the 14mm long plastic tab using the key grip, for example, this threshold is 8N, whereas the 95% threshold for healthy people, calculated from the data of 91 females with an average age of 71.5 years, is 10.5N.

When compared with normative data for all tear tabs, patients are able to apply only 53.1% of the force that healthy persons can manage. Further comparisons stratified by material, tear tab size, and grip technique, show significant differences for the 14mm long plastic tab in all age groups (Figure 5).
Difficulties in package opening

Patients indicated five (median) out of the eight packaging types as causing difficulties (range 0-8). When asked about difficulties with different types of packaging, 82% of the patients mentioned jam jars, 78% peelable meat/cheese packaging, 69% bottles, 68% peelable coffee containers, and 62% peelable cereal packs (Figure 6).

Clinical measurements

The results of both pinch gauge measurements correlate well with those for the 14mm plastic tear tab (Table 3). Furthermore, good correlation was seen between the PEM total score and question 3, and with question 6. Moderate but significant correlation was seen between the EQSD and key pinch strength, and between the two questionnaires. Only poor correlation was found between opposition of the thumb or the subjective grip of the patient (PEM question 6).

Table 2 80th percentile of the force that female patients could apply to different tear tab sizes and materials using either the tip-to-tip or the key grip

<table>
<thead>
<tr>
<th>Material</th>
<th>Grip</th>
<th>7mm 80th Percentile</th>
<th>14mm 80th Percentile</th>
<th>21mm 80th Percentile</th>
<th>p-Value Tab Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>Tip-to-Tip</td>
<td>7.0N</td>
<td>8.1N</td>
<td>9.3N</td>
<td>≤ 0.001</td>
</tr>
<tr>
<td>Plastic</td>
<td>Tip-to-Tip</td>
<td>3.6N</td>
<td>5.4N</td>
<td>6.4N</td>
<td>≤ 0.001</td>
</tr>
<tr>
<td>p-Value Material</td>
<td>-</td>
<td>≤ 0.001</td>
<td>≤ 0.001</td>
<td>≤ 0.001</td>
<td></td>
</tr>
<tr>
<td>Aluminum</td>
<td>Key</td>
<td>7.9N</td>
<td>10.4N</td>
<td>14.9N</td>
<td>≤ 0.001</td>
</tr>
<tr>
<td>Plastic</td>
<td>Key</td>
<td>4.6N</td>
<td>8.0N</td>
<td>9.2N</td>
<td>≤ 0.001</td>
</tr>
<tr>
<td>p-Value Material</td>
<td>-</td>
<td>≤ 0.001</td>
<td>≤ 0.001</td>
<td>≤ 0.001</td>
<td></td>
</tr>
</tbody>
</table>
and the 14mm plastic tear tab, and the key pinch strength. Entering key and tip-to-tip pinch strength values into a linear regression model showed that this model significantly determined the force on the 14mm plastic tear tab pulled with the key grip, and explained more than half of the variance ($R^2 = 0.557, p \leq 0.001$). Entering only one variable into the model still resulted in $R^2 = 0.548 (p \leq 0.001)$ for key pinch and $R^2 = 0.496 (p \leq 0.001)$ for tip-to-tip pinch.

**DISCUSSION**

The results of this study investigating the forces that patients with hand disorders can generate onto different tear tabs showed that patients are able to apply the greatest force on the longest

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**Figure 5** Mean values and standard deviation of the key pinch pull strength at the 14mm plastic tear tab for 100 patients compared with normative data stratified by age group. *$p \leq 0.05$; **$p \leq 0.001$*

**Figure 6** Number of patients having difficulties in opening different kinds of packaging in daily life
Packaging - a Problem for Patients with hand disorders?

The aluminum tab using the key grip, but that this is no more than 53% of the force exerted by healthy people. Peelable packaging, such as the meat/cheese packaging illustrated, is considered to be among the most difficult to open.

**Pinch Pull Force**

The longer the tear tab, the more force patients can apply, which reflects the normative data from the AVV\(^2\). It is easier to use the key grip on a longer tab, and significantly more force can be exerted. (In the present study, two patients with rheumatoid arthritis were unable to use the key pinch on the 7mm long tear tabs because of their finger deformities.) Trials show that the use of the key grip is feasible with a tear tab length of 10mm or more\(^2\). Regarding the material, patients could apply more force to aluminum tear tabs than plastic ones. This is explained by greater friction between the skin and the material, which allows higher pull strength values than the plastic tear tab with its very smooth surface\(^2\).

These results are in line with those obtained by the DTI, which conducted a trial with a similar experimental setup for both healthy and disabled people\(^8\)\(^-\)\(^2\). The longer the tab, the larger was the force applied. Using the key grip also led to significantly higher PPF values than using the tip-to-tip grip in both disabled and healthy people. Eighty-eight percent of elderly healthy people were able to apply 10N to a 12mm long plastic tear tab, whereas only 69% of disabled people could exert 10N. These figures are lower than the results of the present study, which can be explained by the DTI using a tear tab that was 2mm shorter.

**Difficulties in package opening**

More than three-quarters of the patients considered meat/cheese packaging to be difficult to open. This proportion is significantly higher than that found in elderly people, of whom only 40-50% have

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**Table 3** Spearman’s correlation coefficients for clinical measures and PPF of 100 patients with hand disorders

<table>
<thead>
<tr>
<th>PPF 14mm Plastic Tear Tab Key Grip</th>
<th>PG Key Grip</th>
<th>PG Tip-to-Tip</th>
<th>Thumb Opposition</th>
<th>Age</th>
<th>EQ5D PEM</th>
<th>PEM 3 (Pain)</th>
<th>PEM 6 (Strength)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPF 14mm Plastic Tear Tab Key Grip</td>
<td>1</td>
<td>0.77***</td>
<td>0.80**</td>
<td>0.27**</td>
<td>-0.03</td>
<td>0.43***</td>
<td>-0.43***</td>
</tr>
<tr>
<td>PG Key Grip</td>
<td>1</td>
<td>0.91***</td>
<td>0.14</td>
<td>0.02</td>
<td>0.54***</td>
<td>-0.44***</td>
<td>-0.33***</td>
</tr>
<tr>
<td>PG Tip-to-Tip</td>
<td>1</td>
<td>0.43</td>
<td>0.49**</td>
<td>-0.42**</td>
<td>-0.27**</td>
<td>-0.41**</td>
<td></td>
</tr>
<tr>
<td>Thumb Opposition</td>
<td>1</td>
<td>0.13</td>
<td>-0.27**</td>
<td>-0.20*</td>
<td>-0.22*</td>
<td>-0.22*</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>1</td>
<td>0.12</td>
<td>-0.14</td>
<td>-0.22*</td>
<td>-0.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EQ5D</td>
<td>1</td>
<td>-0.58***</td>
<td>-0.47***</td>
<td>-0.43***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEM</td>
<td>1</td>
<td>0.74***</td>
<td>0.76***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEM 3 (Pain)</td>
<td>1</td>
<td>0.48***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEM 6 (Strength)</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

PPF = Pinch Pull Force; PG = Pinch gauge; EQ5D = EuroQoL SD; PEM = Patient Evaluation Measure; PEM 3 = Patient Evaluation Measure item 3; PEM 6 = Patient Evaluation Measure item 6

Correlation r ≥ 0.5 is marked in bold

*p ≤ 0.05; **p ≤ 0.001; ***p ≤ 0.001
Packaging - a Problem for Patients with hand disorders?

difficulties in opening peelable seals. This type of package causes considerable difficulties, with 9% of disabled people not being able to open it at all. However, opening packaging requires more than just hand strength. Besides manual function, sensitivity as well as visual and cognitive aspects are important when opening consumer products. Hand conditions not only result in reduced strength but in many cases are also accompanied by other restrictions that explain the great difficulties patients have in opening packaging. Furthermore, factors such as the visibility and simplicity of the opening mechanism play important roles in the ease of opening a package.

Clinical measurements

Results show that pinch strength determines the level of force applied in PPF testing. Although not very high, the correlation of the PEM and EQ5D with strength indicates that PPF and the pinch grip are associated with subjective function and quality of life. This is supported by other studies, for example following distal radius fractures, where objectively measured strength correlated moderately well with patients' subjective satisfaction with their own strength.

Recommendations for the industry

Even small changes in the size of the tear tab, the material used, or its geometry have a large impact on the force needed to open the packaging. With respect to peelable packaging, the results of this study suggest that tabs should be at least 14mm long and made of a rough material, for example, aluminum. If a package with a 14mm long plastic flap can be opened with a force of 8N, 80% of patients with hand disorders will be able to open it successfully. Further aspects that need to be considered are good accessibility of the tear tab, its visibility (which can be improved by special coloring), and the simplicity of the opening mechanism with a clear description of how to use it, as well as uniform packaging for different products.

Although packaging is supposed to protect the contents and be sealed, manufacturers are encouraged to produce consumer-friendly packaging that will promote greater overall consumer satisfaction, not only among disabled people.

Recommendations for clinical practice

A specific PPF tester is not available in clinical practice. However, given that pinch grip correlated well with PPF, health professionals are encouraged to use the pinch gauge as an alternative assessment tool. As key pinch measurement shows favorable values in the regression model, this grip technique should be the evaluation tool of choice in clinical practice. If patients have low key pinch values, it can be assumed that they will have considerable difficulties in opening consumer products. Furthermore, health professionals should advise patients to use the key grip for peelable packaging to achieve more power.

Limitations

One limitation of the study is that the sequence of PPF measurements was the same for every patient because of the software used. Fatigue might therefore have caused lower values for the later measurements with the largest tab. The differences in values for the short and the long tabs might have been more pronounced had the measurement sequence been randomized.

The main limitation, however, is the imprecise inclusion criterion “hand disorder”. Patients presenting with a variety of diagnoses were included, leading to a broad range of data and...
therefore large SDs. Nevertheless, this study population closely resembles the population routinely consulting orthopedic secondary care hand surgeons. Further studies focusing on the difficulties of particular groups of patients, for example, those with rheumatoid arthritis, would yield more information about providing special containers and aids for these populations. In addition, it would be interesting to know more about the forces that patients can apply to real food containers. This is a question for further research.

CONCLUSIONS

Patients with hand disorders are able to apply most force to the longest aluminum tab using the key grip. When compared with normative data, patients are able to apply no more than 53% of the force exerted by healthy people. Among the most difficult packs to open are those with peelable packaging, such as are used for meat and cheese. Recommending the industry to produce peelable packaging with tabs that are at least 14mm long will allow customers to use the key grip. The tear tab should be made of a rough material, for example, aluminum. As the key pinch grip shows good correlation with PPF, health professionals are encouraged to use the pinch gauge as an outcome measure to detect relevant difficulties in package opening and hence quality of life.

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