The Quad Is Awesome/Terrible:
Examining the Applicability of Sliding Anchor Rigging Methods

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Quads and Fixed Leg Systems

A relatively common debate among certain segments of climbers, both in-person and online, is the value of sliding rigging systems for climbing anchors. The most notable of these, and often ardently defended or vilified, is "the quad." A quad rigging is constructed from a doubled loop of material, often a sewn UHMWPE runner (trade names dyneema, dynex, spectra, etc.) or hand-tied cord of various material and diameter. Each end of the doubled loops is secured to an anchor point, each point of which may themselves be composed of one or two components such as a bolt, cam, or stopper. An inline overhand knot is tied on each side of the nadir of the rigging, creating a "pocket" of 4 strands of material between the two overhand knots (see Figure 1). Clipping a carabiner to fewer than 4 of the strands results in an attachment to the anchor that is often called "self-equalizing;" that is, the carabiner can slide between the overhand knots and could therefore redistribute the load to each anchor point as the load at the pocket moves.

In theory, loading the pocket of the quad should result in an equal load to each anchor point, which would thereby reduce the likelihood of potential failure of either anchor point on its own. In practice, this is not the case (see Club Alpino Italiano, 2006 as one example). The sliding system also carries with it the risk of "extension" upon failure of an anchor point. Should an anchor point fail, the result is that the load in the pocket slides along the material and stops at the overhand knot tied nearest the failed anchor point. The slide coupled with the sudden arrest creates what is known among climbers as "shock loading," but may be more properly described as jolt (i.e. change in acceleration). The point that is hotly contested is whether the shock loading is of sufficient force to be relevant in a climbing system.

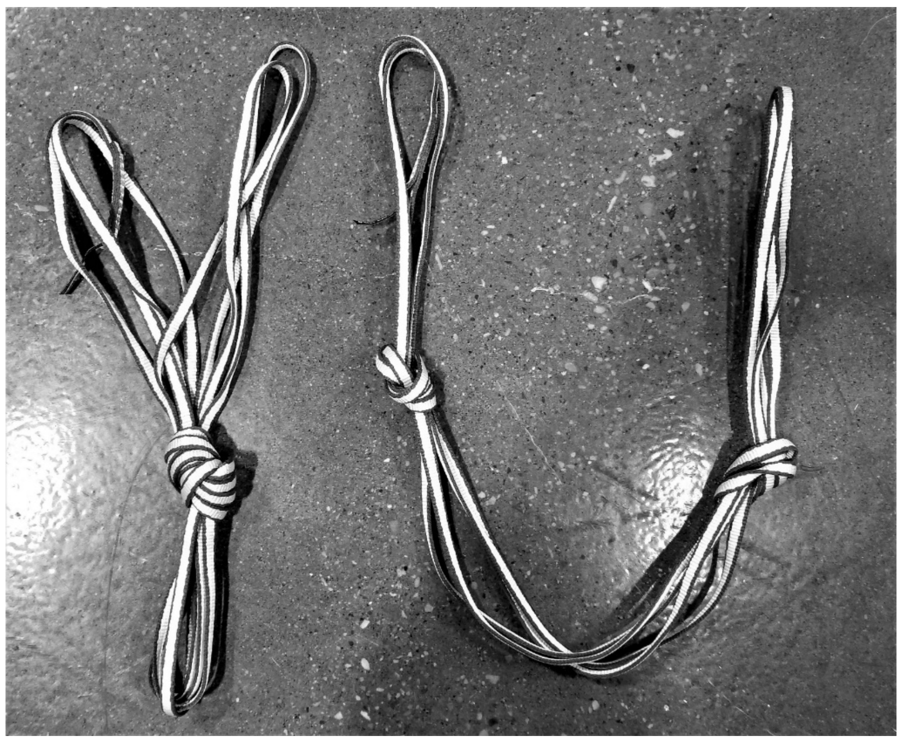

Figure 1. A fixed leg rigging (left) and a quad rigging (right).

Also contested is the relative merit of the quad or similar riggings as compared to the common fixed leg anchor rigging system. Such a fixed leg system is often created with a loop of material clipped to each anchor point. The material between each point is pulled downward to create a bight at each anchor point, thereby creating a nadir for the rigging. The entirety of material at this point is typically secured with an overhand or figure-8 knot (see Figure 1).

Extension, Shock Loading, and Force

Two tests are commonly cited in support of the quad: 1) 2006 tests conducted by Jim Ewing of Sterling Rope and author John Long as reported in *Climbing Anchors* (2nd ed.) and 2) a 2020 video from Ryan Jenks of HowNOTtoHIGHLINE. As the test results are presented in English, they tend to be more commonly known among climbers in the United States. These tests (and many others) support that increased loading following extension in an anchor does occur; however, proponents of the quad use them as evidence that extension and attendant loading doesn't matter because the loads are so small as to be irrelevant. That is indeed true for the test cases they present, but all of these test cases are <=FF1 and don't include at least two masses in the system. Consequently, we should expect the forces experienced by the anchor to be small. The problem is that because the loads are so small, these data become irrelevant.

The cases which are of consequence are fall factor 2 (FF2) and near FF2, i.e. clipping an anchor component as the first piece of protection. Clipping an anchor component as the first piece of protection actually produces greater force than FF2 thanks to the pulley effect (see DeBruin 2018 beginning at slide 9 for an explanation of the pulley effect). Why are these the cases that matter? They're the ones that produce the most force, and they're the ones where complete anchor failure occurs. There have been at least 6 examples of catastrophic anchor failure in Yosemite alone in the span of 30 years (Else, 2002), plus others elsewhere (Semmel, 2019).

Dynamic rope is often asserted as the panacea to the problem, but dynamic rope in the system is of little consequence. When an anchor component fails, the secondary load that follows the extension occurs too rapidly for the climbing rope to "relax" and serve as the shock absorber it needs to be to keep the party attached to the mountain. This effectively causes a much higher fall factor on what could be thought of as more akin to a static rope.

How much force can this produce? A few fairly realistic tests I've conducted yield edge case results of up to 12kN on the remaining anchor component following failure and extension of the first component (DeBruin, 2019). This 12kN force is problematic because such force breaks cams, nuts, screws, pitons, harnesses, and human bodies.

In short, extension in the anchor rigging can get you and your partner killed if you fall before placing the first piece on a multipitch route.

Limiting Knots and Load Sharing

Often, the first practical argument in favor of a quad is that knots are used to limit extension. There is a lower bound to how close the knots can be on a quad before they are useless, and the limit is farther than many climbers appreciate. This is because the offset of the pull angle between an aluminum carabiner and a UHMWPE sling needs to be about 15 degrees before the static friction between the carabiner and sling is overcome and causes the carabiner to slide. Consequently, to fulfill its proposed use case, a quad needs to have at least 30 degrees of travel in its "pocket." Alternative clipping schemes (capturing offset strands), twists akin to a sliding-x, and materials other than UHMWPE (ex. cord), all increase friction, necessitating limiting knots that are farther apart. Further, some tout the ease of pre-rigging a quad as a significant benefit and have the knots as far apart as possible. Examples of this are common on social media (Remsberg, 2021). This is claimed as a positive feature that makes the rigging more versatile, but potential extension is maximized. If a component fails, this extension could kill the entire party. That's a hell of a gamble.

What does the spacing of knots have to do with load sharing? If the knots are too close together, the desired sliding effect can't occur (because of friction) so the rigging is equivalent to a static system, albeit a very poorly constructed one. At that point, a fixed leg rigging becomes obviously preferable as it does not suffer the problem of extension and requires only one knot to rig (instead of the two required by the quad).

The other load sharing argument ignores the fact that in many of the test and actual use cases the sliding system and fixed system are pretty comparable for load distribution. A 60/40 split is best case for a quad (tied with UHMWPE). Fixed leg rigging systems can get close to this, too (though such rigging never shares load quite as well as a quad). But in most cases, the quad doesn't perform best case, and both systems end up with spreads somewhere between 60/40 and 80/20 load splits. (Some of this data is available in the works cited of DeBruin, 2019. Additionally, see Funderburke, 2017 and Bransby, 2013).

I think of the load distribution between two points in an anchor as something akin to a normal distribution (aka "bell curve") for a sliding system and a fixed system. The measure of central tendency for the fixed system will be shifted toward less equal load distribution compared to a sliding system, and at the tails, the sliding system with be closer to the goal of an even 50/50 split in the load sharing. But there will be significant overlap in the middle between the two options, and you're likely on target for close to a 65/35 split in either case a lot of the time. See Figure 2 below for a not-to-scale and purely hypothetical visualization of this. For example, a vertical crack with a fixed leg rigging will achieve close to a 65/35 split (and typically has roughly 60/30/10 split with 3 pieces). Most of the time, there is not a substantive or field-reliable difference for a competent anchor builder.

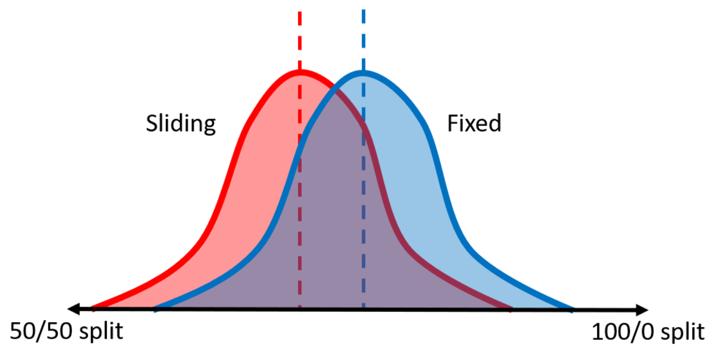

Figure 2. Hypothetical visualization of overlap between load distribution among anchor components when using a fixed vs. sliding rigging.

It bears repeated emphasis that the drop test at FF2/near FF2 is the relevant loading case as it produces sufficiently large forces to be of concern (since previous testing makes clear that lower fall factors do not produce high enough loads to be problematic). In a leader fall, the force that dominates is gravity, so the net vector of pull is always down. However, depending on where the leader is when they fall, the load typically comes from one side or the other (it would be a rare fall for the leader to come straight down since typically they would be landing on the belayer). The comparative load between anchor points often settles to something similar to what's seen in slow pull tests.

However, the initial load during a drop test can be multiples larger on one anchor point compared to the other based on where the carabiner sits, where the belayer is located, which side the leader fell from, etc.

Consequently, the quad incurs the risk of extension and therefore total anchor failure for an uncertain (if any) gain associated with load distribution. Skilled practitioners may also adjust the load sharing in a fixed leg anchor system with intentional construction, whether adding strands to a distant component, using a runner to make a distant component "closer," using fewer strands or positioning a joining knot on more marginal or nearby components, etc. Such adjustments improve the load distribution of a fixed leg system, weakening the argument in favor of a quad.

When to Use a Sliding System?

A sliding system really only makes sense if both components are equally terrible and neither could hold the anticipated worst-case load on their own. If either of them could possibly hold the load independently, more reliable rigging would be to concentrate load on the good piece and back it up with the other. For a full explanation, see David Coley's remarks regarding the sliding x and the attendant logic (2014).

However, those who warn against the quad will often say that rigging is irrelevant on two good bolts. Why? Because bolts are more than adequately strong and secure such that the probability of failure of an anchor component is very small. Therefore, extension is not particularly relevant since the bolt won't fail, it's unlikely a carabiner will come unclipped, and the sling used to rig the quad won't get cut. (This presumes that no one rigs a quad, a system that is *intended* to slide, over a sharp edge which might cut the sling.) Extension could happen if the sling gets cut due to rockfall, but if rock fall strikes the anchor, catastrophic failure of the entire anchor from cutting is quite likely anyway. (An aside: I know about that one guy who had rockfall cut just one leg of a two-leg anchor (Dec, 2016). He's a good friend and I'm glad he's still around, but he is also incredibly lucky.)

Anchor Component Failure and Human Error

Given the very low probability of a bolt failing, extension becomes relevant to anchor rigging if the components could conceivably fail (or a carabiner could come unclipped and temporarily unloaded). This applies to anything placed by the climber: cams, nuts, ice screws, pitons, etc. The reason is simple: none of us is as good at evaluating a placement and/or rock/ice quality as we think we are or wish we were. Two studies (Beverly & Attaway, 2014 and Manes, Bedogni, & Rogora, 2012) show the wide variability in both the actual failure strengths of protection as well as experts' (in)ability to consistently evaluate that strength. Note that failure is not exclusive to protective equipment breaking under severe load. Equipment can also fail due to pulling for some other reason, such as rock/ice failure, dirt or sand in a crack, etc. However, loads greater than body weight might be required to cause this, so these types of failures are therefore not immediately evident. One need only look to the "protection pulled out" category in *Accidents in North American Climbing* for further evidence of the ambiguity of protection that might otherwise appear bombproof (Caroom, 2020).

Thus, the quad is a fine tool for bolted anchors and poorly suited for other applications given the straightforward cost-benefit tradeoff.

Quad as Convenience

Use of the quad is regularly justified as a convenient anchor rigging since it can be preassembled and used without disassembly for the duration of a multipitch climb. Provided the limiting overhand knots are placed as close to the ends/as far from the nadir as possible, the quad can also accommodate a variety of component configurations and distances (though this maximizes potential extension). Further convenience is realized for ice climbing, where tying and untying knots may be cumbersome or difficult while wearing gloves (and removing gloves in undesirable). However, this convenience *must* be weighed against the possibility of complete anchor failure (which may be further exacerbated while ice climbing given the quite variable and unpredictable nature of ice that might otherwise appear adequate for climbing loads).

Alternative Rigging

Other convenient rigging options exist, however. A banshee belay can be preassembled with a 120cm sling and a bowline with a bight knot in one end. To complete construction, only a clove hitch is needed. While ice climbing, an even simpler version is one ice screw as the focal point with a single alpine draw to a second screw above (and offset to the side to avoid the orthogonal fracture planes of ice). (A few examples of banshee belaying can be seen in DeBruin, 2018 and Godino, 2020). A girth hitch masterpoint is also an option. While rigging will likely need to be adjusted at each anchor, no knots are required, and when using 2-bolt anchors, minimal adjustment is typically needed.

This entire discussion calls into question the value of attempting to reduce the load to any given piece by distributing the load in the first place. Provided no anchor component is clipped as the first piece of protection (creating a pulley effect) and therefore an anchor component has not failed and caused extension, maximum loads on an anchor are around 6-7kN. Consequently, the banshee belay or other fixed point belay rigging systems are adequate, and sometimes preferable. I'll still attempt load distribution in many cases. This is simply because load distribution likely reduces the probability of anchor component failure and simple rigging options exists that perform this task adequately, if imperfectly.

Risk Management Systems

This whole discussion is fundamentally underpinned by any given climber's risk management paradigm. Relative to other fields, climbers do not tend to approach risk management in a systematic manner that accounts for and attempts to reduce human factor concerns. Consequently, climbers might do well to adopt a systems approach to the risk management challenges in climbing, much as is becoming more common amongst our fellow skiers in the mountains, as well as in aviation, medicine, firefighting, etc. Further reading on a systems approach to risk management can be found in the approachable and freely available *Field Guide to Human Error Investigations* (Dekker, 2001).

Hazards we encounter in climbing can be thought of in 4 categories based on probability and consequence (see further reading at Funderburke & DeBruin, 2020). Low probability, low consequence events are given comparatively little attention: ex. tripping while hiking up the trail to the crag. They are managed almost without thought. High probability, low consequence events can be identified and generally mitigated: ex. falling off a boulder but using a pad and spotter as mitigation. Climbers regularly manage high probability, high consequence hazards, usually with a technical system: ex. belaying and catching a sport climber.

Climbing Anchors Don't Fail (Until They Do)

The greatest concern arises from low probability, high consequence events. Climbers are quite practiced with the high probability hazards, but little, if at all, with low probability events (owing to their rarity by definition). The relative paucity of total anchor failures is often given as a reason not to be concerned with issue at all. However, the opposite is true: catastrophic anchor failure *does* occur (see citations above) and climbers should absolutely be concerned about it.

Certainly, climbers should learn and practice effective belaying, solid gear placement, moving capably and confidently, negotiating complex terrain efficiently, etc. That is, high probability hazards must be managed, and it makes sense to start by focusing there. But once these skills are learned, attention must be paid to the low probability but high consequence problem. (A straightforward and accessible video about these types of incidents can be seen at Graham, 2012).

Protective Defaults

Low probability, high consequence hazards are typically best managed either with simple systems approaches or relentless training (or both). Most climbers just do not undertake the sort of training required for these hazards, so a simple system is the next desirable option. Given the biases inherent in the limitations of human cognition, a preferable "default" helps manages these hazards. As behavioral psychology shows humans have a strong bias toward the default ("Status," n.d.) a simple, repeatable, consistent, and protective default choice is best.

Consequently, the quad should not be used as a first choice. If the quad is appropriate, a climber can elect to use it when a good use case is recognized. For example, the quad can be quite useful for rigging two bolt top rope anchors when a crag has available top access—just clip the bolts, clip the rope, and toss the whole mess off. It might also be used intentionally on a multipitch route with known 2-bolt anchors in good repair.

This is contrasted with using the quad by default. The climber now must recognize those situations in which the quad is not a good idea. But, by virtue of being low probability situations, the climber may not even recognize the potential problem. Even if the potential is recognized, the climber may not be able to adequately evaluate the associated consequences (as noted previously). Even if they succeed there, they may not have the knowledge or practice to properly construct an alternate rigging. Once external factors such as fatigue, under hydration/nourishment, poor conditions, difficult route finding, a new partner, etc. are added, the likelihood of a successful outcome in these scenarios decreases farther.

Use the Best Possible Default

In conclusion, **climbers would be best served to use a robust default tool**, such as a **fixed length rigging or a banshee belay**. A different tool should be applied only when the appropriate context for that tool is recognized. If a quad is selected as the default, those climbers must understand that **the quad comes with a known catastrophic failure mechanism** not present in other rigging options. There is nothing wrong with choosing a quad per se as **risk tolerance is personal, but climbers should ensure their choice is intentional**.

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