JMP Instructional data set 022

Bone Plate Durability Test

JMP platforms and statistical methods

Graph Builder:	Mosaic plot; comparative dot plots and box plots.
Distribution:	Bar charts; summary statistics; inference for population proportion
Reliability:	Life distribution (Weibull)

Problem statement

Surgeons often use bone plates and screws to provide the necessary mechanical support to facilitate proper healing of a bone fracture (Figure 1).

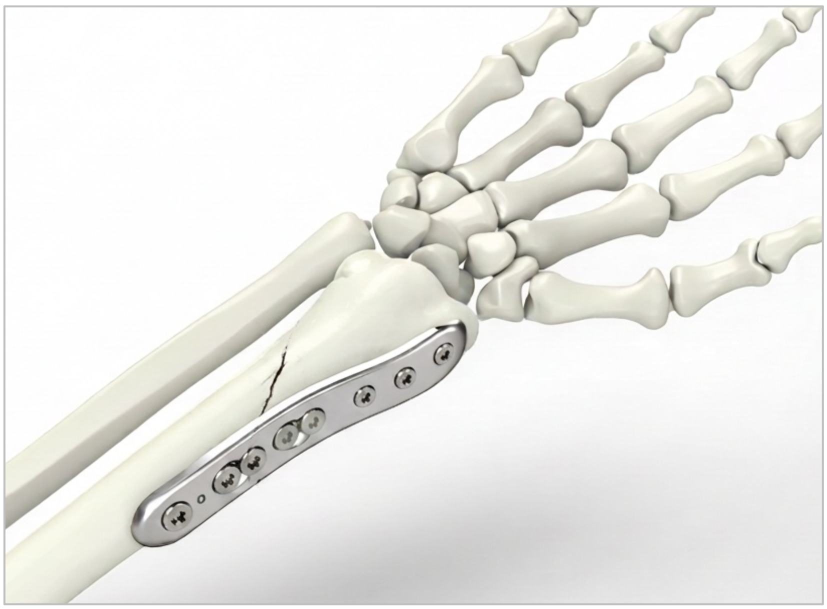

Figure 1.

Manufacturers of these plates and screws are required to subject their products to frequent testing to validate their durability. These tests are also part of R&D efforts as scientists and engineers work on structural changes and materials to improve upon the performance and durability of their products.

One such test procedure, known as flexure testing, applies a repetitive pulsating force onto the specimen; the number of cycles to produce an undesired amount of deformation of the specimen is observed. The force used for the testing is much greater than what would be experienced in real usage to accelerate failure (Figure 2).

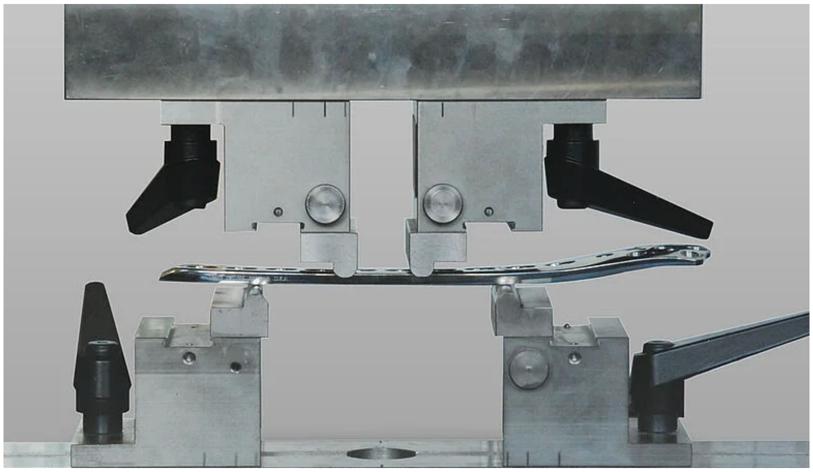

Figure 2.
Image of Flexure Testing Machine from ZwickRoell.
https://www.zwickroell.com

The engineering team is working on two new formulations designed to reinforce the base material. As the team is still early in the development stage, an initial sample of 20 specimens of both the XR and XT reinforcement material has been made in the product development lab. These specimens along with a sample of 25 base specimens, were tested. The tests were stopped after 5,000 cycles even if the undesired deformation had not occurred.

Data

IDS_022.jmp

Material	Identification Type of material used for the plate (Base, XR, XT)
Cycles	Number of cycles until failure or test stopped
Outcome	Indicator to identify if the specimen failed at the number of cycles in the ‘Cycles’ variable or if had not (Fail, Not Fail)

Exercises

1. Create a Mosaic Plot showing the proportion of specimens of each Material Type that had failed and not failed by 5,000 cycles.

> ***Instructions:***
> *Graph > Graph Builder. Place ‘Outcome’ on the Y axis, and ‘Material’ on the X axis. Columns. Select the Mosaic icon in the graph palette.* 

2. For each Material Type, construct 95% Confidence Intervals for the proportion of bone plates that would fail by 5,000 cycles categorizing the data as a binary outcome (Fail, Not Fail). Provide an interpretation of these intervals. Does this provide any evidence indicating differences between the Material Types? What key information about these tests do these confidence intervals and the graph created in Exercise 1 not account for that would be important to in order to determine which Material Type performs best/worst?

> ***Instructions:***
> *Analyze > Distribution. Place ‘Outcome’ in the Y, Columns. Place ‘Material’ in the By role. For each material type, select Confidence Interval > 0.95 under the red triangle.*

3. Create comparative dot plots of the number of cycles until failure (or when testing stopped) for the three Material Types. Interpret the graph comparing the performance of each Material Type. Is this the same conclusion you had reached in Exercise 1?

> ***Instructions:***
> *First create a row state that will use different colors for those specimens that have and have not failed in the graph. Rows > Color or Mark by Column. Choose ‘Outcome’. Click OK.*
>
> *Graph > Graph Builder. Place ‘Cycles’ on the Y axis, and ‘Material’ on the X axis. Columns. Select the Mosaic icon in the graph palette.*

4. Perform life distribution analyses for each Material Type.

   a. Select a probability distribution that is a good model to describe Cycles-to-Failure for each Material Type?
   b. For each Material Type, examine the 95% Confidence Interval estimate of the Average Cycles-to-Failure. Interpret these intervals.
   c. For each Material Type, provide a 95% Confidence Interval estimate of the proportion of bone plates that would fail by 5,000 cycles. Compare this result to the analysis done in Exercise 2. Which of these analyses do you think provides a more accurate estimate of proportion of bone plates that would fail by 5,000 cycles? Explain why.
   d. For each Material Type, provide a 95% Confidence Interval estimate of the number of cycles that 1% of the bone planes would fail by. Is there statistical evidence to indicate that at least 99% of plates made from any of the materials could survive at least 4,000 cycles in this accelerated test?
   e. Comment on the width of the confidence intervals from c) and d). What would be needed for these confidence intervals to have a smaller margin of error?

Instructions:
Analyze > Reliability > Life Distribution. Place 'Cycles' in the Y, Time to Event role. Place 'Material' in the By role. Click OK.

a) Select the Weibull distribution in the Compare Distributions controls for each material type. Evaluate the plots to confirm the Weibull distribution provides a good model for the data?
b) 95% confidence intervals are provided by default once the distribution is chosen
c) In the interactive Distribution Profiler, enter the value "5,000" on the Cycles axis. The point estimate of percentage of specimens that would fail and corresponding 95% confidence interval are displayed to the left of the graph.
d) In the interactive Quantile Profiler, enter the values ".01" on the Probability axis. The point estimate of the number of cycles until that percentage of plates would fail by and corresponding 95% confidence interval are displayed to the left of the graph.

5. What other testing or experimentation would you recommend for the engineers to conduct in order to develop deeper understanding in the performance of these bone plates?