Male condoms that break in use do so mostly by a “blunt puncture” mechanism☆

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Abstract

Background: Published condom breakage studies typically report the percentage of failures but rarely provide any evidence on the mechanism of failure.

Methods: Over a period of 7 years, broken condoms returned to a supplier (SSL, Durex™) via consumer complaints were examined to determine the cause of failure. Also, some consumers who reported breakage but did not return condoms were sent a questionnaire on the causes of breakage. Finally, theories proposed for the mechanism of breakage were investigated on a laboratory coital model.

Results: Nearly 1000 (n=972) returned condoms made from natural rubber and polyurethane were examined. Visible features on those that were broken, were classified. Evidence combined from examining returns, questionnaire responses and the coital model strongly suggests a single predominant mechanism of failure we named “blunt puncture,” where the tip of the thrusting male penis progressively stretches one part of the intact condom wall until it ultimately breaks.

Conclusions: Blunt puncture appears to be the mechanism of breakage responsible for more than 90% of condom breakage not attributable to misuse. Knowledge of the main mechanism of breakage should help develop better user instructions, better test methods and, ultimately, better condoms.

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1. Introduction

In the 1930s, the introduction of natural rubber (NR) latex led to widespread condom use. Since then, many billions of male condoms have been sold. Surprisingly, there is little published information on the mechanism of breakage in use. Although published user studies generally report the frequency of breakage [1–9], they rarely provide any information on the mechanism. Because condom failure is relatively rare, with breakage rates typically 0.4–2% [9] for NR latex condoms and 0.6–6% for synthetic condoms [9], the actual number of breakage events in a typical 1000-use study is small — often fewer than 10. This limits the breakage information that can be gleaned from each study, frustrating attempts to correlate breakage with user factors such as experience, age or education [10] or condom factors such as lubrication or strength [11]. Another weakness in many user studies is that broken condoms are not returned to the study center for verification and examination, leaving doubts about the accuracy of self-reporting. This investigation analyzed normal commercial Durex™ condoms that had broken during use and were returned by users as consumer complaints, focusing on the mechanism of breakage. Over 7 years, 972 used returned condoms were examined. Almost all were returned from the UK market.

During this period, all Durex™ condoms had a teat end and all were sold prelubricated, usually with silicone fluid (polydimethyl siloxane; viscosity, 350 cS). Most condoms sold were made from NR, but some (in one specific subbrand) were made from polyurethane (PU). The returned condoms showing some sort of defect (677) came from the many different subbrands in the Durex™ range. Most (n=511; 75.5%) of the broken condoms returned were made from NR latex, reflecting the predominant market share of the NR

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condom, but a significant minority \( n=166; 24.5\% \) were made from PU. Broken PU condoms exhibited certain visible features more prominently than NR condoms (see below). Over the period of study, condom shapes were generally similar among NR subbrands and the level of specified lubrication was generally similar among all subbrands.

It is estimated that approximately 1 billion Durex™ condoms were sold in the UK between August 1998 and August 2005; hence, the frequency of condom return because of breakage or other defect is approximately 0.7 per million sold.

2. Methods

The returned condoms were washed in Cidex™ or, latterly, Virkon™ for disinfection, dried, powdered for ease of handling in a talc/isopropyl alcohol slurry and finally dried in ambient air flow. The condoms were then visually examined using a binocular microscope (Leica MS5) with a cold light source (Volpi Intralux 4000-1 using a single swan neck light guide and a 90-W quartz halogen bulb) at magnifications typically between \( \times15 \) and \( \times100 \). The location of breakage and type of defect were recorded.

Additionally, for approximately 12 months of this study in 1997–1998, SSL sent a written questionnaire by post to people who complained about broken condoms but had not returned them. The purpose of the questionnaire was to try to determine why the condoms had broken. A total of 24 questions about duration of intercourse, coital position, any additional lubricant, prior experience of breakage, and so forth, were asked.

To evaluate possible mechanisms of breakage, we employed a simple mechanical coital model developed at SSL (Fig. 1). The coital model comprises a physiologically accurate model of an erect male penis made from reinforced foam rubber and an artificial female vagina made from rubber. The vagina model is capable of having its hollow tubular wall pressurized to alter the cavity diameter and, thereby, resistance to thrusting. In use, the penis model thrusts repeatedly into the vagina model, allowing us to study, for example, lubrication effects.

Finally, condoms were unrolled on a prelubricated plastic demonstrator and repeatedly stretched over the hemispherical end to reproduce certain types of breakage.

3. Results

Of the 972 condoms in this study, 474 were broken, 203 revealed some other form of defect, 290 were not defective and 5 were competitor condoms.

A high proportion of the returned broken condoms (more than 60%) were broken in the relatively small “teat” (closed end) area and immediate surroundings. It can be surmised that, in most instances of sexual intercourse, this part of the condom will experience the greatest amount of stress. However, some of the broken returned condoms show clear evidence of breakage somewhere on the side wall of the condom.

Careful examination along the line of failure using a high-quality binocular optical microscope almost never showed a visible flaw or defect in the condom film, even at the initial point of failure, where that point could be identified.

Some of the broken condoms showed a particular feature best described as an “eruption” through the wall of the condom (Fig. 2). This was usually at the closed end or in the teat itself but, surprisingly, sometimes at an...
arbitrary point along the side wall. This eruption pattern was most commonly exhibited by PU condoms, but less pronounced examples could also be seen on a small number of condoms made from NR latex (see further explanation below).

Additional information was provided by the questionnaire sent to complainants. Perhaps surprisingly, the response rate was good, with more than 50% of those who were sent the questionnaire replying. In total, 74 responses were received. Almost all (97%) reported that condoms had broken during vaginal sex, with the remainder (3%) during foreplay. Most (60%) noticed breakage on withdrawal, and a further 29% noticed it during sexual activity. Answers typically did not report that any unusual or athletic practices were taking place, and 92% of respondents denied using any additional lubricants. (Some additional lubricants such as mineral oil or petroleum jelly are known to swell and weaken NR condoms [12].) Responses indicated that where additional lubricants were used, they were water based.

The final question showed a simple outline drawing of a condom, and respondents were asked to mark the pattern of failure on this outline. In many cases, the response depicted a split or breakage into fragments. However, several drawings showed a small (ca. 5 mm) circular hole in the condom usually, but not always, toward the teat end of the condom (Fig. 3).

In an attempt to replicate this type of failure, we took an NR condom and unrolled it onto a prelubricated, closed-end, plastic condom demonstrator (similar to a large test tube). Repeatedly stretching the condom over the demonstrator to an extreme degree eventually resulted in breakage. In many cases, a major split was caused and sometimes fragments resulted. In some cases, however, a small circle of the condom detached from the stretched end, leaving a small but stretched circular hole through which the rounded end of the demonstrator protruded. Subjectively, the amount of force required to break the condom this way could be quite low after several stretches.

4. Discussion

As the number of broken condoms accumulated over the period of this study, it became apparent that many of the features associated with the failure could be classified into certain characteristic types. For example, broken NR condoms often showed a major line of failure, for example, a large split, and were sometimes broken into two or more pieces.

Based upon complaint letters, users often believed that because a condom broke, it “must” have had a manufacturing fault and that the breakage “proved” it. In fact, careful examination along the line of failure using a high-quality binocular microscope almost never showed a manufacturing flaw or defect in the condom film. If a flaw had been the cause of weakness leading to breakage, then the line of failure would be expected to run through it. Our examination of several hundred broken condoms does not support pre-existing flaws as a significant cause of breakage. The authors believe that users are breaking normal, nondefective, previously intact condoms because of the circumstances that arise during an individual act of intercourse.

As this study progressed, we concluded that the eruption failures had been caused by the erect male penis pushing its way through the intact wall of the PU condom and that the resulting hole had therefore been caused by a mechanism we labeled “blunt puncture.” The pictures of broken condoms themselves provide compelling evidence that blunt puncture is the cause of failure in these samples and that the shape of the broken condom retains evidence of the history of significant stretching before failure.

It seems clear that the whole condom cannot have been stretched to breaking point; hence, the stretching was probably localized to the area of failure. In addition, it is difficult to see how enough stretch could have been generated, even in a localized area, by one penile thrust during intercourse. Thus, we therefore propose that a
progressive elongation took place, with the condom being stretched around the tip of the erect penis during a thrust, but, critically, not returning fully to an unstretched state between thrusts, because the condom tightens around the penis as it stretches. Several cycles would result in a small area of the condom reaching its ultimate elongation and breaking.

Apart from the samples showing single eruption failure, a few condoms show both major distension in one area and rupture in another area of the condom, implying that, in this particular act of intercourse, strain first occurred in one area followed by movement of the penis tip and further strain that led to breakage in another (Fig. 4).

With the use of the SSL coital model, it is relatively easy to create progressive stretching of the condom over the tip of the penis model with each thrust, followed by blunt puncture failure after relatively few thrusts, by ensuring excess lubrication inside, between the artificial penis and condom, and minimal lubrication outside, between the condom and the artificial vagina, with a relatively tight fit between the artificial penis and artificial vagina. The failed condoms resulting from simulating blunt puncture on the coital model closely resemble some of those returned by users.

An NR film shows greater elastic recovery than PU and is therefore less likely to show a history of stretching, but careful examination of the returned samples shows a similar pattern of distension and failure in several instances in NR condoms (Fig. 5).

Repeatedly stretching an NR condom by hand over the lubricated tip of a plastic condom demonstrator until it breaks often causes a small (ca. 5 mm) circular hole like those seen in returned condoms. Such holes are in fact far too large to have been missed by routine checking during manufacture (i.e., “100% electronic testing”). We therefore believe that the presence of such holes in used, broken NR condoms is not a pre-existing manufacturing defect but is one reasonably likely outcome of blunt puncture failure in NR condoms.

Based upon the condoms returned to us and on the responses to the Questionnaire, very few condoms appear to be breaking in use because of tearing by fingernails or other sharp objects, or because of the use of inappropriate lubricants such as baby oil. From complaint letters most appear to have broken unexpectedly.

While some of the returned broken condoms, such as those showing eruption failures or the small circular holes described above, can indicate a plausible mechanism of failure, many failed condoms are not very informative. We therefore decided to classify all of the used, returned, broken or distorted products into classes based upon whether we believed they did result from blunt puncture (eruption or circular hole), could have resulted from blunt puncture (large tear or separation) or could not have resulted from blunt puncture (clear other cause of failure, e.g., gross swelling by mineral oil).

When classified this way, we found that more than 90% of the condoms could plausibly have arisen from the blunt puncture mechanism of progressive stretching and then failure (Fig. 6).

We believe that this finding is of importance both for existing condoms and for the development of new condoms for the following reasons:
Existing instruction warnings are not generally based upon avoiding the predominant mechanism of failure in use (blunt puncture).

New laboratory strength tests causing the same type of failure may be devised, which, unlike current strength tests [11], will likely better predict condom performance in use. Such tests will speed new condom design development and lessen dependence on slow, expensive and imprecise clinical studies.

Knowing how condoms fail in use should ease the development of condoms that break less frequently. For example, progressive slippage, friction and lubrication appear to be important factors. Redesigned condoms that reduce blunt puncture could ultimately result in condoms that break 10 times less frequently, which would be a major advance.

5. Conclusions

The systematic examination of failed condoms returned by users suggests a single common mechanism for most condom failures in use.
point of failure. We have called this type of failure blunt puncture, and our data strongly suggest that it could be responsible for more than 90% of breakage (excluding inappropriate use) of both NR and PU condoms.

Knowledge about the predominant mechanism of breakage of condoms should lead to more informative consumer education and better instructions for use; better, more predictive laboratory test methods of condom strength; and, ultimately, better condom designs that break less in use, without sacrificing sensitivity and aesthetics.

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References