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ORIGINAL ARTICLE

Controlled comparative tensile tests of backed versus non-backed edges' adhesion: Inferences into stone tool functional properties

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Abstract
Backing is a procedure for retouching a stone tool edge to an angle of or near 90°. Archaeologists have recorded backed lithic specimens in the Pleistocene and Holocene around the world. One prominent hypothesis for the occurrence of backing is that it increases a stone tool's adhesion relative to what it would have otherwise been with unmodified, sharp edges. We conducted a highly controlled semi-static tensile test in which we assessed lithic specimens that possessed both a backed and a non-backed edge, opposing each other. We hafted each specimen's backed and non-backed edges to wood, and the bi-hafted stone implement was then pulled apart using an Universal Instron Materials Tester, allowing for a direct 'head-to-head' comparison of the two edge types' adhesive properties. Our tensile test results suggested no significant difference between backed and non-backed edges in terms of adhesion, which does not support the hypothesis that backing increases a lithic specimen's adhesion.

KEYWORDS
stone tools, backing, adhesion

INTRODUCTION

Past humans 'backed' a variety of stone tool forms—by retouching at least one edge to an angle of or near 90°—in geo-temporal contexts ranging from the late Lower Paleolithic to the Holocene and from South Africa to the Arctic (Pargeter et al., 2022, *passim*; see also Caruana et al., 2023; Delpiano et al., 2024; Fasser et al., 2024; Leplongeon et al., 2022; Moore et al., 2022; Muller et al., 2018; Roux et al., 2020; Ruta, 2021; Taipale et al., 2022; Taller & Taipale, 2020; Wiśniewski et al., 2020). Given the widespread and 'patchy' (Taller & Conard, 2022: 98) occurrence of backing in the archaeological record, it should come as no surprise that lithic analysts have proposed several hypotheses to explain the phenomenon. For example, blunting an otherwise sharp tool edge via backing likely facilitates a person's grip on a non-hafted stone implement and potentially decreases the chance of injury (Barham, 2013; Lemorini et al., 2006), the latter having been demonstrated with animal-processing experiments using non-backed tools (e.g., Callahan, 1994; Eren, Bebber, et al., 2024). Or given that backed stone tools appear to have been used to process a variety of raw materials (Finlayson & Mithen, 1997; Igreja & Porraz, 2013; Macdonald, 2013; Robertson, 2005; Wadley & Binneman, 1995), perhaps they provided advantages in processing tasks (Pargeter et al., 2022). Although they do not provide details, Taller and Conard (2022: 98) suggest that backed tools are 'easier to haft'. This latter hypothesis is conceivable: hafting backed stone tools may require a simpler, straighter, shallower trough in the organic component of a composite tool that is easier to incise relative to a trough for non-backed tools. Clarkson et al. (2018: 186) postulate that compared with non-backed 'thin flakes and microblades', backed iterations are more durable because they reduce the potential of bending failure through an increase of the thickness-to-width ratio. And then there is the null hypothesis: backing represents a non-utilitarian cultural phenomenon (e.g., Close, 2002; Deacon & Deacon, 1999; Macdonald, 2013; Mackay, 2011; Mackay et al., 2014; Munt et al., 2023; Sampson, 1974; White et al., 2011; Wurz, 1999, 2000) that arose due to drift, transmission bias or the need to communicate non-utilitarian social information such as identity or artistic expression. We note that some of these hypotheses for backing are not mutually exclusive, and different hypotheses may explain the occurrence of the backing in different contexts.

Another hypothesis for backing, and our focus here, is that it enabled past humans to attach (haft) stone tools more effectively to wooden or bone handles or shafts (Barham, 2013; Bleed, 2002; Clark, 1969, 1970; Hiscock, 1994; Wadley & Mohapi, 2008). The adhesion hypothesis suggests a backed edge's increased adhesiveness, relative to that of a non-backed edge, stems from the former being wider, rougher, stronger, and blunter (for a discussion, see Pargeter et al., 2022: 2). We recently conducted our first experiment of the adhesion hypothesis, a dynamic ballistic test in which backed crescents (lunates) and straight non-backed bladelets were hafted onto the lateral and distal portions of poplar projectile shafts (Pargeter et al., 2022). Following previous experiments (Bebber et al., 2020; Buchanan et al., 2022; Eren, Bebber, Wilcox, et al., 2022; Lowe et al., 2019), we then shot these projectiles at a wood (oak) board in a controlled indoor setting at the Kent State University Experimental Archaeology Laboratory. We then analysed how many backed and non-backed lithic segments remained fixed to their shafts, and how many wooden shafts split upon impact. The results of the experiment suggested that (1) backing does not improve adhesion, but instead significantly worsens it; and (2) backed segments appear to increase the chances of shaft splitting.

Our indoor laboratory results described above are consistent with the relatively less controlled outdoor ballistics results of Pétillon et al. (2011). In their experiment, Pétillon et al. produced replicas of Magdalenian composite projectile heads, consisting of backed microliths hafted into an osseous shaft. Human participants then fired these projectiles via the atlatl (spearthrower) into deer carcasses (a much softer target than our oak board). Five of 22 successful hits resulted in laterally hafted flint bladelets being 'ripped off' the point when the projectile entered the target's body (Pétillon et al., 2011: 1276). Pétillon et al. (2011: 1276) note that these backed microliths were either 'found clustered on the target's hide, next to the hole made by the point, or were expelled by the force of impact up to several meters from the target'. Of the remaining 17 successful hits, the backed implements of two of them could not be found, preventing Pétillon et al. in determining if they had ripped off upon impact or remained inside the carcass. In the remaining 15 successful penetrations Pétillon et al. (2011: 1276) documented that 'part of the lithic row(s) sometimes came off upon impact'. Overall, Pétillon et al. (2011: 1279) noted that a 'low cohesion of the [backed] flint bladelets with the points appears as a recurrent feature of our experimental projectiles'.

We realize that Pétillon et al. (2011) did not conduct a *comparative* assessment of backed versus non-backed edges. However, hypothetically, had none of their backed tools 'ripped off' their composite points, that result would have been *inconsistent with* the results of Pargeter et al. (2022). Along those lines, that is exactly what happened in the ballistic experiments of Roux et al. (2020: 118): none of their backed bladelets 'ejected' from the composite projectile. Roux et al. also did not conduct a comparative assessment of backed versus non-backed edges, and instead attributed the non-failure to the glue application.

Given the results described above, and recognizing that experimental variables, interactions, conditions and procedures could be influencing results, much more experimental testing is needed before drawing any firm inferences with respect to whether backing increases adhesion relative to non-backed (sharp) edges (Eren & Meltzer, 2024). Therefore, we continue our experimental assessment of backing and adhesion, but report here on a very different sort of test to the previous dynamic ballistics tests described above. We conducted a highly controlled semi-static tensile test in which we assessed lithic specimens that possessed *both* a backed and non-backed edge, opposing each other. Each specimen's backed and non-backed edges were hafted to wood, and the bi-hafted stone implement was then pulled apart, allowing for a direct 'head-to-head' comparison of the two edge types' adhesive properties.

MATERIALS AND METHODS

The lithic specimens

Co-author M.I.E., using Texas Georgetown chert, knapped over 100 stone flakes. From these we chose 30 that possessed one sharp, and relatively straight, edge. M.I.E. then used anvil percussion to back an edge directly opposite each of the 30 sharp edges and 'square off' the lateral edges of each specimen. This procedure resulted in 30 rectangular flakes (Figure 1). We recorded the mass (g) of each lithic specimen as well as the edge angle (°) of the sharp and backed edges (Table 1). Edge angles were measured in Adobe Illustrator by recording the edge angles at each edge's two lateral ends and calculating the average (Figure 1).

Images and raw recorded data of each lithic specimen are available in the supplementary online materials.

The 'hafted' test specimens

Co-author M.W. 'hafted' each of the 30 lithic specimens twice, once on the backed edge and once on the sharp edge (Figure 2). Of course, we acknowledge the vast number of possible materials that could be used to haft backed and non-backed specimens, and also feel it necessary to emphasize that there are likely many unknown hafting techniques and materials due to experimental archaeology's 'poltergeist of the unpreserved' (Conrad et al., 2023). Thus, our goal here was to produce test specimens that were hafted in a uniform, secure, and safe manner.

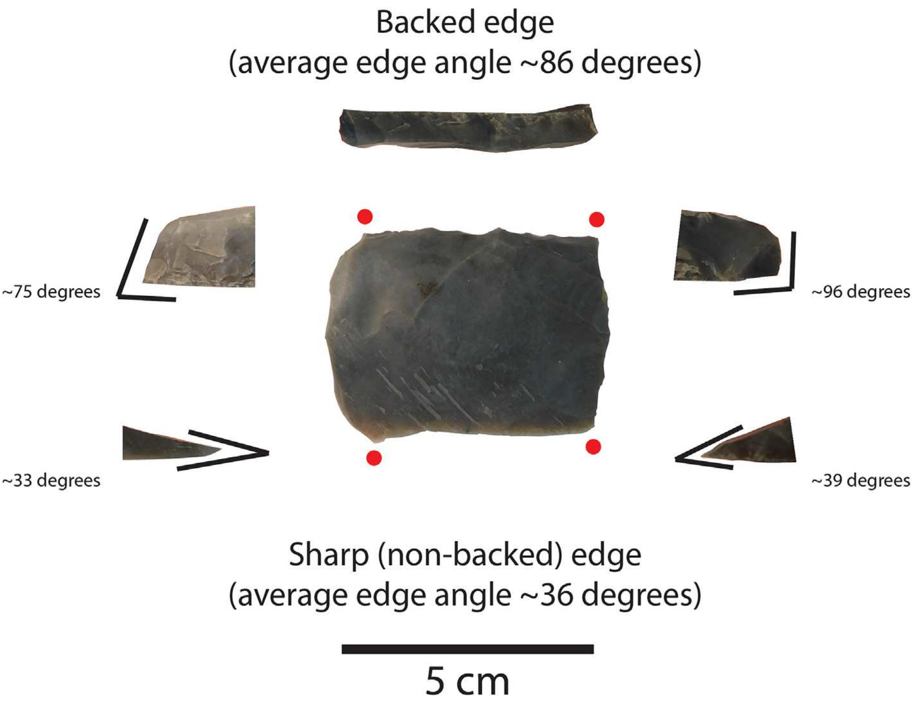

FIGURE 1 Example of an experimental lithic specimen possessing both a backed edge and a sharp edge. The edge angle for the backed edges were recorded at the two locations indicated by the red dots, and then averaged; the same procedure was used to calculate the sharp edge angle.

TABLE 1 Summary data of the lithic specimens prior to hafting. The backed and sharp (non-backed) edge angles reported here are an average of two measurements; the location of measurement are depicted in Figure 1.

	Mass (g)	Average backed edge angle (°)	Average sharp (non-backed) edge angle (°)
Mean	28.2	83.9	45.4
SD	18.8	7.9	10.7
Minimum	9.0	64.9	26.3
Quartile 1	13.8	78.7	37.5
Median	22.0	85.9	44.3
Quartile 3	35.0	89.6	55.0
Maximum	80.0	96.1	67.6
Range	71.0	31.2	41.3

Note: All raw data are available in the supplementary online materials.

For the wooden shafts, we used 3.175 cm (1.25 in.)-diameter rods of Southern yellow pine (*Pinius palustris*). For the adhesive, we used a thermoplastic glue (Ferr-L-Tite), which has been shown in a previous experiment to perform similarly to pine pitch (Wilson et al., 2021). Both the wooden shafts and the thermoplastic glue are commercially available.

The hafting process of the lithic specimens began by cutting the dowel rods in half, resulting in a piece of wood that possessed one flat face and one convex (semi-circular) face. We produced a ‘trough’ for the backed and non-backed specimen in the convex face. On a table saw, we removed a 1.5 cm (0.6 in.)-wide, by 1 cm (0.4 in.)-deep groove along the flat face of the dowel. The grooved shaft halves were then cut to standardized 8.9 cm (3.5 in.)-long blanks

FIGURE 2 Procedure for creating the test specimens started with cutting pine wood and giving each piece a standardized 'trough' (top left). Test specimen components were heated (top right) and then hafted together (bottom left). All the backed edges were hafted first, then the sharp edges (bottom right). See the main text for details.

(Figure 2). To prepare for the backed and non-backed blades hafting process, we first placed a set of steel blocks in the freezer—these would aid in levelling and cooling the adhesive later. We then put our adhesive in a small pan to warm on an electric hot plate. Next, a 100 ml heavy wall chemistry beaker was installed to a mechanical grip, which we used to hold the beaker without injury while the adhesive was warmed. We also used the mechanical grip to pour the melted glue into the pre-warmed haft area (the 'trough') (Figure 2). To build the test specimens, we warmed each wood trough with Sterno canned heat to bring it up to gluing temperature, and then set the flat face down on the workspace, with convex, trough face up. We warmed the backed and non-backed lithic specimens as well. Next, the cold steel blocks were removed from the freezer and set up against either end of the warmed wooden specimen (Figure 2). We then inserted the warmed lithic specimen into the warmed trough. While the lithic specimen was held in the correct position, we poured the melted glue into the trough, making sure it did not run over the trough's edges. After pouring, we shifted the steel blocks from a test specimen's sides, to the top of (covering) the trough, on both sides of the lithic specimen. This procedure of placing the cold steel block on top of the trough both hardened the glue and levelled it out so that we could achieve a consistent glue depth and consistent test specimen morphology. We trimmed off any remaining glue around the edges of the trough which left a streamlined, single-hafted, lithic specimen. We 'hafted' all the backed edges first. We then repeated the process described above for the non-backed (sharp) edges. For any readers of this manuscript who wish to repeat our experiments (which we encourage!), please take note: creating these test specimens was a tedious, laborious, and at times frustrating process. Also note that the steel blocks were returned to, and retrieved from, the freezer several times during the process to keep them cold; otherwise, the thermoplastic glue would have stuck to the warming steel. We recorded several variables from each of our 'hafted' test specimens (Table 2). We recorded the overall test specimen mass, as well as the mass of the glue and wooden components (the latter was calculated by subtracting the lithic specimen mass from the overall test specimen mass). We also recorded the length and thickness of the lithic specimen at the point it emerged from the wooden trough, on both the backed and sharp ends (Figure 3). Finally, we recorded the wooden trough thickness and width on each test specimen (Figure 3). Images and raw recorded data of each test specimen are available in the supplementary online materials.

TABLE 2 Summary data of the Instron test specimens prior to testing. Numbers in parentheses indicate where measurements were recorded on specimens (see Figure 3). The average backed and sharp (non-backed) 'trough widths' reported are an average of two measurements; 'trough thicknesses' are an average of two measurements; 'thicknesses exposed' are an average of three measurements. All raw data are available in the supplementary online materials.

	Total mass (g)	Average backed edge trough thickness (1) (mm)	Average sharp (non-backed) edge trough thickness (4) (mm)	Average backed edge trough width (2) (mm)	Average sharp (non-backed) edge trough width (5) (mm)
Mean	63.4	7.0	7.1	12.5	11.2
SD	17.8	0.8	0.6	2.0	0.8
Minimum	44.0	5.6	6.0	10.2	10.2
Quartile 1	51.1	6.7	6.8	10.8	10.6
Median	58.2	7.2	7.2	11.7	11.1
Quartile 3	70.3	7.3	7.4	14.6	11.5
Maximum	117.5	9.2	8.7	16.9	13.4
Range	73.5	3.5	2.7	6.6	3.2
	Glue + wood mass	**Average backed edge thickness exposed (3) (mm)**	**Average sharp (non-backed) edge thickness exposed (6) (mm)**	**Backed edge length exposed (7) (mm)**	**Sharp edge length exposed (8) (mm)**
Mean	35.2	10.1	6.6	44.7	43.8
SD	3.0	3.7	2.1	8.5	8.9
Minimum	30.5	4.7	3.2	31.9	29.8
Quartile 1	33.0	6.9	5.0	37.7	37.0
Median	35.3	9.4	6.4	45.4	45.0
Quartile 3	37.9	12.4	8.2	50.7	48.8
Maximum	40.5	18.3	10.3	68.3	70.0
Range	10.0	13.6	7.0	36.5	40.2

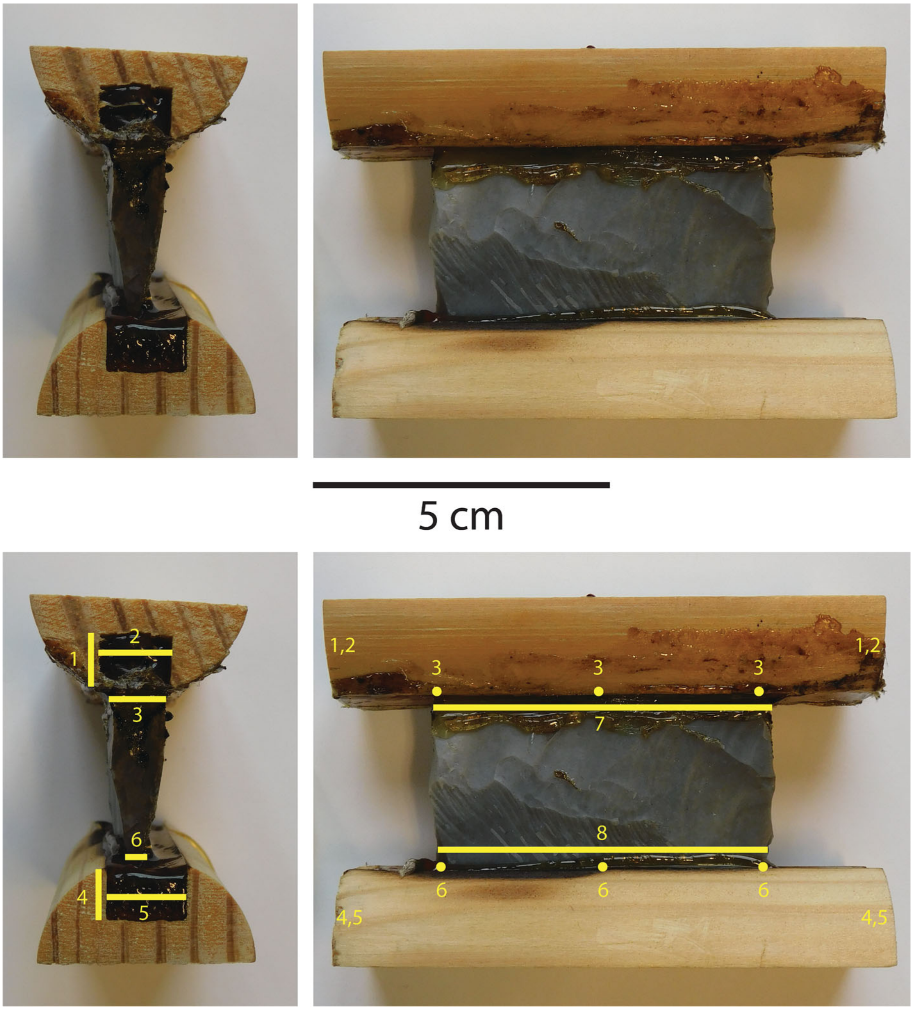

FIGURE 3 Example of a finished experimental test specimen (top) and the measurements recorded from it (bottom). 1 = Backed edge trough depth (average of two measurements); 2 = backed edge trough width (average of two measurements); 3 = thickness of the exposed backed edge (average of three measurements); 4 = non-backed (sharp) edge trough depth (average of two measurements); 5 = non-backed (sharp) edge trough width (average of two measurements); 6 = thickness of the exposed non-backed (sharp) edge (average of three measurements); 7 = length of backed edge exposed; and 8 = length of non-backed (sharp) exposed.

On the use of Ferr-L-Tite

We feel it necessary to briefly discuss our use of Ferr-L-Tite adhesive, given the recent results of Tydgadt and Rots (2022). Tydgadt and Rots (2022: 1255) note that 'in reaction' to Wilson et al. (2021), they tested Ferr-L-Tite in shear-compression tests because it is 'obviously not archaeologically compatible'. Tydgadt and Rots' (2022: 1257) tests suggested that 'Ferr-L-Tite proved unfit for simple lap joint adhesion on nearly every composite sample'. They also stated that 'Ferr-L-Tite failed to adhere to flint in most cases, with only three samples [out of 15] adhering long enough to be secured in the test bench and submitted to the test. The others [i.e., $n = 12$] showed no adhesion, and thus had a resulting breakage maximum force of 0 N/mm^2' (Tydgadt & Rots, 2022: 1257). We cannot currently reconcile their results with our current and previous experimental observations and results. For example, in the present experiment's tensile tests the use of Ferr-L-Tite yielded force values > 0 in all 30 instances (see the results below and Table 3). In Pargeter et al. (2022), many non-backed lithic specimens remained hafted to their wooden shafts after a tremendous impact shearing shock. Eren, Bebber, et al. (2024) documented, in a bison butchery experiment, that chert bifaces hafted to wooden handles with Ferr-L-Tite were more likely to result in chert biface breakage than adhesive failure. Baldino et al. (2024) documented that among seven chert points hafted with Ferr-L-Tite to wooden thrusting spears, all withstood a maximum total of 29 thrusts into 20% ballistics gel without adhesive failure. Wilson et al. (2021) demonstrated that 10 chert arrowheads hafted with Ferr-L-Tite were able to withstand an average of 9.7 dynamic impacts without adhesive failure. And we have successfully conducted other experiments using Ferr-L-Tite as well, involving dynamic and static tests of projectiles, endscrapers, knives, and chopping

TABLE 3 Results of the experimental tensile tests.

Specimen	Backed edge position during experiment	Sharp (non-backed) edge during experiment	Edge that did not become dislodged (the 'winner')	Peak force prior to adhesive failure (kN)
1	Up	Down	Backed	0.435
2	Down	Up	Sharp (non-backed)	0.545
3	Up	Down	Sharp (non-backed)	0.439
4	Down	Up	Sharp (non-backed)	1.188
5	Up	Down	Backed	1.155
6	Down	Up	Backed	0.752
7	Up	Down	Sharp (non-backed)	0.790
8	Down	Up	Backed	0.388
9	Up	Down	Backed	0.588
10	Down	Up	Backed	0.271
11	Up	Down	Backed	0.506
12	Down	Up	Backed	0.679
13	Up	Down	Backed	0.802
14	Down	Up	Backed	0.285
15	Up	Down	Backed	0.855
16	Down	Up	Backed	0.242
17	Up	Down	Backed	0.467
18	Down	Up	Backed	0.422
19	Up	Down	Sharp (non-backed)	0.186
20	Down	Up	Sharp (non-backed)	0.394
21	Up	Down	Sharp (non-backed)	1.012
22	Down	Up	Sharp (non-backed)	0.829
23	Up	Down	Backed	0.493
24	Down	Up	Backed	0.714
25	Up	Down	Sharp (non-backed)	0.398
26	Down	Up	Backed	0.419
27	Up	Down	Sharp (non-backed)	0.862
28	Down	Up	Sharp (non-backed)	0.814
29	Up	Down	Backed	0.960
30	Down	Up	Backed	0.529

tools (Bebber et al., 2020; Bebber & Eren, 2018; Eren et al., 2021; Eren, Mukusha, et al., 2022; Eren, Miller, et al., 2024; Gala et al., 2022; Lowe et al., 2019; Maguire et al., 2021; Mika et al., 2020; Mukusha et al., 2024; Mullen et al., 2023; Perrone et al., 2020).

There are several possible reasons why Tydgadt and Rots' (2022) data show 12 out of 15 trials yielded maximum force values of 0 N/mm^2, but whatever the reason, their Ferr-L-Tite results are currently outliers in need of explanation because when it is applied properly Ferr-L-Tite is highly and consistently effective as an adhesive. Additionally, we encourage readers to consult the above studies and compare those tests and results with Tydgadt and Rots (2022) before making any conclusions about 'archaeological compatibility' of Ferr-L-Tite as a useful proxy material in archaeological experiments.[1]

Experimental procedure

The experiment took place in the Kent State University Experimental Archaeology Laboratory and used the lab's Instron Universal Materials Tester (Model 5967). In order to accommodate the test specimens and conduct the experiment, M.W. and M.I.E. designed specialized fixtures compatible with the Instron. These new fixtures were manufactured by Quick Service Welding & Machine, Inc. (Kent, OH, USA) (Figure 4, left). Once the fixtures were attached to the Instron, we fitted each test specimen into the fixtures. We systematically alternated whether the backed edge was up and the sharp edge was down, or vice versa, for each test specimen throughout the experiment (Figure 4, centre, and Table 3). We implemented the latter procedure just to ensure that test specimen positioning did not bias the results. The Instron then pulled each test specimen apart at a velocity of 1 mm/min until either the backed or sharp edge failed to adhere to its wooden component (Figure 4, centre). This procedure yielded two sets of results for each test specimen. First, this procedure revealed which edge, either backed or non-backed, 'won' by adhering to its wooden component or 'lost' by becoming dislodged from it (Figure 4, right). Second, this procedure recorded the maximum tensile force value in kilonewtons (kN) just prior to an edge's failure.

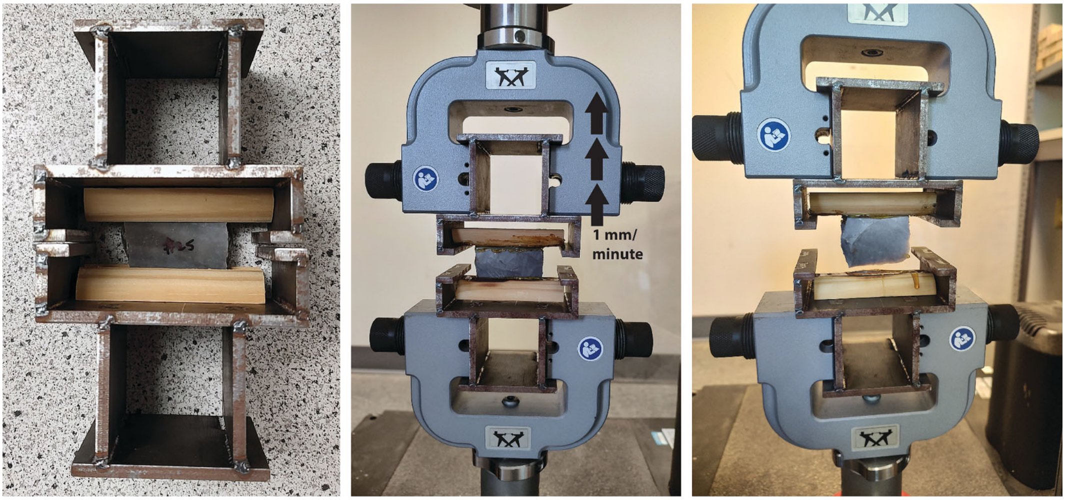

FIGURE 4 Fixtures designed for the Instron materials tester pulled the bi-hafted test specimens apart (left). The test specimens were pulled apart at 1 mm/min (centre). An example of a non-backed (sharp) edge pulled out of its haft (right).

Statistical analysis

After completing all 30 tests, we carried out a binomial test on the proportion of backed edge winners—those cases when the backed edge adheres to the wooden component longer than the sharp edge—to sharp edge losers—cases when the sharp edge pulls from the wooden component before the backed edge. We then conducted a series of two-sample tests on the 12 variables (see the above sections 'The lithic specimens' and 'The hafted test specimens') describing the fixtures by separating the samples into winning and losing groups to determine if the measured variables were significantly different. To accomplish this, we first examined the sample distributions using Shapiro–Wilk tests for normality. Plots of the 12 sample distributions are available in the supplementary materials online. For variables that did not conform to an underlying normal distribution, we tried the logarithmic transformation. This procedure 'normalized' only one of the variables (overall specimen mass). Either a parametric or a non-parametric two-sample test was then used to test for differences in each of the variables. For the parametric two-sample *t*-tests we also used an *F*-test to determine if the sample variances were equal and used the appropriate test (Welch's test) modification in two cases (sharp edge exposed and sharp edge trough thickness) where it was not. We did these analyses using R 4.3.1 (R Core Team) the R script is available in the supplementary materials online (see also Figures S1-S5).

RESULTS

Of the 30 tests conducted the backed edge won 19 times over the sharp edge (Table 3). This proportion (0.633) of backed winning is not significant ($\chi^2 = 1.633$; $p = 0.201$). Shapiro–Wilk tests show that four variables did not conform to normality (overall specimen mass, backed edge trough width, sharp edge trough width and backed trough thickness), one variable did so after log-transformation (overall specimen mass) (see supplementary materials online, Figures S1-S5). We carried out appropriate two-sample tests of differences between winning backed and winning sharp edges to determine if any of the measurement variables for the winning group of backed or sharp edges were significantly different. Results of the two-sample test of force (*F*-test $p = 0.407$; $t = -0.991$; $p = 0.330$) and overall mass (*F*-test $p = 0.135$; $t = -1.192$; $p = 0.243$) indicated there was no significant differences between winning edges (Table 4). Tests comparing the winning and losing backed edges of length of edge exposed, edge thickness, edge width, edge angle, trough width and trough thickness showed no significant difference. Similarly, tests comparing the winning and losing sharp edges of length of edge exposed, edge thickness, edge width, edge angle, trough width and trough thickness showed no significant difference (Table 5).

We also compared the measurements from the winning backed edges and winning sharp edges to determine if there were any significant differences. We carried out the same procedures as above for these tests. Table 6 shows that except for edge angle, none of the variables was significantly different. Edge angle, as expected, differs between backed and sharp edges.

TABLE 4 Two-sample tests comparing winning versus losing groups.

Variable compared by winner–loser	Test	*F*-test variance *p*-value	*t*/*W*	*p*
Force	*t*-test	0.407	−0.991	0.330
Overall mass (log)	*t*-test	0.135	−1.192	0.243

TABLE 5 Two-sample tests comparing winning versus losing groups.

Variable compared by winner–loser	Test	*F*-test variance *p*-value	*t*/*W*	*p*
Backed edge exposed	*t*-test	0.185	−1.155	0.258
Backed edge thickness	*t*-test	0.343	0.415	0.681
Backed edge angle	*t*-test	0.334	0.017	0.986
Backed trough width	Wilcoxon	n.a.	95.5	0.715
Backed trough thickness	Wilcoxon	n.a.	152.5	0.041
Sharp edge exposed	Welch's	0.047*	−0.995	0.336
Sharp edge thickness	*t*-test	0.625	−0.577	0.568
Sharp edge angle	*t*-test	0.444	−0.378	0.708
Sharp trough width	Wilcoxon	n.a.	86.0	0.439
Sharp trough thickness	Welch's	0.012*	−0.184	0.856

*Significant at the alpha = 0.05 level, but after Bonferroni adjustment for 10 tests (alpha = 0.005) none of the tests is significant.

TABLE 6 Two-sample tests comparing variables associated with winning backed and winning sharp specimens.

Variable compared by winner–loser	Test	*F*-test variance *p*-value	*t*/*W*	*p*
Edge angle	Wilcoxon	n.a.	208.0	< 0.000*
Edge width	*t*-test	0.2652	2.66	0.013
Edge exposed	*t*-test	0.084	−0.831	0.413
Trough thickness	Wilcoxon	n.a.	119.5	0.533
Trough width	Wilcoxon	n.a.	126.0	0.372

*Significant at the alpha = 0.05 level, after Bonferroni adjustment for five tests (alpha = 0.01) only edge angle was significant.

DISCUSSION

Backing stone tools was a global phenomenon during the Pleistocene and Holocene and the reason(s) for its adoption by distinct groups of past peoples was likely varied and context-specific. However, it is also possible that backing provided one or more utilitarian benefits that numerous peoples in diverse contexts valued. Archaeological experiments can help us make inferences as to whether ontogenetic, functional, economic, or senescent factors (see Eren, Bebber, Knell, et al., 2022, Lycett and von Cramon-Taubadel, 2015; Lycett et al., 2016; Story et al., 2019) potentially played a role in the adoption of lithic backing in one or more of those contexts. Given that increased adhesion has been proposed as one such beneficial property of backed specimens (relative to non-backed specimens), we initiated an experimental program to test that hypothesis. Our first experiment—a dynamic, less controlled, shear-force focused ballistics test of backed crescents versus straight microblades on poplar wood shafts—suggested that backingedges significantly worsens adhesion. Our second experiment reported here—a static, more controlled, tensile-force focused Instron test of backed and non-backed edges hafted to pine wood—instead suggested no significant difference between backed and non-backed edges in terms of adhesion. This difference in results should come as no surprise because the two experiments are quite different in numerous respects (Eren & Meltzer, 2024). More work now is required to reconcile those differences by assessing which experimental variables are the cause.

Yet, in a broader sense, the distinct results of our first two experiments are still consistent with each other because *neither set of results supports the hypothesis that backing increases adhesion*. In other words, while it appears that particular variables can affect how well a backed edge adheres to an organic tool component (an observation also suggested by Pétillon et al., 2011: 1279), there is currently no evidence to suggest that backing an edge will improve a lithic specimen's adhesive capability over that of an edge left unmodified and sharp—all else being equal.

While archaeologists can learn much from archaeological experiments, any one experiment—or even a small number of related experiments—is only a small potential contribution to the archaeological understanding of the past (for a discussion, see Eren, Bebber, et al., 2024: 25). Given the geo-temporal ubiquity of backing in the archaeological record, the number of possible variables and variable interactions that could be tested is vast (e.g., lithic specimen types, stone raw material types, wood types, glue types, glue amounts, functional tasks, etc.) (Eren & Meltzer, 2024). We are thus under no illusion that our first two experiments have fully falsified the backing adhesion hypothesis: much more testing is necessary, testing we plan to conduct (Pargeter et al., 2022). Given our stated (and necessary) caveats, we find it odd that, in discussing our first set of experiments (i.e., Pargeter et al., 2022), Taipale and Rots (2023: 14) write:

> The experimental set-up and reporting of this study, however, contain several weaknesses. The experiment compared segments with curved backs to non-backed lithics with relatively straight edges. The backed pieces were also larger than the non-backed ones, which the authors justified by saying that thin pieces are difficult to back, a statement that can easily be contradicted by measurement data on archaeological backed lithics (e.g. Chiotti et al., 2013, figure 60). The quantity of glue used, its extension onto the surfaces vs the back of the lithic, and the length of the contact surface were also not reported. The projectiles were shot against a wooden board, meaning that the detachment of the lateral elements happened by shock rather than shearing, *a situation that is only partly comparable to prehistoric hunting*. The results of the study are, therefore, inconclusive, and further adhesion tests can be recommended. (added emphasis)

We agree almost entirely with their criticisms,[2] as we already acknowledged many of these issues and the need for more testing (Pargeter et al., 2022: 3–4, 7–8). We especially agree that our experiments are only partly comparable with prehistoric hunting. But it should be noted that *all* modern experiments are *only partly* comparable with the past; to think otherwise misunderstands and overestimates the power and role of experiments in archaeological inference (e.g., for discussions, see Binford 1981; Conrad et al., 2023; Eren et al., 2016, 2021; Eren, Meltzer, et al., 2022; Eren, Bebber, et al., 2024; Eren & Meltzer, 2024; Jennings et al., 2021; Lin et al., 2018; Lycett & Eren, 2013; Magnani et al., 2019; Outram 2008; Shea 2020; and Thomas 1986).

AUTHOR CONTRIBUTIONS

All authors contributed to the study conception, design and funding acquisition. Material preparation was performed by M.W. and M.I.E. Testing and data collections were performed by M.R.B. and M.I.E. Statistical analysis was conducted by B.B. All authors wrote, read, commented on and approved the final manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare no competing interests.

DATA AVAILABILITY STATEMENT

Data are available within the article or its supplementary materials.

DECLARATIONS

The authors have no relevant financial or non-financial interests to disclose.

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ENDNOTES

[1] For important discussions about, or excellent examples of, 'proxy materials' in archaeological experiments, see Clarkson (2017), Dibble and Pelcin (1995), Dibble and Rezek (2009), Dogandžić et al. (2020), Hecht et al. (2015), Iovita et al. (2014, 2016), Key and Lycett (2011, 2014, 2015, 2017), Key et al. (2018), Khreisheh et al. (2013), Loendorf et al. (2018), McPherron et al. (2020), Milks et al. (2016), Neill et al. (2022), Pargeter (2007), Rezek et al. (2011), Schillinger et al. (2014a, 2014b, 2015, 2016, 2017), Schoville et al. (2017), Schunk et al. (2024), Speer (2018), Stout et al. (2015) and Wilkins et al. (2014).

[2] We note Taipale and Rots' (2023) reference to a single archaeological example in which backing occurs on thin pieces does not negate the argument that backing thin pieces was difficult for us and may have been difficult for past knappers. Moreover, their reference to a single example in which backing occurs on thin pieces does not speak to potential population-level morphometric differences in thin versus thick backed and non-backed archaeological specimens in different geo-temporal contexts (an analysis that, to our knowledge, has not been conducted).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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