Snap, Snap, Snap!

I. Introduction

In the United States, nearly 58 million Americans aged six or above participate in recreational fishing each year. Naturally, these anglers want to maximize their expected catch rate while minimizing equipment failure, as broken fishing lines can result in lost fish, lost tackle, and unnecessary waste. Although fishing line manufacturers provide a rated breaking strength for their products, a large and often unaccounted factor of the breaking strength of a fishing line is the knot used to connect the line to the hook. Different knot designs distribute the tension differently which could potentially affect the force that is required to cause failure.

Among many knots available, the most commonly used knots are: the Improved Clinch Knot, the Uni Knot, and the Surgeon's Loop Knot. These are frequently recommended for beginners due to their simplicity and widespread use. However, anglers often receive conflicting advice regarding which knot type produces the strongest connection. Determining which knot provides the greatest breaking strength can help anglers make better decisions when selecting a knot for recreational fishing.

The goal of this study is to determine whether the type of knot affects the mean breaking strength of fishing lines and identify which knot type provides the greatest mean breaking strength.

II. Statistical Question

Is there a difference between the breaking strength of fishing lines when tied using the Improved Clinch Knot, Uni Knot, or Surgeon's Loop?

- μ_C = the true mean breaking strength of fishing lines when tied using the Improved Clinch Knot.

- μ_U = the true mean breaking strength of fishing lines when tied using the Uni Knot.
- μ_S = the true mean breaking strength of fishing lines when tied using the Surgeon's Loop Knot.

H_0: The true mean breaking strength of fishing lines between the various knot types is the same. ($\mu_C = \mu_U = \mu_S$)

H_a: At least two of the true mean breaking strength of the fishing lines between the various knot types are different. (At least one μ differs)

III. Data Collection

In order to conduct our experiment, we ensured to follow the foundational principles of experimental design to minimize bias, reduce variability, and control potential confounding variables. Our three treatments were Improved Clinch Knot, Uni Knot, and Surgeon's Loop Knot, and our response variable was the breaking strength of a fishing line segment, measured as the force (in Newtons), required to cause the line to fail.

We began by locating the fishing lines that would be used to test our hypotheses. To minimize confounding variables and variability, we decided to stick to one type of fishing line throughout the entire experiment, the Sufix ProMix Clear Monofilament 10lb Line. To extend our reach of generalization, we used cluster random sampling to generalize to all the specified fishing lines sold at DICK's Sporting Goods at Pembroke Pines, FL on May 2nd, 2026, instead of only the ones in the experiment. Since each fishing spool is relatively similar to each other, we can assume that each spool is a strong representation of the entire population. Each available spool was assigned a number 1 through 13, and a random number generator generated 2 unique numbers from 1 to 13. Spools 5 and 9 were chosen as the sample for the experiment.

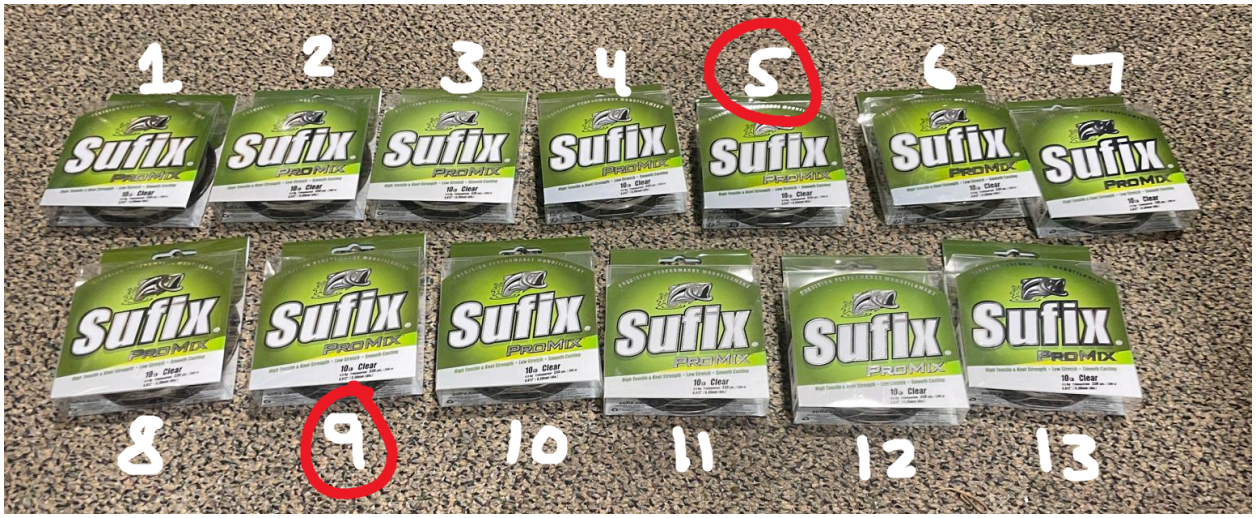

Figure 1: Photo of Sufix ProMix Clear Monofilament 10lb Lines

We sought to minimize the potential confounding variables through random assignment. In order to achieve a significant amount of replication, we randomly assigned 30 fishing line segments to each knot type using the following steps:

1. Cut the fishing lines into 90 segments with equal length of 40 cm, 45 segments from one fishing line spool and 45 segments from the other spool.
2. Assign numbers to each fishing line segment from 1 to 90.
3. Randomly select 30 unique numbers from 1 to 90 using a random number generator. The corresponding fishing line segments are assigned to the Improved Clinch Knot treatment.
4. Randomly select another 30 unique numbers from 1 to 90, different from the first 30. The corresponding fishing line segments are assigned to the Uni Knot treatment.
5. The final remaining 30 fishing line segments will be assigned to the Surgeon's Loop Knot treatment.

After assigning treatments we tested each fishing line segment. To ensure consistency across all trials, we followed the same procedure for each segment:

1. Select a fishing line segment according to its assigned treatment group.

2. Tie the assigned knot (Improved Clinch Knot, Uni Knot, or Surgeon's Loop Knot) onto a hook. The Improved Clinch Knot, Uni Knot, and Surgeon's Loop Knot were tied by following the procedures shown in each instructional video:
    a. Improved Clinch Knot: https://youtu.be/watch?v=2YO7JWNdVC0
    b. Uni Knot: https://youtu.be/watch?v=IOv8vJqK1H0
    c. Surgeon's Loop Knot: https://youtu.be/watch?v=mlOhAY2R6jY&t=1m34s
3. Attach the hook to a force sensor, and place the force sensor between two chairs with a small gap in the middle for the hook to hang underneath.
4. Apply tension to the fishing line until the line breaks. This is done by wrapping the excess fishing line multiple times around a pencil and applying a downward force.
5. Record the maximum force measured by the force sensor right before the line breaks.
6. Repeat steps 1 - 6 for all 90 fishing line segments.

As a result, by controlling testing conditions and following the same procedure for every fishing line segment, we minimized potential confounding variables and experimental bias while ensuring the three knot types were compared under identical conditions with proper replication.

Figure 2: Experimental setup used to measure the breaking strength of fishing line segments.

Figure 3: Photo of the Force Sensor used to measure the downward force in Newtons

IV. Data Display

Group Name	n	mean	SD	min	Q_1	med	Q_3	max
1: Improved Clinch Knot (N)	30	34.48	3.314	28.1	32.5	33.8	36.5	42.2
2: Uni Fishing Knot (N)	30	39.55	4.559	30	35.7	39.95	42.5	47.1
3: Surgeon's Loop Knot (N)	30	46.453	3.664	40.2	43.6	46.45	48.7	55.1

Figure 4: Statistical Summary of Breaking Strength for Each Knot Type

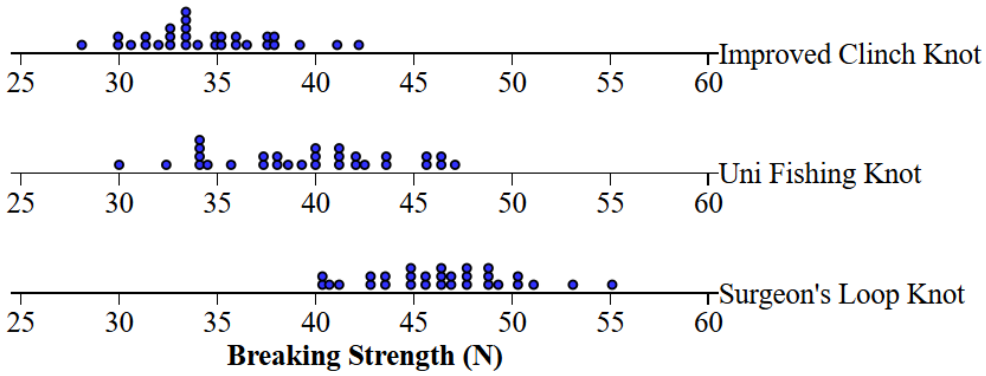

Figure 5: Dot Plot of Breaking Strength for Each Knot Type

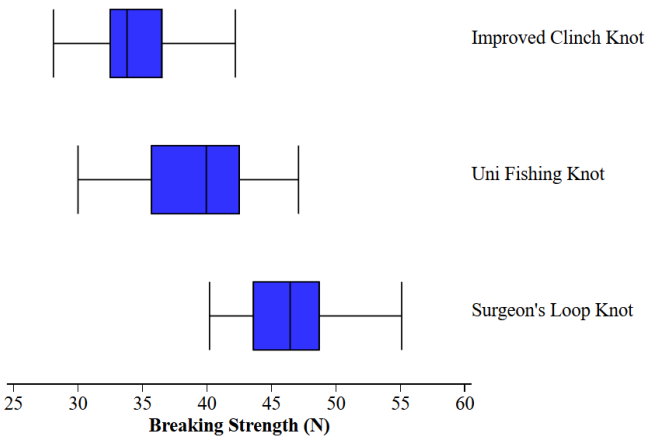

Figure 6: Boxplot of Breaking Strength for Each Knot Type

V. Statistical Test - ANOVA

From the summary statistics and graphs above, we observe differences between the means of each type of knot. The maximum breaking strength data point of the Improved Clinch Knot is very close to the third quartile of the Uni Knot, and the median of the Uni Knot is very close to the minimum of the Surgeon's Loop Knot. Evidently, we are inclined to perform a one-way omnibus ANOVA test to assess if there is a difference in breaking strength between the three types of knots. We begin by assessing if the conditions to perform the inference are met:

1. Random: The data indeed was obtained through random selection and has undergone random assignment. We randomly chose the fishing line using a cluster sampling method and randomly assigned each fishing line segment to one of three knot treatments.

2. Independent: A cause for scrutiny may lie in the fact that the entire fishing line is dependent due to coming from the same supplier. Indeed, we concede that if a manufacturing defect existed within that spool, then multiple observations could be affected simultaneously. Still, we maintain a strong level of independence since each segment underwent a unique knotting and breaking process. Thus, the resulting data from a fishing line segment should have little to no impact on another segment. We further minimized the dependence between lines by randomizing segments. Had we not randomized and simply assigned nearby segments to the same knot treatment, potential discrepancies in the fishing lines would not be evened out and lurking variables would persist. Therefore, the independence condition was reasonably satisfied, with a minor limitation due to common spool origins.

3. Normal: We assigned 30 fishing line segments for each knot type. Since the sample size is at least 30, the robust nature of an ANOVA test through the Central Limit Theorem, in addition to the fact that all three groups are relatively symmetric with no outliers, guarantees that the sampling distribution of the sample mean breaking strengths is approximately normal.

4. Homoscedasticity: We can use Hartley's test to check if the groups have similar variances. Since the ratio of the largest variance to the smallest variance is $20.784 / 10.981 = 1.893 < 2$, we can confidently say the groups have similar variances and thus the homoscedasticity condition is fulfilled.

We may now perform the one-way omnibus ANOVA test:

Source	df	Sum of Squares	Mean Square	*F*-statistic	p-value
Groups (Between)	2	2167.2161	1083.608	71.9397	<0.00001
Error (Within)	87	1310.4576	15.0627		
Total	89	3477.6737			

VI. Test Conclusion - ANOVA

Since the p-value of <0.00001 is less than the significance level of 0.05, we reject the null hypothesis and conclude there is statistically significant evidence that at least two of the true mean breaking strength of the fishing lines between the various knot types are different. The *F*-statistic of 71.9397 means that the variability between the knot groups is 71.9397 times greater than the variability within the knot groups, which is *significantly* greater than the critical value of 3.101.

VII. Statistical Test - Post-Hoc Test

In order to identify which pairs of groups are statistically different, we perform Tukey's HSD Post-Hoc Test. Since all the knot groups have an equal sample size of 30, the conditions are fulfilled to perform the test.

Comparison	Null Hypothesis	Alternate Hypothesis
Improved Clinch Knot vs. Uni Fishing Knot	There is not a difference in mean breaking strength between the Improved Clinch Knot and the Uni Fishing Knot.	There is a difference in mean breaking strength between the Improved Clinch Knot and the Uni Fishing Knot.
Improved Clinch Knot vs. Surgeon's Loop Knot	There is not a difference in mean breaking strength between the Improved Clinch Knot and the Surgeon's Loop Knot.	There is a difference in mean breaking strength between the Improved Clinch Knot and the Surgeon's Loop Knot.
Uni Fishing Knot vs. Surgeon's Loop Knot	There is not a difference in mean breaking strength between the Uni Fishing Knot and the Surgeon's Loop Knot.	There is a difference in mean breaking strength between the Uni Fishing Knot and the Surgeon's Loop Knot.

Comparison	Mean Difference	q-statistic	p-value	Significant?
Improved Clinch Knot vs. Uni Fishing Knot	5.07	7.1551	<0.00001	Yes
Improved Clinch Knot vs. Surgeon's Loop Knot	11.9733	16.8976	<0.00001	Yes
Uni Fishing Knot vs. Surgeon's Loop Knot	6.9033	9.7424	<0.00001	Yes

VIII. Test Conclusion - Post-Hoc Test

Since the p-value of <0.00001 is less than the significance level of 0.05 for every pair, we reject all the null hypotheses and conclude there indeed is a statistical difference between the breaking strength in each knot type. Analyzing the means, we see the order of the mean breaking strength is:

Improved Clinch Knot < Uni Fishing Knot < Surgeon's Loop Knot

IX. Reflection

The goal of the study is to analyze whether there is a difference in breaking strength under various knot types. We designed an experiment to test this notion, controlling confounding variables within the brand types and spool inconsistencies, randomly assigning our fishing line segments to their treatments, and replicating our experimental design among a large number of segments. Selecting 2 out of the 13 available spools and using only a portion of fishing line from each spool ensures our data does not come from a census. Through our study, we found statistically significant evidence that suggests there is, in fact, a difference in mean breaking strength; the Surgeon's Loop Knot performed the best, followed by the Uni Knot and then the Improved Clinch Knot.

A possible limitation of our experiment is that we tied the knot by hand by ourselves. Although we tied the same type of knot following the standard instructional video, differences in knot tightness and loop sizes may have affected the measured breaking strength. These inconsistencies may have resulted in increased variability within each treatment group. Another limitation of this experiment is that all the breaking strength is measured using dry fishing line segments. In the actual fishing conditions, fishing lines would be submerged under water and may be exposed to different temperatures and other dynamic forces. These factors could affect the breaking strength of different knot types. Thus, anglers should proceed with caution when generalizing this experiment's result to the actual fishing conditions.

Due to the designs of this experiment, our results are only generalizable to Sufix ProMix Clear Monofilament 10Ib Lines sold at the DICK's Sporting Goods. If we were to repeat this experiment, we would hope to incorporate different fishing brands and perform a two-way ANOVA test. We would also investigate whether knot types affect the breaking strength of the fishing line after prolonged water exposure. This would improve not only generalizability but

also the applicability to real recreational fishing. Since we rejected the null hypothesis, there is a possibility that we committed a Type I error. However, there remains *exceptionally* strong evidence against the null hypothesis due to our exceedingly low p-value of <0.00001. Overall, we are confident that the results of our study can be used by anglers, from beginners to experienced, in their fishing journey.

X. Appendix

No adult guidance was sought throughout the project.

Raw Data:

Segment #	Knot Type	Breaking Strength (N)	Segment #	Knot Type	Breaking Strength (N)	Segment #	Knot Type	Breaking Strength (N)
1	Improved Clinch Knot	33.5	7	Uni Fishing Knot	37.4	2	Surgeon's Loop Knot	53.1
3	Improved Clinch Knot	35.1	8	Uni Fishing Knot	38.0	4	Surgeon's Loop Knot	40.5
5	Improved Clinch Knot	37.9	9	Uni Fishing Knot	34.3	10	Surgeon's Loop Knot	46.3
6	Improved Clinch Knot	31.4	17	Uni Fishing Knot	46.3	13	Surgeon's Loop Knot	47.8
11	Improved Clinch Knot	36.0	19	Uni Fishing Knot	46.5	14	Surgeon's Loop Knot	43.0
12	Improved Clinch Knot	28.1	20	Uni Fishing Knot	42.0	16	Surgeon's Loop Knot	46.4
15	Improved Clinch Knot	33.5	21	Uni Fishing Knot	41.1	22	Surgeon's Loop Knot	40.2
18	Improved Clinch Knot	34.7	23	Uni Fishing Knot	43.7	24	Surgeon's Loop Knot	44.7
30	Improved Clinch Knot	34.0	25	Uni Fishing Knot	45.5	26	Surgeon's Loop Knot	47.7
32	Improved Clinch Knot	32.5	27	Uni Fishing Knot	34.3	28	Surgeon's Loop Knot	46.5
36	Improved Clinch Knot	39.2	29	Uni Fishing Knot	34.5	31	Surgeon's Loop Knot	42.6
38	Improved Clinch Knot	35.2	33	Uni Fishing Knot	39.3	34	Surgeon's Loop Knot	51.1
43	Improved Clinch Knot	30.6	35	Uni Fishing Knot	40.2	37	Surgeon's Loop Knot	48.7
50	Improved Clinch Knot	33.6	40	Uni Fishing Knot	37.3	39	Surgeon's Loop Knot	45.0
52	Improved Clinch Knot	35.4	42	Uni Fishing Knot	42.5	41	Surgeon's Loop Knot	55.1
57	Improved Clinch Knot	32.5	44	Uni Fishing Knot	38.6	45	Surgeon's Loop Knot	43.6
58	Improved Clinch Knot	29.8	47	Uni Fishing Knot	40.1	46	Surgeon's Loop Knot	48.7
59	Improved Clinch Knot	33.3	53	Uni Fishing Knot	47.1	48	Surgeon's Loop Knot	50.1
63	Improved Clinch Knot	42.2	54	Uni Fishing Knot	30.0	49	Surgeon's Loop Knot	49.3
64	Improved Clinch Knot	37.7	55	Uni Fishing Knot	39.8	51	Surgeon's Loop Knot	41.2
69	Improved Clinch Knot	32.0	62	Uni Fishing Knot	42.1	56	Surgeon's Loop Knot	50.5
76	Improved Clinch Knot	36.5	66	Uni Fishing Knot	34.1	60	Surgeon's Loop Knot	44.9
78	Improved Clinch Knot	41.1	67	Uni Fishing Knot	43.5	61	Surgeon's Loop Knot	45.5
79	Improved Clinch Knot	33.2	71	Uni Fishing Knot	41.4	65	Surgeon's Loop Knot	48.9
80	Improved Clinch Knot	31.3	73	Uni Fishing Knot	33.9	68	Surgeon's Loop Knot	47.3
81	Improved Clinch Knot	38.0	75	Uni Fishing Knot	38.1	70	Surgeon's Loop Knot	43.5
83	Improved Clinch Knot	32.7	82	Uni Fishing Knot	41.0	72	Surgeon's Loop Knot	46.9
84	Improved Clinch Knot	30.1	85	Uni Fishing Knot	45.8	74	Surgeon's Loop Knot	40.7
86	Improved Clinch Knot	37.4	87	Uni Fishing Knot	32.4	77	Surgeon's Loop Knot	45.7
90	Improved Clinch Knot	35.9	88	Uni Fishing Knot	35.7	89	Surgeon's Loop Knot	48.1
Avg. Breaking Strength		34.5			39.6			46.5
Sd. Breaking Strength		3.313753992			4.558565261			3.664247896
Variance		10.98096552			20.78051724			13.42671264