When Prusiks Go Bad, or Are you Sure That Thing is Gonna Hold?

The results of five studies involving Prusik hitches were examined together. Only tests with 3 wrap Prusiks on static rope were considered in this analysis. Of the 3 studies providing detailed information on drop testing, the overall rate of failure for tandem Prusiks (n=187) was approximately 20% or 1 in 5. One small study providing information on the results of pull testing (rather than drop testing) indicated that the average breaking strength of a Prusik set in tandem was 4346 lbs; whereas single Prusiks average breaking strength was 3440 lbs. Another study did not provide detailed results but concluded that Prusiks "would appear to be our main weak link in rescue systems"(Willard, 1987). Most Prusik failures occurred where the hitch melted on to the main line. Prusik failure does not appear to be related to Prusik diameter, Prusik material, rope diameter, or rope material; but may be related to using Prusiks with a load releasing hitch; however the number of tests in this and some other categories (i.e. twin ropes) were so small that a definitive conclusion is not warranted. The overall findings indicate that even when Prusiks are "properly" tied, set, and spaced they have an alarming tendency to catastrophically fail in drop testing under a variety of circumstances. The questions are raised: a) is drop testing is an appropriate method for evaluating the field effectiveness of Prusiks; b) given these results, are Prusiks appropriate for use in preventing catastrophic system failure (e.g. as "backups") or should they only be used in ratcheting applications; c) what further testing may resolve this important issue?

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Jerome Stiller began doing scary stuff over 20 years ago as a theatrical and concert rigger. He has been a member of Alpine Rescue Team (Evergreen, CO) since 1997. Mr. Stiller has served as a rock climbing instructor for Alpine Rescue Team Prospective Member Training; a Hug-A-Tree and Survive seminar presenter; an instructor for Horizon Adventures. Inc., Climbing For Life, Inc. and for the Colorado Mountain Club Basic Rock Climbing Seminar; and was the Safety Director, Colorado Mountain Club Basic Rock Climbing Seminar, 2000. He has over 10 years experience rock climbing in Colorado, Utah, Wyoming, New Mexico, New York, Alaska, and Mexico and 3 years experience ice climbing. Mr. Stiller continues to do concert rigging and occasionally shows up for his job as a Biostatistician with the AMC Cancer Research Center in Denver, CO.

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Abstract

The results of six studies involving Prusik hitches were examined together. Only tests with 3 wrap Prusiks on static rope were considered in this analysis. Of the four studies providing detailed information on drop testing, the overall rate of failure for tandem Prusiks (n=197) was 19%. One small study providing information on the results of pull testing indicated that the average breaking strength of Prusiks set in tandem was 4346 lbs; whereas single Prusiks average breaking strength was 3440 lbs. Most Prusik failures occurred where the hitch melted on to the main line. Prusik failure does not appear to be related to Prusik diameter, Prusik material, rope diameter, or rope material. The overall findings indicate that even when Prusiks are "properly" tied, set, and spaced they have an alarming tendency to fail catastrophically in drop testing under a variety of circumstances. The questions are raised: a) is drop testing is an appropriate method for evaluating the field effectiveness of Prusiks; b) given these results, are Prusiks appropriate for use in preventing catastrophic system failure (e.g. as "backups") or should they only be used in ratcheting applications; c) what further testing may resolve this important issue?

Introduction

In mountain rescue applications, the Prusik[1] hitch is perhaps the most common method for attaching to or grabbing one rope with another[2]. From its conception in 1931[3], the role of the Prusik hitch in rescue work has expanded from being a means for a single climber to ascend a rope to that of a rope grab mechanism used in belaying rescue loads. While there is little doubt that the Prusik may be used to grab a rope, there is not much research concerning the load bearing properties of the Prusik in a ***rescue*** scenario, and especially scant recent research regarding alternative rope grab mechanisms (e.g. knots such as the dog n' tails; toothless mechanical devices, newer products, etc.).

The goals of this paper are to synthesize and review the existing research, present the aggregated findings to date, and suggest further areas of study. A larger (and certainly more important) goal of this inquiry is to provide definitive practical recommendations for using rope grab mechanisms in rigging rescue belays. I hope that this paper will generate sufficient interest so that clear and comprehensive testing can and does occur.

Methods

The results of six studies involving Prusik hitches were examined together. The studies were conducted by a variety of rope technicians and riggers[4] from 1986 to 1997. In most cases, a simulated rescue load of 200-300 kilograms (440 – 660 pounds: presumably a litter, one patient, and one or two attendants) was dropped one meter on three meters of 11.1mm – 12.7mm static line (a fall factor of 0.33). The load was to be caught by a set of 8mm low stretch accessory cords tied into loops with double fisherman's knots, wrapped three times around the belay line, and set in tandem. This standard was used in over 95% of the testing reported here, although some deviations exist (e.g. 7mm accessory cord, longer drops, four wrap Prusiks, etc.). For comparison purposes, only those tests with 3 wrap 8mm or 9mm tandem Prusiks on 11.1-12.7 mm rope are used to calculate the overall failure rate[5].

Results

Of the 4 studies providing detailed information on drop testing, the overall rate of failure for tandem Prusiks (n=197) was 19% or approximately one in five. If the tandem Prusik failure rate definition is expanded to include any reported melting of the Prusiks or belay line, breakage of the tandem Prusik attachment to the belay line (typically a double bowline), complete failure of one Prusik but not the other, and/or significant sheath slippage or bunching on the belay line, the rate goes up to 35% or approximately one in three. The failure rate for single Prusiks (n=15) was 27% under the complete failure definition and 47% under the more relaxed definition.

One small study (n=6) providing information on the results of pull testing (rather than drop testing) indicated that the average breaking strength of Prusiks set in tandem was 4346 lbs; whereas single Prusiks average breaking strength was 3440 lbs[6]. Another study did not provide detailed numerical results but concluded that Prusiks "would appear to be our main weak link in rescue systems"[7].

Most Prusik failures occurred where the hitch melted on to the main line. Prusik failure does not appear to be systematically related to Prusik diameter, Prusik material, rope diameter, or rope material. Specifically, the failure rates do not appear to be significantly different for 7mm versus 8mm Prusik cords, cords from various manufacturers, ropes from _ inch to 12.7 mm in diameter, or for ropes from various manufacturers.

There is some evidence that failure may be related to using Prusiks with a load-releasing hitch. Of the 15 tandem Prusiks tested with load releasing hitches, 4 failed completely (27%) and 5 more showed some significant damage (total 60%), typically at the LRH rather than the Prusik. However, it must be noted that the number of tests was so small that a definitive conclusion regarding load releasing hitches is not warranted.

Conclusions

The overall findings indicate that even when Prusiks are "properly" tied, set, and spaced they have an alarming tendency to fail catastrophically in drop testing under a variety of circumstances. If rescue operations involve using tandem Prusiks as part of a belay or back up system designed to catch a rescue load if the main anchor fails, it would appear that Prusiks are not adequate for this purpose. A conservative failure rate of about 20% means that if the main belay anchor fails, either through equipment or human malfunction, then there is a significant likelihood that the secondary system will fail as well, resulting in total system failure. In other words, if you have a litter on belay, and that belay is lost for whatever reason, your backup may fail too (AKA 'down zoom'). This is clearly not acceptable.

So, what do we do? First, I think we need to question the ways in which we evaluate Prusiks (and all rope grab devices, for that matter). Second, we need to question how we use Prusiks for rescue loads, and understand the implications of using Prusiks as part of a belay or back up system versus using them in a ratcheting application. Third, we need to decide how best to proceed to resolve this issue.

Current Standards of Evaluation

Both drop testing and pull testing simulate real world field applications, but how likely is it that a system component will be fully shock loaded instantly without ***any*** load coming onto the component first, as is in the case of drop testing; or that a consistent steady pull will be exerted on a system component, as is in the case of pull testing? Experience indicates that, unlike the instantaneous shock load of a falling lead climber, rescue loads tend to at least have the potential to be minimally distributed to the backup anchor through system friction, rope drag, and/or human intervention. Thus, it seems unlikely that tandem Prusiks ever truly "see" a full rescue shock load under the same circumstances as in drop testing. We are testing for a worst-case scenario, which may not be the best representation of field situations.

By the same token, systems and system components in field use tend be loaded differently over time as the terrain and the conditions change, so it is unlikely that Prusiks will ever "see" a consistent load, such as is the case with pull testing. Here we are testing for a best-case scenario, which is also probably not a good representation of field applications.

In addition, all of the drop test results reviewed for this paper include data regarding maximum arrest force. This paper does not attempt to examine the forces absorbed or transmitted in a fall as a result of using Prusiks. The only outcome measure here is the binary PASS/FAIL criterion. Some standards exist for maximum arrest force (typically 12kn –15kn, depending on who you listen to), and Prusiks appear to perform reasonably well in meeting these standards ***when they hold***. Because maximum arrest force is a secondary criterion for effectiveness only after a falling load is successfully arrested, it is not considered a crucial outcome evaluation measure.

Prusik Use

By using Prusiks to "catch" a falling load, the rescue community has taken a method designed to allow a single person to ascend a rope and drafted it "to provide protection against a fall by handling a secondary unloaded rope…to hold [the rescue] load in case of failure of the main line(s)…"[8]. The safety considerations involved in providing such protection are obviously quite different than those involved in a single person ascending a rope. It is unclear if significant development has gone into solving the protection problem, or if Prusiks (and other rope grab devices) have been accepted because they "*seem to work just fine*". Protecting against total system failure by introducing redundancy at key points (e.g. back-ups, belays) is undoubtedly a prime concern in rigging rescue systems. However, the use of current rope ascension technology as a means of arresting an out of control rescue load is clearly questionable. Furthermore, even if the rope grab does hold, the practical issue of releasing the load so that it maybe moved again is problematic if not impossible.

Prusiks are often used to hold rescue loads in a much more static environment, such as when transferring the load form one anchor to another in a knot pass. In this application, it would appear that Prusiks are perfectly adequate for the loads involved.

Some Suggestions for Further Testing

Since the results of this review indicate that current methodology for belay systems may be inadequate, it seems incumbent upon us to engage in additional testing and development of a more reliable rope grab method or device. The questions most relevant to a new testing agenda are:

1) What is the maximum acceptable failure rate for a rope grab device?
2) What is the maximum acceptable arrest force?
3) What are the "load-catching" characteristics of alternative "soft" techniques, such as the Hedden (kreutzklem) hitch, Klemheist, Bachman, dog n' tails, etc?
4) What are the "load-catching" characteristics of alternative "hard" devices, such as the WallHauler, HogWaller, 540°, etc.?

The answers to questions 1 & 2 may be obtained by establishing some consensus within the rescue community[9]. It would appear that an extremely low failure rate (e.g. less than 1%) would be the only acceptable option; and that some consensus already exists in regard to maximum acceptable arrest force. Questions 3 & 4 may be answered empirically, and hopefully will be in the near future.

It is essential to obtain data on alternative methods and newer devices if we are to provide the type and level of protection that is necessary for safe rescue operations. In the meantime, it is wise to be aware that Prusiks may not provide the level of protection you think they do.

Notes:

1. For the purposes of this paper, the terms Prusik hitch, Prusik, and tandem Prusiks will just be called Prusiks.
2. Another useful way of thinking about or referring to a rope grab device is the term "progress capture device" or PCD.
3. Invented by Dr. Karl Prusik (1894-1961), an Austrian mountaineer credited with 70 first ascents.
4. John Dill, Arnor Larson, Reed Thorne, Ade Scott, Phil Crook, Chris Hawkins, Jim Kovach, Katie Mauthner, Kirk Mauthner, Loui Clem, Rex Meyers, John Peleuax, Jon Olsen, Rod Willard, Corvallis Mountain Rescue Group, and probably many other whose names I do not have.
5. For purposes of this calculation, failure was defined as the load hitting the ground and/or complete severance of the main line.
6. Kovach, 1996.
7. Willard, 1987.
8. Larson, BCCTR, Belay Competence Drop Test Method, date unknown.
9. Yeah, as if.

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The data reviewed for use in this paper are available as an Excel workbook to anyone who is interested. Please e-mail me at stillerj@amc.org and I'll send you a copy.