Revisiting the Quad for Load Distribution and Stance Management

By Dick Chasse

Technical rope work is both a science and an art. It is a balancing act between situation, simplicity, efficiency, and proven understanding. The guiding profession has started to move past the "that's just how you do it" mentality and started to quantify systems and techniques. Anchoring is an excellent example of this. Systems we once considered to be superior have been demonstrated to have limitations. We have also revisited older concepts with new techniques and mindsets. This has led the way to an increased understanding of anchoring systems and their strengths and limitations. Every system if understood fully and applied correctly is valid, but to exclusively use one system without consideration of other situational factors is limiting and shortsighted.

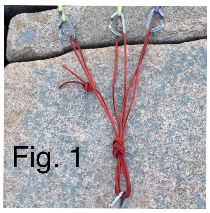


Fig. 1

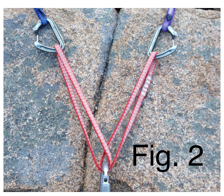


Fig. 2

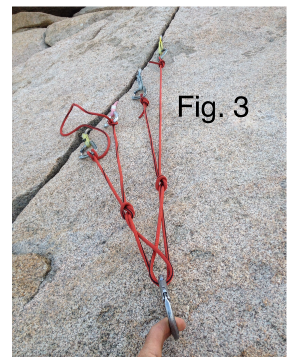


Fig. 3

Anchor systems are the way in which multiple anchor points are connected together to create an overall system that is stronger than any individual anchor point within the system. There are three main styles of anchor systems commonly used in climbing, sequential("pre-equalized" Fig. 1, anchors in series), distributive("self-equalizing", Fig. 2), and hybrid systems that combine components of both("Equalette", Fig. 3). The principles of each anchoring system can be applied to all types of anchoring situations: rock, ice, snow, fixed, and natural.

If each individual anchor point within the system is bombproof it almost doesn't matter what style of anchor system one uses, but there will be some point when the need for increased performance from an anchor system is desirable. This could be due to a variety of reasons including suboptimal anchor points, the need for more effective stance management, or situations where the anchor needs to accommodate multiple directions of loading.

Two of the main concepts with multi-point anchor systems are to have some level of load sharing between individual anchor points and accommodation of anticipated direction, or directions, of load. As the number of anchor points in the system increases addressing these core concepts becomes more complex and potentially less effective/practical. Adding more pieces does not necessarily create stronger anchor systems. It can increase the complexity of the anchor system, and the unpredictability of applying load to the individual anchor points, and typically decreases efficiency in terms of construction time and equipment use often with only marginal gains in strength if any at all. Increased predictability in load sharing throughout the system can lead to more effective anchor systems constructed from fewer anchor points.

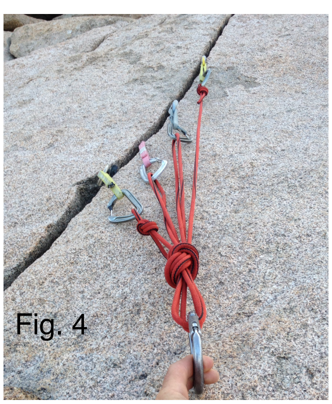


Fig. 4

As the most commonly used of the sequential anchor systems the classic pre-equalized anchor(Fig. 4) has been used for well over 25 years in the field and has some positive attributes. It's clean, quick to tie, redundant, efficiently uses material, has a well defined masterpoint, and has no extension of the masterpoint if there is an anchor arm failure. The main problems with the classic pre-equalized anchor system are potential unequal and unpredictable load distribution. Factors that affect load distribution are anchor arm length, the amount of material in each anchor arm(single strand vs a loop), and anchor points more or less in line with direction of pull. Unequal anchor arm length within the system leads to variable amounts of material elongation in each anchor arm. This potentially creates a situation where the shortest anchor arm of the system can receive a significant portion of the overall load. The longer anchor arms elongate more then the shorter anchor arms therefore skewing a greater proportion of the overall load to the anchor arm with the least amount of elongation. Simply put even when this anchor is tied "perfectly" in most cases the shorter anchor arm receives a greater proportion of the overall load. Unequal loading also occurs when there are loops of material in some anchor arms and single strands in others. In an idealized two point anchor system with equal arm lengths, one formed from a loop and one formed with a single strand, the anchor arm with the loop will receive a greater proportion of the overall load. Anchor arm elongation is reduced in the loop arm of the anchor because the load is divided between each strand of the loop. Anchor arms using a single strand of material experience no division of loading and thus have no check on elongation. Single strand anchor arms typically are attached to the anchor point with a bight knot that will also result in anchor arm elongation as the knot compresses when loaded. In general anchor arms with less total elongation, whether due to shorter relative length, or loops, or both receive a greater proportion of overall load.

Direction of pull is also a potential problem with this style of anchor. In sequential anchor systems when individual anchor points are significantly out of alignment with the intended direction of pull, a much higher proportion of the overall load is distributed to the anchor points more directly in line with the direction of pull. Additionally the difference between the theoretical directional of pull and the actual direction of pull can be enough to once again load only one anchor point within the system. Sometimes only a slight shift in the direction of pull can make a significant change in the loading of the anchor system. This can happen especially when the overall angle in the anchor system is smaller then 30 degrees from the outside of the two widest anchor points. This is a common issue in multi-pitch guiding when dealing with stance management and traversing routes.

Inconsistency when presetting the classic pre-equalized anchor system yield slight variations in the loading of individual anchor arms. Retying the same cordelette, on the same anchor points, and in the same direction of pull introduces variable loading in the system. This is a subtle point worth taking into consideration when trying to understand the deeper complexities of anchoring.

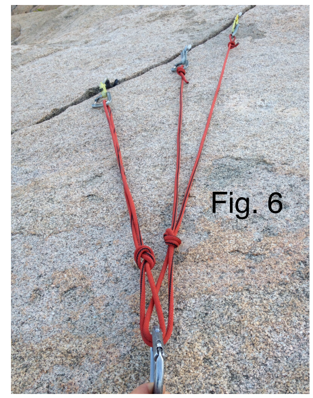
Issues of elongation, direction of pull, and presetting inconsistencies, create situations in pre-equalized anchors where a significant percentage of the load is transferred to an individual piece in the anchor system. As mentioned above with high quality anchor points this may be a non issue, but with less than ideal placements this could lead to anchor point failure and potentially catastrophic anchor failure.


Fig. 5

Distributive anchors are anchor systems that theoretically distribute the overall load evenly to all anchor points within the system and can accommodate multiple directions of pull at the masterpoint. Equal distribution of the overall load to all anchor points within the system leads to less stress to individual anchor points which reduces the likelihood of failure. The self adjusting nature of the masterpoint allows a wide range of motion which can compensate for directional changes. The "sliding x" (Fig. 5) is the most common of the traditional distributive anchors.

There have been many attempts at creating distributive anchoring systems that effectively work with varying degrees of success. Some of the potential problems with distributive anchor systems are constructing anchors consisting of more than two anchor points, frictional points preventing effective load distribution (material to material contact in the "sliding x" reduces the capability for self adjustment of the anchor, using cord instead of webbing or runners partially mitigates this), extension of the masterpoint if there is anchor arm failure, and creating redundancy in the material.

The Equalette (Fig. 6) is a hybrid anchor that blends components of sequential and distributive systems. It addresses many of the problems of both the classic pre-equalized and distributive anchor systems. The Equalette maintains redundancy in the material throughout the entire system. It has the potential to load points within the system more predictably and has the ability for the masterpoint to shift when there is anticipated or unanticipated load change. One of the advantages of the Equalette is that it always loads at least two anchor points within the system. In a three point Equalette there will be one leg of the system that theoretically receives 50% of the load throughout it's entire range of designated motion. Even while improving upon the issues associated with pre-equalized and "sliding x" anchor systems, the Equalette still presents challenges to users. The sequential side(the pre-equalized legs) of the Equalette still has the problem with uneven arm lengths effecting load distribution. The Equalette also suffers from friction at the masterpoint, because of twists in the material inherent with the "sliding x", which affects load sharing. The masterpoint is less defined compared to the classic pre-equalized anchor. This can be considered an issue in multi-pitch stance management when clipping multiple carabiners to the same masterpoint. The Equalette is a step forward in anchoring construction, but is not the end of the evolution of anchor systems.



The Quad (Fig. 7) is a newer distributive style of anchor system that has been primarily used with two point bolted anchors. The Quad addresses redundancy by incorporating multiple isolated strands of material that guard against system failure due to cutting of individual strands. The Quad utilizes a "straight v" inside the "quad pocket" which gives it similar load sharing qualities at the masterpoint as the Equalette. This creates a situation, with a two point anchor, where each anchor point receives as close to 50% of the overall load as possible in the field using simple tools like a cordelette. By effectively sharing load more evenly between anchor points the Quad helps reduce the stress at each anchor point which decreases the likelihood of anchor point failure.

Both the Quad and the Equalette have a certain amount of extension which is inherent with any distributive or hybrid anchor system. Extension can be managed with the thoughtful placement of limiting knots(Fig. 5). The more that extension is limited the more the lateral range of the system is reduced.

The Quad has commonly been used with two point anchor systems by most people. When encountering multiple two point anchors, like in some multi-pitch rock and ice climbing, the Quad can be pre-tied and used over and over again for more efficient transitions. The Quad can also be used quite effectively with three and four point anchor systems with a few variations. When used in this configuration the Quad essentially becomes the next step in the evolution of anchor systems beyond the Equalette.

After two days of material(see table 1) and equalization testing with Jim Ewing at Sterling Rope several key points became apparent. After many slow pull and a limited number of dynamic tests 7mm nylon cord proved to be the best overall choice for an anchoring material based on strength, durability, and dynamicity. Clipping two strands in the Quad Pocket yielded only slightly better equalization than the sliding x with either equal arm lengths or offset arm length configurations. It appears that the inherent friction of the cord contacting the carabiner is enough to inhibit perfect equalization with the Quad. Eliminating the "x" in the sliding x and clipping a straight v in the Quad pocket resulted in very little gain in equalization. A high efficiency pulley was added to the two strands in the Quad Pocket to test this which resulted in near perfect equalization in both off set arm lengths and equal arm length configurations. We hypothesize the Quad's capacity to equalize in the real world setting may be more consistent than the sliding x due to the fact that there is no binding of material which can often occur with the sliding x. The equalization test anchors were pulled to 5kn to see the distribution of load on a two point anchor system. In an offset anchor arm scenario the shortest arm consistently received around 3kn whether tied with a sliding x or a Quad. The Quad did equalize slightly better in these tests. A couple of tests were pulled to 10kn with roughly the same results. (Note: This finding has implications for common two point anchor systems that are vertically oriented such as ice screw anchors. The data would suggest that the bottom screw should be the largest or most well placed of the two anchor points regardless of the style with which the points are connected). The testing also showed the Quad Pocket masterpoint to be a stronger arrangement than the Equalette masterpoint. The larger knots in the Quad affected the strength in the cord much less dramatically then the small knots within the Equalette. The gap between overall strength in these two configurations is more pronounced with the use of high strength material such as Technora or Spectra. These preliminary tests have yielded some useful but limited information, further static and dynamic testing with other materials (Spectra and nylon runners) could demonstrate if material friction could be lowered and equalization enhanced.

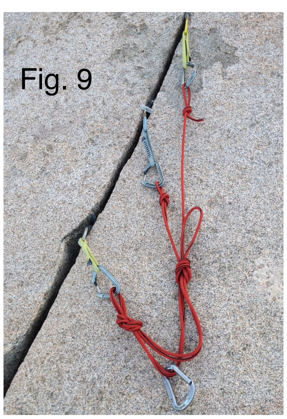


Fig. 9

The systems in Fig. 9 and Fig. 10 are essentially Equalettes tied to create the "quad pocket". This can be tied with a cordelette in either an open ended or loop configuration. The system in Fig. 9 is created with the cordelette not tied into a loop where the system Fig. 10 is created with the cordelette tied into a loop. The benefits of either configuration are twofold, first there is load sharing because of the "straight v" at the master point. Secondly by only clipping two of the four strands in the "quad pocket", instead of three of the four (as was how this anchor was traditionally used), the Quad gives the user two independent masterpoints and a full strength "quad pocket".

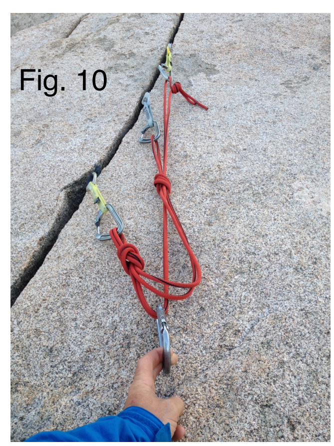


Fig. 10

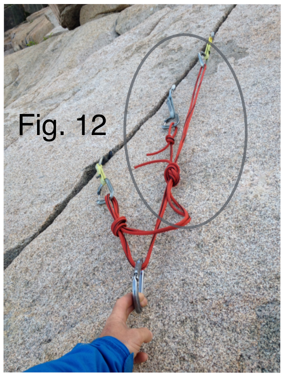


Fig. 12

Even with these benefits there is still the problem with offset anchor arms on the sequential side of the system. We can adjust the sequential side of the anchor to compensate for offset anchor arm length or if the user wants to skew more of the load to one anchor point over the other. In the anchor in Fig. 12, the sequential side of the anchor has been modified to compensate for the offset anchor arm lengths. The longer leg of the system has a loop of cord and the shorter arm is a single strand(Fig.13). As alluded to above in the discussion of pre-equalized anchor systems, the loop effectively reduces the elongation of the material. In the field we can never truly know exactly how the forces are being distributed in the sequential side of the Quad anchor, but we can make educated decisions to manipulate the forces within the anchor system.

Fig. 13

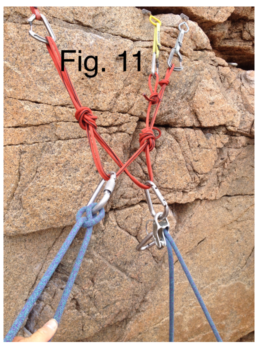


Fig. 11

An example when one may want an anchor system that has two masterpoints and can smoothly adjust laterally is when climbing a multi-pitch route that has belay stances in the middle of traversing pitches. The anchor needs to be able to compensate for the load the second climber may place on the anchor in case they fall while traversing, when the party is weighting the anchor while belaying, and if the leader falls traversing during the next pitch(Fig. 11). This could be a huge range of motion that the anchor may need to compensate for.

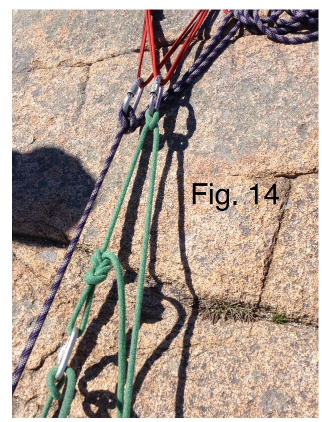


Fig. 14

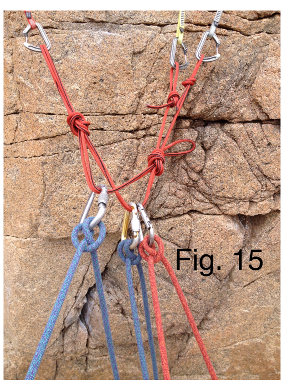


Fig. 15

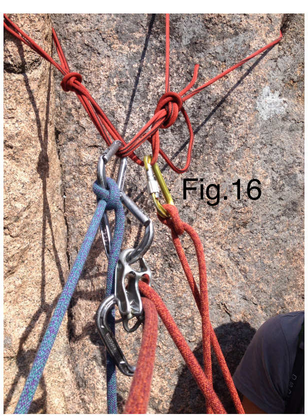


Fig.16

The user has the opportunity, with the Quad, to utilize two independent masterpoints. This can be a huge advantage in several common multi-pitch and single pitch guiding scenarios. Overall neatness in one's set up is important especially when utilizing two separate ropes like in a belayed rappel or having an isolated anchor line for clients to be attached to in a top managed system(Fig. 14). When multiple carabiners share the same masterpoint, and are under load, a "clam shell" effect can happen pinching the carabiners together making manipulation of those carabiners difficult. Utilizing the two masterpoints of the Quad helps mitigate this problem(Fig. 15). Multi-pitch stance management often has multiple people attached to the same masterpoint with slightly to significantly different directions of pull being applied to the anchor. This sometimes presents a problem in hanging to semi hanging belays. Having a second master point can provide greater accommodation for client comfort(Fig. 16). This is often an issue when using caterpillar or split rope techniques. Split rope technique is more common in ice guiding than in rock guiding. By splitting the ropes to two separate climbs the guide may choose to utilize two independent belay devices to avoid the potential for a plaquette style device to not lock if both climbers fall(Fig. 17). Once again an anchor system that has an

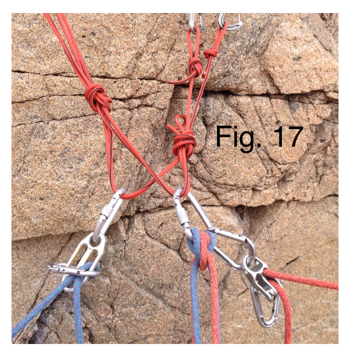


Fig. 17

excellent ability to compensate for loads in multiple directions and has two independent masterpoints may be beneficial in this scenario.

Every anchoring situation has multiple factors that one most consider. There is no perfect anchor system. The more options a guide has in their toolbox the more opportunity they have to tailor each situation to maximize their desired outcome. The Quad and it's variations have many attributes that are beneficial to not just climbing and guiding but also in technical rescue and industrial rope-work uses. A deeper understanding of different anchoring styles and principles has real world application which increases the efficiency, comfort, and safety of our systems.

Thank you to Jim Ewing and Sterling Rope for providing time, knowledge, materials, and the testing facility.

Table 1

Test #	2 pt Anchor Configuration	Material (Sterling)	Breaking Strength(kn)
#1	sliding x	6mm nylon	28.22
#2	sliding x	6mm nylon	25.56
#3	sliding x	6mm nylon	24.76
#1	sliding x w/2 limiting knots	6mm nylon	18.17
#2	sliding x w/2 limiting knots	6mm nylon	18.82
#3	sliding x w/2 limiting knots	6mm nylon	18.88
#1	sliding x	7mm nylon	35.81
#2	sliding x	7mm nylon	38.17
#3	sliding x	7mm nylon	33.5
#1	sliding x w/2 limiting knots	7mm nylon	29.24
#2	sliding x w/2 limiting knots	7mm nylon	28.46
#3	sliding x w/2 limiting knots	7mm nylon	28.26
#1	sliding x	6mm Power Cord	37.02
#2	sliding x	6mm Power Cord	39.1
#3	sliding x	6mm Power Cord	40.77
#4	sliding x	6mm Power Cord	46
#1	sliding x w/2 limiting knots	6mm Power Cord	26.12
#2	sliding x w/2 limiting knots	6mm Power Cord	26
#3	sliding x w/2 limiting knots	6mm Power Cord	26.21
#1	Quad clipping 2 out of 4 strands	6mm nylon	23.1
#2	Quad clipping 2 out of 4 strands	6mm nylon	24.6

Table 1-1

#3	Quad clipping 2 out of 4 strands	6mm nylon	22
#1	Quad clipping 3 out of 4 strands	6mm nylon	27.7
#2	Quad clipping 3 out of 4 strands	6mm nylon	28.56
#3	Quad clipping 3 out of 4 strands	6mm nylon	26.16
#1	Quad clipping 2 out of 4 strands	7mm nylon	36
#2	Quad clipping 2 out of 4 strands	7mm nylon	36.35
#3	Quad clipping 2 out of 4 strands	7mm nylon	36.78
#4	Quad clipping 2 out of 4 strands	7mm nylon	37.2
#1	Quad clipping 2 out of 4 strands	6mm Power Cord	41.39
#2	Quad clipping 2 out of 4 strands	6mm Power Cord	37.02
#3	Quad clipping 2 out of 4 strands	6mm Power Cord	36.02
	Used Quad clipping 2 out of 4 strands	Used 6mm Mammut ProCord	15.07
	Used Quad clipping 2 out of 4 strands	Used 7mm nylon Sterling	29.39
	Used Quad clipping 2 out of 4 strands	Used 6mm Power Cord	24
	Used Quad clipping 2 out of 4 strands	Used TechCord, Maxim	16.32
	Used Quad clipping 2 out of 4 strands	Used 6mm Sterling Xtech	17.39 - 26.91