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Düğümlerdeki İp katları ile ilgili Kısa Bir Değerlendirme: Uygulama, Gerekçe, Kazalar ve Test
A Brief Review of Side Bends: Application, Rationale, Accidents and Testing

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Öz

Tırmanıcılar uzun rotalardan inerken bazen iki ipi birbirine bağlarlar. İpler ancak düğüm noktasından birleştiğinden ve bu kısımda ipin genişliğinin iki katına çıktığından dolayı bir daha ki bağlantıya kadar düz bir ip boyu inmek haliyle önemlidir. Bir tırmanıcı, bir sonraki ipe hazırlanmak için her iki ipi de çekmeye çalıştığında sorunlar ortaya çıkabilir. İki ipi birleştiren düğüm, sürüklenirken kayaya, kaya kenarlarına, çatlaklara veya tabakaların arasına takılabilir (Baillie, TY-Tarih yok; Gommers, 2019; Kemple, 2006). Sıkışmış bir düğüm, takılmaya yol açabilir ve etkili kendi kendini kurtarma stratejileri uygulamadıkları sürece tırmanıcıların inişe devam etmesini engelleyebilir (Fasulo, 1996; Tyson & Loomis, 2006). Bu tür olaylar düzenli olarak gözlemlenmiş ve rapor edilmiştir. Geleneksel olarak iki ipi birleştirmek için kullanılan düğümler, tutarsız olarak tek taraflı, ofset, yan, düz veya dolaylı kıvrımlar olarak adlandırılan bir düğüm sınıfına aittir. Bunlar, şekilleri ve nispeten daha küçük temaslı taban alanları nedeniyle kaya yüzeyleri üzerinde sürüklendiğinde daha az direnç sağlayan düğümlerdir. Çatlaklarda ve tabakalar arkasında sıkışma ihtimalinin daha düşük olduğu ortaya atılmıştır. Öte yandan, ip katlarındaki arızalarla ilişkilendirilen kazalar bu düğümleri tırmanıcılar arasında bir tartışma konusu haline getirdi (AMGA & ACMG, 1999; Baillie, TY; Baillie, 1982; Chisnall, 1985, 2020; Evans, 2016; Gaines & Martin, 2014; Geldard, 2016; Gommers, 2019; Jackson, 2016a, 2016b; Helmuth &Burnhardt, 2003; Jones, 2012; Kirkpatrick, 2008; Lottman, 2016; Magnuson, TY; Martin, 2009; Martin, 2011; Mart 1976; Momsen, 2016; Powick, 2016; Prattley, 2016; Prohaska, 1998; Raleigh, 1998; Needle Sports, 2020; Siacci, 2019). Her ne kadar test verileri ve teorik modelleme bu konuda uyum göstermese de bazı yan halkalar diğerlerinden daha güvenlidir. Buradaki amaç, bu konularla ilgili mevcut bilgileri eleştirel bir şekilde incelemektir.

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Abstract

When climbers descend from long routes, they sometimes need to join two ropes together. This is necessary in order to rappel a full rope length to the next anchor because the ropes are doubled up and looped through the anchor point. Troubles can arise when a climber attempts to pull one line in order to retrieve both ropes to prepare for the next rappel. The knot joining the two ropes could get snagged as it drags against the rock, over edges, into cracks and behind flakes (Baillie, ND-no date provided; Gommers, 2019; Kemple, 2006). A jammed knot might result in entrapment, preventing climbers from descending any farther unless they implement effective self-rescue strategies (Fasulo, 1996; Tyson & Loomis, 2006). Such events have been regularly observed and reported. Knots traditionally used to join two rappel lines together belong to a class of knots inconsistently called one-sided, offset, side, flat or indirect bends. These are knots that afford less resistance when dragged over rock surfaces owing to their shape and relatively smaller contact footprint. It is purported that they have a lower chance of getting jammed in cracks and behind flakes. Accidents have been linked to side bend failures, making them a topic of contention amongst climbers (AMGA & ACMG, 1999; Baillie, No date provided; Baillie, 1982; Chisnall, 1985, 2020; Evans, 2016; Gaines & Martin, 2014; Geldard, 2016; Gommers, 2019; Jackson, 2016a, 2016b; Helmuth & Burnhardt, 2003; Jones, 2012; Kirkpatrick, 2008; Lottman, 2016; Magnuson, ND; Martin, 2009; Martin, 2011; March 1976; Momsen, 2016; Powick, 2016; Prattley, 2016; Prohaska, 1998; Raleigh, 1998; Needle Sports, 2020; Siacci, 2019). Some side bends are more secure than others, although test data and theoretical modelling are not in agreement. The purpose herein is to critically review available information pertaining to these issues.

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Literature Review and Analysis

General Knot Characteristics

Most knots have mirror images or enantiomers and are described as being chiral or having chirality (Figure 1) (Chisnall 2000, 2010, 2011, 2016a, 2016b, 2016c, 2020; Nute, 1986). Surveys indicate that the persistence of one enantiomer over the other is connected to the tier's habit, or procedural memory, and knot chirality has an intricate relationship with tier handedness (Chisnall, 2000, 2010, 2016a, 2016c; Nute, 1986; Spörri, 2008). A tier's position and other situational factors can influence the chirality and even the fundamental structure of any knot tied. This relationship also depends on the number of working ends or wends the tier is using.

Figure 1. Overhand Knot chirality – S (left) and Z (right).

The complexity and attendant security of a knot can be evaluated using crossing number and sinuosity (Chisnall, 2020). If a knot is represented in two dimensions and simplified to eliminate unnecessary loops and crossings, that image is called a planar projection (Figure 2). The invariant crossing number of a planar projection is the lowest number of rope intersections required to represent a knot in two dimensions. Invariant, crossing number and planar projection are terms used by topologists to describe theoretical knots and they can be applied to practical knots (Adams, 2001; Chisnall, 2020; Turner, 1996; van de Griend, 1996).

Sinuosity, a concept applied across several scientific disciplines (Lazarus and Constantine, 2013; Mason and Martin, 2017), is the length of rope, cord or tape within that knot. It can be measured between the entry and exit boundaries after the knot is untied (Chisnall, 2020). Sinuosity can be expressed as a ratio of the length of the unknotted material relative to the diameter of the knot itself.

Concatenation is the quality of a knot's entanglement and how it was tied. It is the interrelationship of the various parts of the completed knot, the knot's nip, the presence of open, closed and crossing loops within the knot proper, the orientation of its wends and stands, and other characteristics (Ashley, 1944; Chisnall, 2006a, 2006b, 2016b, 2020). Hence, crossing number and sinuosity are linked to concatenation.

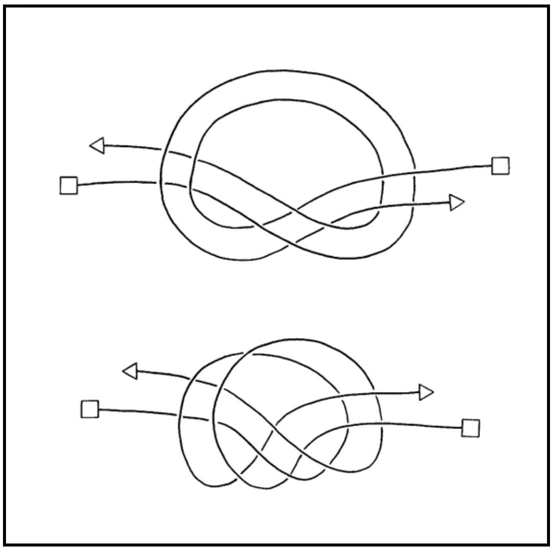

Figure 2. Water Knot planar projection – Top: a proper projection of the Water Knot with the minimum 12 crossing points. Bottom: a projection of a Water Knot dressed in three dimensions with three additional crossing points.

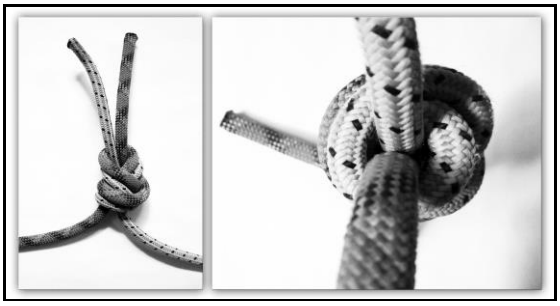

Figure 3. Foot print versus volume. Left: The Figure Nine Side Bend approximates the shape of a cylinder. Right: The actual contact area of the Figure Nine Side Bend is the bottom of the knot between the standing parts. The volume of a knot and its contact footprint against a surface, such as a rock face, are related to its complexity and concatenation. The term knot footprint has been confused with knot volume, size, shape and linear dimensions, but it is a distinct knot characteristic (Gommers, 2013). See Figure 3.

Modes of Failure

There are two ways bends can fail. First, if the knot holds fast and does not slip, the rope will eventually rupture at or near the knot if enough force is applied, that is if there are no sharp edges acting on the rope elsewhere. There has been debate about how and where knots break (All About Knots, 2010; Audoly et al., 2007; Peranski et al., 2010; Saitta et al., 1999). The tensile breaking strength of the knot is often expressed as a percentage of the absolute breaking strength of the unknotted rope, and it is referred to as knot efficiency or residual strength (Chisnall 2020; Moyer, 1999b; Richards, 2005). It is important to understand that a specific unit value for knot strength is related to the underlying tensile breaking strength of the unknotted material (Šimon et al., 2020). Second, and this is of critical interest in this safety analysis, knots can work loose or come untied owing to structural characteristics (Chisnall 2020). This can occur at loads lower than a knot's residual strength. Many knots are fundamentally insecure and can slip loose or change into less reliable structures, depending on a number of conditions (Ashley, 1944; Budworth, 1983). Knot change may occur spontaneously based on inherent insecurity, or by unexpected force vectors and contact friction when the knotted rope is subjected to a working load.

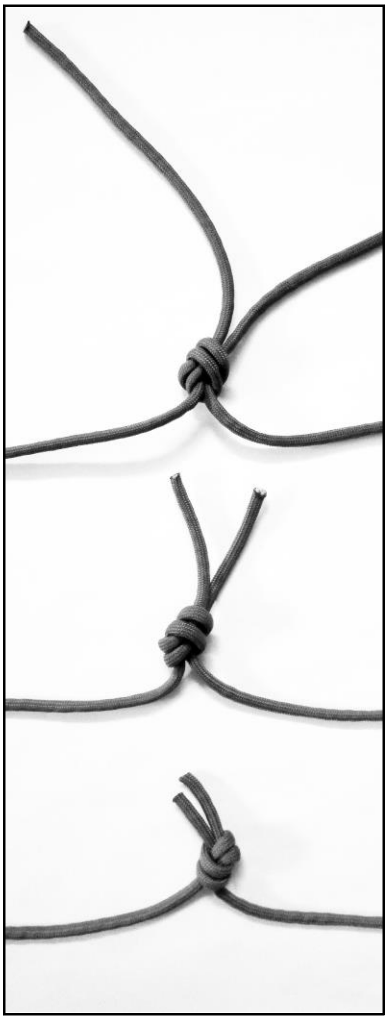

Figure 4. Overhand Bend reptation – From top to bottom: the knot moves toward the wends as the stands are loaded in opposite directions.

Bend security failures are a function of knot change. There are several principal ways in which knots can distort and possibly come untied: capsizement, flipping, flyping, reptation, and ultimately migration and release (Chisnall, 2020; Hage, 2007). Migration ensues when the working end moves relative to the knot, as observed with Slip Knots, and release happens when the end completely pulls free from the knot. Flyping – an old Scottish term – occurs when a knot moves along the rope or cord relative to the wend or wends, changing shape as it moves (Hage, 2007). The knot essentially turns inside out, like a glove being removed. Reptation, a term adopted from molecular biology, is the action of a knot as it moves relative to the wend or wends without changing its basic shape (Bao et al., 2003; Chisnall, 2020).

Popular Side Bend Tests

Security issues stem from the asymmetrical structure of side bends. Two of the more popular side bends tend to reptate or flype and possibly release under certain conditions. (The flyping and reptation behaviour of the knots presented can be demonstrated on a small scale using dental floss or monofilament fishing line.)

The example shown in Figure 4 is the Overhand Bend, Thumb Knot or Openhand Knot (Ashley, 1944). It is disparagingly called the European or American Death Knot by many climbers (EDK or ADK for short). Other name variations have been used, including the One-Sided, Side, Indirect, Offset, or Flat Overhand Knot or Bend (Gommers, 2013; Chisnall, 1985, 2020). If this bend is through-loaded, as illustrated, it has a tendency to move or reptate along the rope toward the ends, depending on the tying material and other factors. Overhand Bend slow-pull tests, performed under variable conditions using different materials, yielded knot efficiencies that fell between 4% and 95%. Reptation occurred at the lower end of the range while rope rupture occupied the upper end from Figure Eight to Pretzel to Figure Eight.

Similarly, the Figure Eight Side Bend can be pushed toward the rope ends if the stands are pulled in opposite directions (Figure 5). The Figure Eight Side Bend alternates between a Pretzel Knot structure and a Figure Eight Knot structure as it flypes, eventually untying completely. The Figure Eight Side Bend is one of the least reliable side bends. Reported test results have conflicted (Baillie, No date provided; Evans, 2016; Gommers, 2019; McKentley, 2014; Moyer, 1999b; Prattley, 2016). Taking into account the tensile breaking strength of the variety of materials employed in several posted, published and unpublished tests, knot efficiency ranged broadly between 2% and 81%. Similar to Overhand Bend reptation Figure Eight. Side Bend flyping occurred at the lower end of that range, and rope rupture data occupied the upper end.

The broad variance in test data highlights the uncertainty regarding the behaviour of these side bends and their possible modes of failure, as well as a lack of consistency in testing methods and results. By comparison, similar available knot efficiency data concerning the Double Fisherman's Knot ranged between 56% and 93% (Figure 6). Its knot efficiency range is half that of the side bends mentioned. This is because the Double Fisherman's Knot is an in-line bend with a higher crossing number and greater sinuosity. Further, all reported

Double Fisherman's Knot failures were due to rope destruction and there was no slippage or release. However, the Double Fisherman offers more resistance and is more likely to jam during rope retrieval.

The maximum load applied to rappel anchors has been measured at around 800 lbf., which means about half that force is directed to the bend joining the ends of the two rappel lines (Baillie, 1982). The load could essentially double during partner rescue evolutions, such as tandem and counterbalance rappels (Fasulo, 1996; Tyson and Loomis, 2006). This relates to safety factor. Safety factor is the relationship between the lowest possible system or component failure load and the highest anticipated working load (Walker and McCullar, 2014). There are two distinct definitions for safety factor used in technical rescue, which can confuse matters. First, component-to-force ratio (CFR) is the ratio between the minimum breaking strength (MBS) of a system component relative to the expected force applied to it. Second, static system safety factor (SSSF) is the component-force ratio of the weakest link in the safety system. These ratios must be sufficient for safety purposes and they should anticipate extreme events. Different standards cite different acceptable ratios. For example, the Construction Safety Association of Ontario (1975) recommends a 5:1 ratio for industrial loads and 10:1 for live loads. Certain recreational climbing safety system components, like trad or traditional lead anchors, meet a 5:1 or even lower ratio owing to the lightweight nature of the gear and the fall forces involved. If a rappel bend must satisfy a minimal 3:1 safety factor, it should not fail below three times the highest expected rappel force of 800 lbf., if rescues are to be accommodated – about 2.400 lbf.

Here is a sample of slow-pull test data. Moyer (1999b) performed a number of tests on side bends tied in used 11 mm. dynamic climbing ropes and 7/16" low-stretch rescue lines. It was reported that the Overhand Bend, under different conditions, "rolled" or reptated from 200 to 1.990 lbf. (0,9 to 8,8 kN.), and if the knot held, the rope ruptured between 2.070 and 2.540 lbf. (9,2 and 11,3 kN.). The ends pulled free at 1.410 lbf. (6,3 kN.) during one trial. With regard to the Figure Eight Side Bend, "capsizement" or flyping occurred between 110 and 2,280 lbf. (0.5 and 10.4 kN.), whereas rope failure was observed at 2.790 lbf. (12,4 kN.) and one test was stopped at 2.800 lbf. (13,5 kN.). Prattley (2016) found that in three tests using Korda's 9 mm. Dana canyoneering or canyoning rope, the Overhand Bend (which he calls a Flat Overhand) kept "rolling" or reptating at loads from 1.722 lbf. to 1.765 lbf. (7,66 kN. to 7,85 kN.). Powick (2016) tested what he calls the Euro Death Knot with three rope combinations: two 10,2 mm. ropes joined, two 8 mm. ropes joined, and a 10,2 mm. and an 8,2 mm. line tied together. The knots ruptured at 4.950 lbf. (22 kN.), 2.850 lbf. (12,7 kN.), and 3.100 lbf. (13,8 kN.), respectively. These slow-pull test results suggest that some side bends may inconsistently meet a 5:1 safety ratio, while others fall below a 3:1 safety ratio.

The inconsistency of these independent slow-pull test results likely hinges on the characteristics of the rope and cord, the test methods, and how the knots were tied and dressed. Like other knots, the seemingly simple Overhand Bend presents subtle structural details that affect performance. It is chiral so it has two enantiomers, similar to the Overhand Knots shown in Figure 1 (Chisnall, 2010). Further, there are several ways to dress the knot, aside from making sure it is generally neat and compact. The arrangement of the standing parts as they exit the knot could affect security and the results of slow-pull testing.

Several internet videos document some typical side bend tests:

https://www.youtube.com/watch?v=YVpbj8ccSdk
https://rockandice.com/videos/climbing/which-rappel-knot-should-you-use/

https://www.youtube.com/watch?v=qONWJXMc210 http://rope-work-101.wikidot.com/offset-bound-overhand-knot-testing

It appears in these videos that the type of rope, whether or not it is wet, the looseness of its sheath, and perhaps its internal structure, affect a rope's propensity for flyping or reptation. It can be observed that the sheaths of some test ropes shifted or "milked" toward the wends and bunched up as the knots tightened. This action likely depended on the inherent sheath slippage of the test ropes. Sheath slippage and milking increased the rope's diameter toward the wends, thus providing a barrier to the bend's continued movement, essentially serving the same function as a backup knot. In some tests, the two intertwined Overhand Knots of the Overhand Bend or the two Figure Eight Knots in the Figure Eight Side Bend traded places as the test knots moved toward the wends.

The phenomena of flyping and reptation are driven by interacting forces in the various parts of the knot, as described by Ashley's principle of the knot (Ashley, 1944; Chisnall, 2020). Forces can be represented by adding vector arrows to planar knot projections in order to assess bend security. For example, force vectors are shown in Figure 7 for a three-dimensional rendering of the Overhand Bend, which has three crossing points more than a planar projection. (Figure 2 illustrates a planar projection and a three-dimensional rendering of a Water Knot, which is similar in structure). If most of the arrows run parallel in the same direction, the knot is less secure. Conversely, if most of the arrows are oriented in opposite directions, the knot is more secure. Compression or nip, expansion, and rollout caused by orthogonal knot strands also influence knot security. A similar analysis can be performed for the Figure Eight Side bend. Relative side bend security may be approximated through mathematical modelling that analyses these oriented force vectors (Chisnall, 2020; Bayman, 1977; Maddocks and Keller, 1987). The propensity for Overhand Bend reptation or Figure Eight Side Bend flyping can be assessed via topological twist fluctuation and circulation energies, a method adapted from analogous calculations used in physics to determine (Keller, 1987) ferromagnetic spin energies (Patil et al., 2020). This mathematical modelling suggests these two bends are less stable than other bends (Chisnall, 2020). This is a function of bend complexity (crossing number, sinuosity and concatenation).

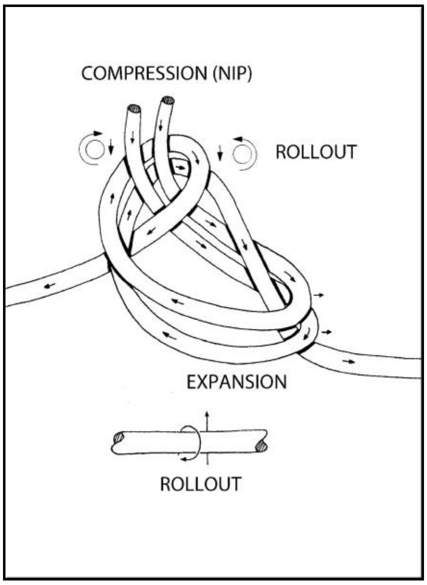

Figure 7. Vector orientation of the Overhand Bend. The forces are generally parallel and complementary, making the knot less secure. Also, orthogonal forces tend to cause rollout. These are the mechanisms of reptation.

Testing Reliability

Considering the ranges in the test data, conventional side bend analysis and strength testing have not been necessarily valid and reliable. The results and conclusions are inconsistent because the methods employed tend to assess knot behaviour conflated with rope characteristics – such as the rope's structure, knottability and coefficient of friction. Strength has been the default test parameter. It may be more appropriate to explore structural security by also performing harmonic and nonharmonic excitation tests, dynamic arrest tests, and inertial loading to evaluate knots tied in materials exhibiting poor friction and knottability characteristics (Chisnall, 1995a, 1995b, 1995c, 2020; DailyDiamond, 2017; Evans, 2016; Martin et al., 2015; Moyer, 1999a; Weller et al., 2015). Clearly more research of a standardized nature is required.

As rare accidents involving failed rappel knots were reported over the years, the conventional advice from Overhand Bend proponents evolved to include several key details (Gommers, 2019; Moyer, 1999b). First, dress and tighten the Overhand Bend for security. That is, make it neat and compact to reduce its volume and increase the ropeon-rope contact within the knot. This also helps to reduce the bend's footprint on the rock. As testing and experience revealed that the Overhand Bend tended to reptate, the inclusion of long tails of equal length was advised – 1 foot or 30 cm. in length.

Like other side bends, the Overhand Bend is recommended by many authorities because it reduces the chances of a jammed rappel knot (Gommers, 2019; Moyer, 1999b). In terms of immediate consequences, security is a priority over the possibility of knot entrapment (Chisnall, 2020; Moyer, 1999b). The outcome of rope disconnection is sudden and irreversible. Knot entrapment is a hardship at worst, but usually just an inconvenience. Ironically, the Overhand Bend and its long tails have been known to jam in cracks, thus diminishing the advantage of choosing that knot. A bend of any size and shape can jam in cracks and behind flakes because rock composition and geometry are naturally diverse. Cracks, flakes, horns, chicken heads, geological rugosities, and all manner of rock formations come in manifold shapes and sizes. Measuring bend resistance during rope pulls, and evaluating the likelihood a bend will jam, is limited to the research parameters selected. They include rope properties, and the geometry of the test obstacles. Pull tests over a 90-degree edge give an approximate sense of drag or resistance under those test conditions (Baillie, No date provided; Gommers, 2019). In general, side bends reduce pull drag and the incidence of irreversible snags, but not necessarily the chances of jamming.

Figure 8. A sample of alternative side bends, which are more secure – Left to right: Figure Nine Side Bend, Double Overhand Side Bend, Alpine Butterfly Bend.

Other Issues and Options

There are additional procedural issues that are relevant to climbers. Some mountaineers and multi-pitch climbers belay a thicker rope and drag a thinner line for rappels and rope retrieval employing different anchoring configurations. (These include versions of the reepschnur technique, which involves jamming bends against anchoring hardware) The need to join two ropes having unequal diameters for rappels might further reduce Overhand Bend security, but there is insufficient data to say one way or the other. Fatigue, haste, darkness and inclement weather can affect a tier's actions during long descents. Proper dressing and tail length may be overlooked for expedience, resulting in sloppy and less secure side bends during rapid descents.

Potentially more reliable bend options exist. These have higher crossing numbers, and greater sinuosity and concatenation. However, some are challenging to tie, so effective learning, persistence of memory and regular checking are vital issues. A sample is shown in Figure 8 (Prattley, 2016; Prohaska, 2001; Zabrok, 2003; Zartman, 2005). There is a relatively quick method of providing redundancy to the Overhand Bend. Simply tie a second Overhand Knot, thus creating two side-by-side Overhand Knots joining the rappel lines (Figure 9). The Overhand Bend is transformed into the more secure Tandem, Stacked or Double Overhand Bend, which has other names. Some preliminary investigations of the Tandem Overhand Bend suggest that tying the second knot with opposite chirality increases security even further. Care must be taken to minimize the gap between the two Overhand Knots. The Double Overhand Side Bend (Figure 8, centre) is another candidate that has tested well (Prattley, 2016). The Tandem Overhand Bend and the Double Overhand Side Bend have contact footprints comparable to that of the Overhand Bend, but they have double the volume and protrude farther from the rock. Therefore, they may have a higher possibility of jamming, depending on the rock composition and the size of cracks and surface features encountered. Again, there is no standardized method of confirming this adequately with results that can be generalized.

Figure 9. The Tandem, Stacked or Double Overhand Bend or Side Bend (left), which is more secure than the single Overhand Bend (right), especially if the two Overhand Knots have opposite chirality.

Of greater importance is the fact that these configurations are more stable and secure, unlike the standard Overhand Bend and Figure Eight Side Bend, even when tied sloppily with shorter tails (Chisnall, 2020). Limited testing suggests that the knot efficiencies of the Tandem Overhand Bend and the Double Overhand Side Bend fall within a relatively narrow and appropriately higher range (Prattley, 2016; Needle Sports, 2020). Failures are the result of rope rupture rather than flyping or reptation. This is not true of the single Overhand Bend and the Figure Eight Side Bend. Nevertheless, it seems the Tandem Overhand Bend and the Double Overhand Side Bend are not used as frequently for joining rappel lines (Gommers, 2019; Moyer, 1999b).

Discussion

Details regarding the appropriateness and reliability of knots highlight the importance of any tier's understanding of structure, function and application. In some cases, the chosen knots may be tied properly, but those knots might be inadequate for their intended purpose. Their habitual use may be the result of ignored or misleading information regarding the subtleties of critical knot characteristics and behaviour. Agreeing on the ideal knots for certain applications is a matter of consistent standards. Consensus pertaining to terminology and knot applications is a key issue, as is agreement regarding research methods and results. When reviewing the plethora of grass-roots and formal testing focussing on the safety of knots, it is apparent that using mainly slow-pull tests to determine tensile failure limits is the norm (Baillie, No date provided; Borwick, 1973; Chisnall 1995a, 1995b, 1995c; 2020; Evans, 2016; Ewing, 1973; Gommers, 2019; Marbach and Rocourt, 1986; McKentley, 2014; McKentley and Parker, 2000; Microys, 1977, Moyer, 1999a, 1999b; Patil et al. 2020; Pope, 1972; Šimon et al., 2020; Warner, 1996, Wheelock, 1967). There is agreement concerning general issues, but relevant priorities and test results can range broadly when it comes to the functionality of particular knots.

Theories that govern fundamental test questions and influence conclusions can be poorly constructed. Research is required to be empirically verifiable and falsifiable (Oreskes, 2015), but many reported knot tests are unrepeatable owing to a lack of information and accurate knot images. Such tests need to be reliable and valid according to the precise structure of the knot being tested, how that knot's behaviour is evaluated under the conditions of use, and how the resulting conclusions can be applied in practice (Chisnall, 1995a, 1995b, 1995c, 2020). Universal agreement needs to accommodate priority safety characteristics, but overcoming fundamental biases and flawed assumptions is a challenge.

The use of controversial knots, like the bends described, presents a subtle danger related to risk perception, probabilities, bias, and risk homeostasis (Chamarro and FernándezCastro, 2009; Denscombe, 1991; Funderburke and Debruin, 2019; Helms, 1987; Kahneman, 2011; Langseth and Salvesen, 2018; Little, 2018; Llewellyn and Sanchez, 2020; Oreskes, 2015; Pinker, 1997; Ropeik, 2010; Schad, 2000; Specter, 2010; Taylor, 2013; Thompson, 2008; Udall, 1987; Wilde, 1998). Some side bends work most of the time, but not always. The likelihood of knot failure, based on experience and inconsistent data, is perceived to be low. As Rosenthal (2005) states: "Ignoring the extremely improbable is a sound, rational way to approach decisions, but if we take it to extremes, we might be tempted to recklessness or negligence." Regarding rare or "black swan" events, Taleb (2010, page 341) warns: "since we do not see these events coming, we need to be more robust to them." Accidents are infrequent and the disagreement surrounding certain knots is ongoing. This lack of consensus suggests uncertainty and a need for clarity. Clarity can be achieved through proper test methods when appropriate assumptions are made and relevant questions are asked.

Psychological factors influence the behaviour of individuals within the climbing community, and these phenomena govern decisions made in formulating the safety policies and procedures of organizations. As with most safety decisions and behaviours, confirmation bias, narrative fallacy, motivated inference, cognitive dissonance, and herd mentality may be influential (Taylor et al., 2013). Unintended bias can emerge from familiarity, accepted assumptions and limited test data, so all stakeholders must be on the alert (Denscombe, 1991; Kahneman, 2011; Little, 1980).

Conclusions

If a side bend holds, the rope will rupture when sufficient force is applied. Tensile breaking strength is primarily a function of the type and quality of the rope (Šimon et al., 2020). When side bend rupture does not occur, flyping and reptation are the mechanisms of failure for some side bends, and those actions occur at lower loads. The tendency for reptation and flyping indicates the relative insecurity of those bends.

Climbers who use side bends to join rappel lines must strive to understand the structural and behavioural subtleties of the knots they use and apply that understanding logically. In accordance, they should identify and prioritize applicable knot characteristics. Safety procedures can improve when evaluated regularly and updated as required. Amendments, or the validation of existing practices, rely on good data and detailed accident reports. Consensus concerning standardized testing methods needs to be achievable. Controversy and disagreement point to universal uncertainty.

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