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PERFORATION WITH STONE TOOLS AND RETOUCH INTENSITY: A NEOLITHIC CASE STUDY

Abstract

A measure of retouch intensity, the EKCI, was devised based upon function and archaeological context. To arrive at the function of Pre-Pottery Neolithic A el-Khiam points from the Near East, controlled experiments were performed to determine the relative density of the contact material, which could affect use and retouch patterns. It was shown that el-Khiam points were likely used to pierce and scrape soft materials such as leather. The EKCI was then devised, measured, and tested. Experimental replication showed that the EKCI was an accurate measure of retouch intensity, and application of the EKCI to the lithic assemblage at Dhra' reaffirmed the EKCI's utility for analyzing PPNA archaeological assemblages. Although this curation index is effective for el-Khiam points, it may not be applicable to other hafted point types, which highlights the need for independently developed measures of retouch that account for the form, function, and context of the artifacts rather than attempting to generate universal measures of curation.

INTRODUCTION

Archaeological assemblages from the first farming villages in the Southern Levant have produced high-quality and large-quantity lithic data sets that Near Eastern archaeologists rely upon for interpreting the past. This vast resource of prehistoric knowledge has remained relatively untapped as a source of understanding individual decision-making in prehistoric lithic technology, especially from the perspective of artifact life histories and retouch intensity. Before archaeologists can

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begin to debate life cycles and retouch patterns of lithic artifacts, however, we must first develop the means of quantifying change in artifact morphology and assemblage characteristics that are directly linked to individual decision-making processes. In this study we provide a preliminary exploration of the practice of lithic curation in Near Eastern Neolithic assemblages, assessing retouch on perforating stone tools based on form, function, and archaeological context, which can be used to address issues of economic, social, and technological organization.

The concept of curation, defined as the ratio of realized to maximum utility of lithic artifacts (Shott 1996; Shott and Sillitoe 2005), has interpretive benefit for understanding lithic technological organization in the past. Assessing curation requires researchers to identify the intensity of use of lithic artifacts. Toward this goal, archaeologists over the past two decades have attempted to create ways of measuring retouch and applying those measurements to archaeological collections (Andrefsky 2006; Blades 2003; Clarkson 2002; Eren et al. 2005; Kuhn 1990). There are a few baseline assumptions upon which measures of curation are built. Curation is equated on a one-to-one basis with postproduction retouch. The key characteristic of postproduction retouch is morphological modification of the artifact. By quantifying the morphological change of an artifact, researchers gain a proxy measure of curation. Additionally, the measures of morphological change should be directly related to postproduction retouch. Every event of postproduction retouch will change the morphological characteristics of the artifact, even if in minor ways. It is the job of the researcher, therefore, to identify and define which morphological characteristics are changing and then develop a system of recording those characteristics. The resulting documentation system must be quantified in a way that equates increasing curation to increasing measurement values. With these two assumptions in mind, measures of retouch are important tools for discussing lithic curation intensity and become effective for interpreting archaeological assemblages only after results of experimental studies provide empirical patterning that validates their accuracy.

In building any measure of retouch, it is important to take into account manufacturing techniques, the form and function of the artifact, and retouch techniques. Indices that attempt to measure

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curation without taking these variables into account can lead to spurious interpretations based on overstepping the boundaries of the measurements (Andrefsky 2006; Davis and Shea 1998). Many archaeologists who are interested in measuring retouch have often tried to create general indices that can be applied to artifacts with varying forms, functions, and archaeological contexts. As a result, universal measures of retouch have been critiqued when they fail to work for a certain type of tool or a certain assemblage (see Eren and Prendergast, this volume; Hiscock and Clarkson, this volume; Wilson and Andrefsky, this volume). Variability in form, function, and archaeological context should be noted by archaeologists when they are developing retouch indices, as these variations often dictate the amount and type of retouch evident on tools. Contextually specific curation indices account for morphological change in lithic artifacts based upon select formal and functional requirements of the artifacts. Among other things, morphological changes in lithic artifacts are dictated by the form of the artifact, the way in which it is used, the contact material it is used upon, the temporal and spatial archaeological setting, and the site type, raw material availability, and retouch techniques. Different tool types are more effectively measured for curation with different indices based on the shape of the tool, how it is used, how it is resharpened, the type of site where it is used, and the context of that site in the larger spatial and temporal conditions of the region. Therefore, when attempting to quantify curation in the archaeological record, we must build contextually specific indices that actually measure the morphological change of the artifacts being studied.

This study is designed to quantify the retouch intensity on el-Khiam projectile points that are found in the Pre-Pottery Neolithic A period (PPNA) (11,500–10,500 Cal. yr. BP) in the Southern Levant. Recent microwear studies performed by Sam Smith from the University of Reading suggested that these points functioned as perforators, though microwear patterns were inconclusive with regard to contact material (Smith 2005). In this study we test a variety of contact materials that may produce different wear and retouch patterns. Knowing how point morphology is affected by use and retouch technique is imperative in building measures of curation. Once attributes of macroscopic wear are defined and related to use, we develop a

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curation index to measure retouch on el-Khiam points. The new curation index, dubbed the el-Khiam curation index (EKCI), is later verified through controlled experiments and analysis of the archaeological assemblage from Dhra', Jordan.

BUILDING A CURATION INDEX: FORM, FUNCTION, AND CONTEXT

Materials and Methods

This study examines the lithic assemblage from the Pre-Pottery Neolithic A period site of Dhra' Jordan (occupied between approximately 11,500 and 11,200 cal. yr. B.P.) located in the Jordan Valley 5 km from the southeastern tip of the Dead Sea (Figure 7.1) (Finlayson et al. 2003; Goodale et al. 2002; Kuijt 1994, 2001; Kuijt and Finlayson 2001; Kuijt and Mahasneh 1995, 1998). From four field excavation seasons, over one million lithic artifacts were recovered at this early farming community, including over 800 el-Khiam points (Goodale and Smith 2001; Goodale et al. 2002). In this study, all of the complete and a nonrandom sample of the broken el-Khiam points from the 2004 field season were analyzed. These points come from numerous locations and contexts within the site and likely represent much of the variability in manufacture, use, and discard within the site.

In order to build a curation index, we first assessed the points with regard to form, function, and archaeological context. For many years, Near Eastern archaeologists assumed explicit functional attributes of stone tools based on their morphological characteristics. Due to their morphology, el-Khiam points have traditionally been classified as projectile points (e.g., Bar-Yosef and Gopher 1997). Although some el-Khiam points were undoubtedly used as projectile technology, the abundance of these points in the residential context of Dhra', Jordan, suggests that these points had an additional function. Recently, Smith (2005) has employed microwear studies to demonstrate that they were also used as perforators. Based on microwear patterns, it has been argued that these points were being used to drill beads (Goodale and Smith 2001; Smith 2005). Building on this previous research, we conducted a series of controlled experiments to test the efficiency of el-Khiam points as perforators on hard and soft contact materials

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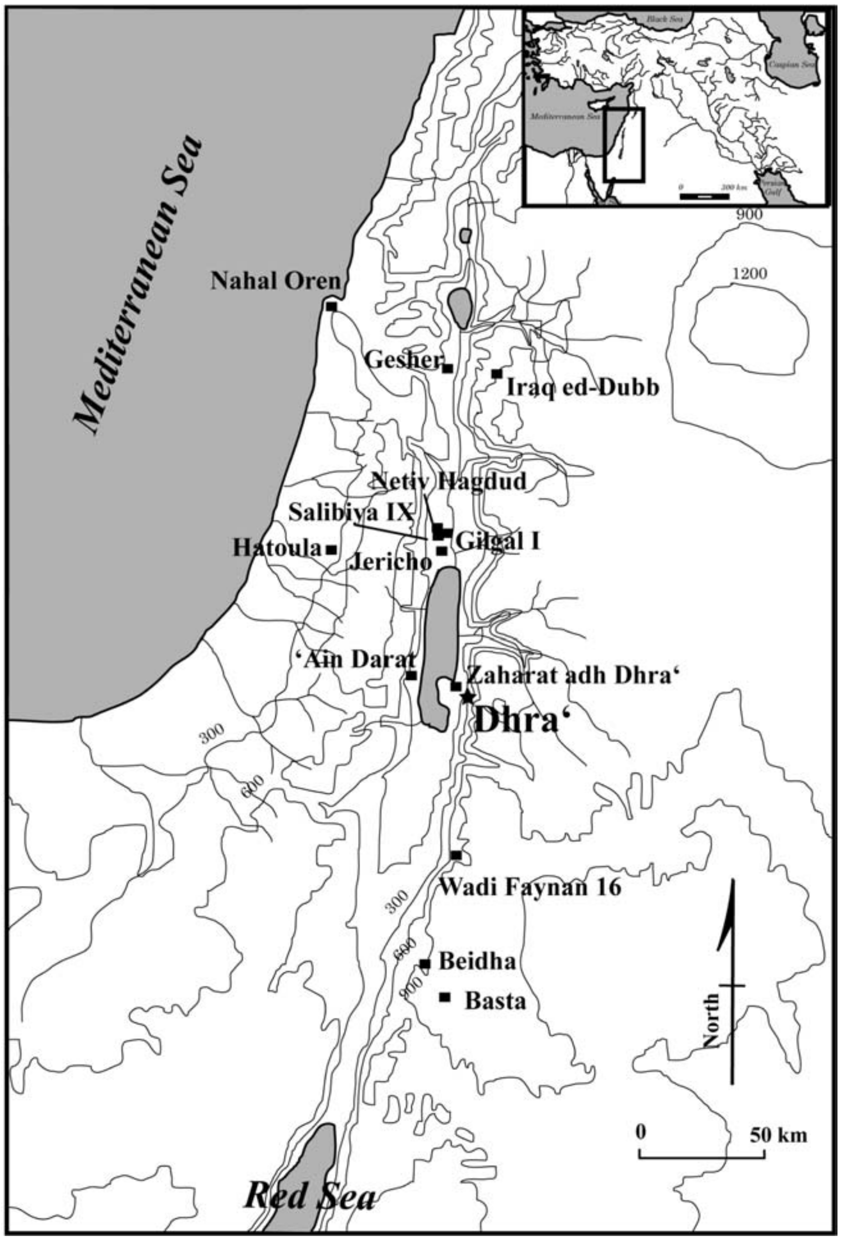

FIGURE 7.1. Location of study area.

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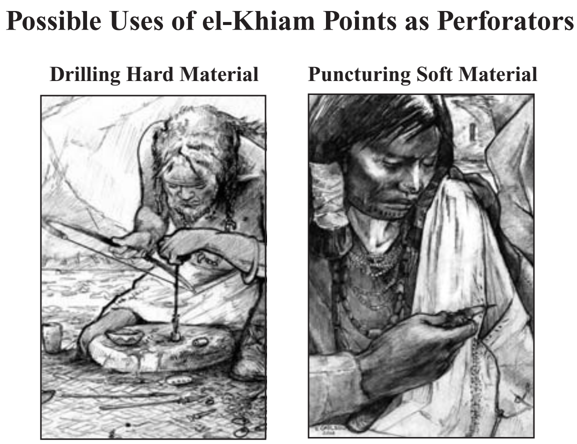

FIGURE 7.2. Illustration of possible uses of el-Khiam points.

(Figure 7.2). Our study uses four lines of macroscopic use-wear evidence, (1) a qualitative estimate of effectiveness in the task, (2) location of retouch, (3) breakage patterns, and (4) an index of point sharpness, to assess the effectiveness of el-Khiam points from Dhra' to perforate materials of various density and hardness.

The experiment began with the production of an el-Khiam point assemblage. First, blades were removed from a flint nodule using a soft hammer indentor made of antler. This nodule was taken from the same flint source, located 30 m off site, used by the prehistoric occupants of Dhra'. The blades that had a single dorsal arris, that were twice as long as they were wide, and that had margins roughly parallel to each other were selected for making el-Khiam points. An antler tine and a wooden anvil were then used to shape the blades into thirteen notched points. Finally, the el-Khiam points were hafted to shafts of willow and ocean spray wood using mastic and binding. These items replicated past technologies and binding materials available to PPNA peoples for creating a strong haft element. Twelve of the specimens were used in a drilling motion, with three points drilling each of the following materials: limestone, malachite, willow, and alder. The points were used to bore holes into the materials using both a hand drill and a bow drill. The use-life of the points ended when either the point broke or the point became useless for the task of drilling. The points were subsequently photographed and data were recorded

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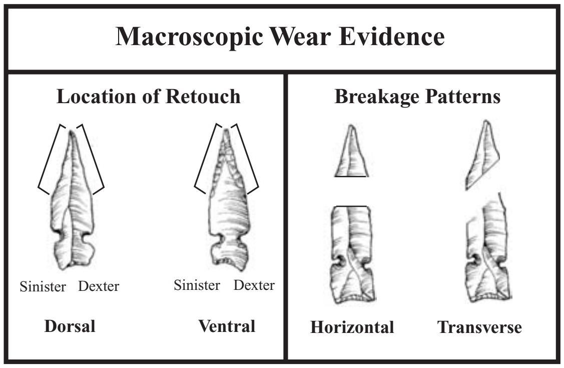

FIGURE 7.3. Location of retouch and types of breakage for el-Khiam points.

for several macroscopic use-wear attributes. The data were analyzed using several statistical techniques, as well as a new index being for measuring point sharpness.

Our first assessment of point function and contact material was a qualitative measure of drilling effectiveness. It was hypothesized that if these points were being used to perforate hard material, they would be effective at drilling through hard material such as stone. If the points did not effectively drill holes in hard materials, then this would make it unlikely that PPNA peoples used el-Khiam points to drill stone. Likewise, if the points were effective when puncturing and scraping soft materials such as animal hides, then there is a possibility that PPNA peoples were using the points for this task. Estimating the effectiveness of el-Khiam points in performing perforating tasks, although important, is somewhat of a qualitative venture. Therefore, additional quantitative measures were taken into account to compare the assemblage of experimentally produced points to a nonrandom sample of points from the archaeological assemblage at Dhra'.

The second assessment measure examines the location of retouch. Four areas on the tips were examined (dorsal dexter, dorsal sinister, ventral dexter, ventral sinister) for evidence of flake removals (Figure 7.3). Manufacturing retouch on the el-Khiam points is almost universally isolated to one surface (either dorsal or ventral) per margin. When there are flake scars on one or both of the two remaining tip locations, we assume that these flake removals were created by use rather than production. In an attempt to quantify use-related wear, we

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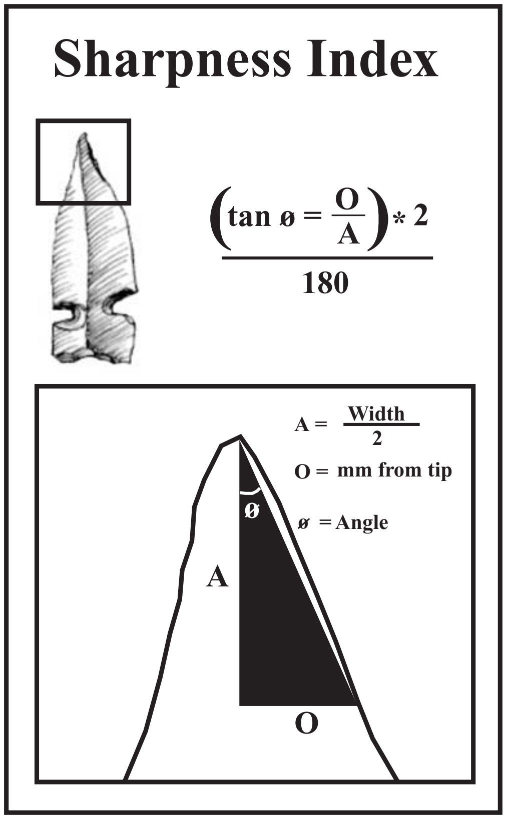

FIGURE 7.4. Calculation method for the sharpness index.

recorded the presence or absence of use-related flake removals for the experimental and archaeological collections.

Breakage patterns are also important for determining the function of the points. Variation in perforating actions, the properties of the contact material, and the application of force can cause the points to break in different ways. In this study, we look at two types of breakage patterns, horizontal and transverse (Figure 7.3), in both the experimental and archaeological collections, to see if the breakage patterns with experimental points used to perforate hard or soft materials replicate those from the archaeological collection.

The "sharpness index" (Figure 7.4) was developed in response to concerns raised by archaeologists about the accuracy of exterior edge angle measurements (cf. Andrefsky 2005) and was our fourth

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assessment measure. In order to avoid the possible pitfalls of measuring the exterior edge angle, this measure calculates the interior edge angle to determine the sharpness of a point. The interior edge angle is calculated at various locations on the points. First, intervals of 1 mm are taken from the tip of the point to 5 mm from the tip. Each millimeter, the width of the specimen is taken using a pair of digital calipers. In order to calculate the interior edge angle, the width at any given distance from the tip is divided in half. The given distance from the tip and one half of the width make up two sides of a right triangle, and using the Pythagorean Theorem, one-half of the interior angle can be calculated using this equation:

$$\tan\phi = \text{Opposite side (one half of the width)/ Adjacent side (distancefromthetip)}.$$

This angle measure is doubled in order to determine the entire interior point angle (see Andrefsky 1986 for a similar calculation for flake curvature). In order to standardize the index from a range of 0 to 1, the interior angle is divided by 180 degrees (the maximum potential angle of the tip). Points that score high on the sharpness index will have the most acute interior angles, whereas the points that score lowest on the sharpness index will have interior angles that are high, with a maximum value of 180 degrees. The expectation is that the sharper the point, the more acute the interior angle, and conversely, the duller the point, the more obtuse the interior angle. The sharpness index, combined with efficiency, retouch location, and breakage patterns, provide the basis for evaluating the contact material of perforating el-Khiam points.

Results

For drilling the different materials, the most obvious qualitative assessment was the efficiency of the points. The el-Khiam points were able to bore holes in the willow, alder, and limestone with relative ease, whereas the malachite proved to be a more formidable material, but it was still possible to bore a hole. Although the flint was able to penetrate these materials, the perforations were much wider and shallower than those perforations observed on the ground stone beads at Dhra'. The

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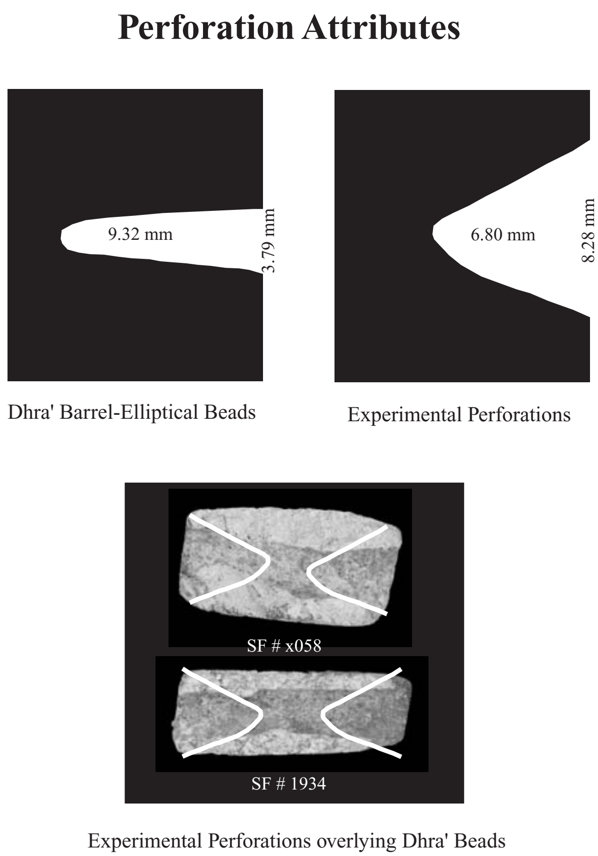

FIGURE 7.5. Schematic illustration showing results of experimental and excavated mean perforation values.

perforations on the archaeological specimens are too deep and narrow for the flint points to have been used to drill them. The most telling evidence is the ratio of perforation depth to perforation width. To explore this further, we compared these results to the width and depth of perforations in beads from Dhra'. In the archaeological sample from Dhra', barrel-elliptical beads had a depth-to-width ratio of 9.32:3.79 (mm), whereas the experimental perforations in hard material had a reversed depth-to-width ratio of 6.80:8.28 (mm) (Figure 7.5).

Our experiments showed that the points were effective tools for puncturing holes in leather pieces of varying thickness and stiffness. Additionally, the points were effective in scraping activities due to the

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Table 7.1. Retouch and breakage patterns on Dhra and experimental assemblages.

	Use-related retouch		Breakage pattern	
	Present	Absent	Transverse	Horizontal
Hard material	11	1	4	0
Soft material	1	8	0	11
Dhra' sample	3	39	5	50

relatively steep edge angle that the manufacturing retouch created. As long as the points kept a sharp tip, it was an effective tool for puncturing leather. Importantly, the scraping edge continued to be efficient throughout the use-life of the tool. Unfortunately, comparisons between experimental perforations and archaeological perforations in leather are unachievable due to limited preservation of organic materials at Dhra'.

The damage patterns on el-Khiam points used to perforate hard materials are different from those found in the archaeological collection from Dhra' (Table 7.1). Experimental work shows that the Dhra' sample tends to conform more closely with retouch patterns produced from working soft materials as opposed to hard materials. The points at Dhra' rarely have use-related flake removals, whereas the experimental hard-material perforators have a high rate of use-related flake removals (Fisher's exact $p < 0.0001$). The points that were used to puncture leather exhibited very low rates of use-related flake removal, which is not surprising due to the physical properties of the soft material. Whereas the points used to drill hard material were very different from the archaeological assemblage at Dhra', the use-related retouch on the experimental leatherworking points and the Dhra' points was similar (Fisher's exact $p = 1$). These data suggest that the use-related damage that occurred on the archaeological points was not severe enough to produce use-related retouch. In sum, the data suggest that PPNA peoples were using the points on a material that would not produce severe use-wear.

Our study of experimentally produced breakage patterns indicates that the experimental points used to perforate stone and wood were different from the points found at Dhra' (Table 7.1). All four of the points that broke during drilling hard contact material had transverse

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fractures. This is significantly different from the Dhra' assemblage, where the breakage patterns of a random sample of 55 broken points were predominantly horizontal (Fisher's exact $p = 0.0003$). Again, this evidence undermines the hypothesis that the archaeological points from Dhra' were used to perforate stone or wood. On the other hand, the breakage patterns of tools used to perforate soft materials were not significantly different from the breakage patterns in the sample from Dhra' (Fisher's exact $p = 0.5802$). Although the breakage patterns do not support the use of el-Khiam points to perforate hard materials, the data do suggest that the points could have been used for perforating soft material, such as leather. In addition to variation based on contact material, the specific action that caused the fractures played a role in the breakage patterning within the experimental assemblage. The points that were used to drill stone and wood broke transversely more often, which may be a result of their use in hand drills and bow drills. The rotational torque placed on the points caused this type of fracture. The horizontal breaks in the leather-puncturing experimental assemblage were not a result of rotation, but rather of a failure in the point while being pressed straight into the material with little lateral rotation.

Finally, the sharpness of the used tip is important for determining contact material. The wood and stone drilling points all had significantly lower sharpness index values at each 1-mm interval from the tip than the archaeological specimens (Figure 7.6a). Additionally, there is little statistical difference between the sharpness of archaeological points and the points used to perforate leather at 1 and 5 mm from the tip. As a whole, the leatherworking points are distributed along with the points from Dhra' at the high end of the sharpness index, whereas the stone drilling points are distinctly duller (Figure 7.6b). The measure of sharpness using the interior angle did show that the archaeological samples were much sharper when they were discarded than the points used to drill stone, and were as sharp as the points used as leatherworking implements. This is important, as people were probably not inclined to resharpen their points immediately prior to discarding them. The damage sustained by drilling the two types of stone and two types of wood was visibly, and quantifiably, more severe than the use damage seen on the archaeological specimens. Likewise, the damage on the leatherworking points was visibly, and quantifiably, similar to the retouch patterns on the archaeological assemblage.

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These data reveal that the el-Khiam points were not used to drill the ground stone beads or any other hard material at Dhra', and it is likely that these tools were not used to drill hard materials at other PPNA sites. The large number of points found at Dhra' (Kuijt 2001; Kuijt and Finlayson 2001) indicate that points were being used in multiple ways in addition to their possible utility as projectiles. The experimentally replicated assemblage of leatherworking el-Khiam points has produced data that are very similar to the archaeological collection in terms of retouch location (only manufacture retouch), breakage pattern (more horizontal breaks), and sharpness index (did not dull). The el-Khiam design is good for puncturing, with its sharp tip, as well as for scraping, due to the steep edge angle of the retouch. Additionally, the microwear analysis that suggested that the el-Khiam points were used as perforators noted the direction of striations (perpendicular to the edge and concentric around the tip) (Smith 2005), which could also be produced by rotating the point while perforating soft materials such as leather.

This study used controlled experiments to assess the effectiveness of el-Khiam points as perforating tools. The macroscopic wear, the efficiency of the tool in drilling, and the breakage patterns indicate that el-Khiam points were not used on hard materials such as stone and wood. The possible use of el-Khiam points as perforating implements on soft material such as leather, however, is supported by the experimental data generated in this study. All of this work on defining the function and contact material of tools is very important if archaeologists are to move past morphological classification systems and toward reconstructions of past behavior. The results of these experiments were useful in placing el-Khiam points within their functional context. The character and pattern of wear on the points conform to our expectations of tool use. Thus, it is now possible to derive and apply a measure of tool retouch that is consistent with the context of el-Khiam form and function.

MEASURING RETOUCH

Before settling on one curation index, we evaluated numerous existing measures, such as Kuhn's (1990) measure of retouch of unifacial stone tools and Clarkson's (2002) index of invasiveness for unifacial tools.

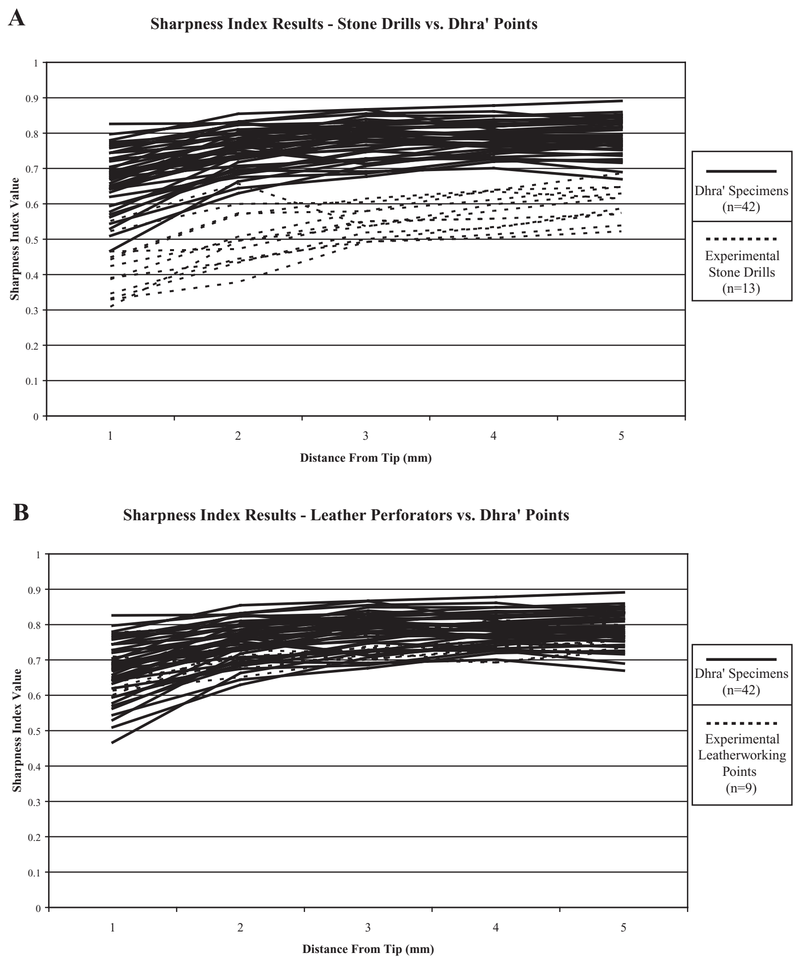

FIGURE 7.6. Sharpness index results comparing Dhra points to experimental points for drilling stone (A) and for drilling leather (B).

These indices, however, were often inaccurate due to the form, function, and context of the points at Dhra' necessitating the development of a new index to record curation of el-Khiam points. Conceptually, the el-Khiam curation index (EKCI) estimates the original size of newly manufactured el-Khiam points based on an attribute that is preserved on manufactured points. Estimating original flake size is not a new concept in lithic analyses (Dibble 1998; Dibble and Pelcin 1995; Dibble and Whittaker 1981; Pelcin 1996, 1998; Shott et al. 2000).

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Although there has been considerable debate about the accuracy of estimating original flake size (Davis and Shea 1998), most of the estimates of original flake size are based on platform characteristics, which can be difficult to measure and consistently replicate (Andrefsky 2005). The EKCI, however, utilizes blade thickness, which is preserved on the el-Khiam points even when they are heavily retouched.

The El-Khiam Curation Index

In order to estimate original blade size for the el-Khiam points, a nonrandom sample of 58 pieces of unmodified debitage from the site of Dhra', Jordan, was analyzed to test predictability of blade length based on blade thickness. We selected blades, pieces of debitage that are twice as long as they are wide, from various contexts at the site to provide a representative sample of blades in the Dhra' lithic assemblage. These blades were chosen based on specific morphological characteristics (straight dorsal ridges, minimal blade curvature, and margins and distal ends with feathered terminations) that PPNA peoples likely used to select el-Khiam point preforms. First, the thickness of the blade was taken below the bulb of force, as this is often removed during el-Khiam point manufacturing. Second, the maximum length perpendicular to the striking platform was recorded for each blade. These attributes were then plotted against each other (Figure 7.7) and the best-fit linear regression line was calculated. The regression equation is

$$\text{Estimated Length} = 11.8 \times (\text{Thickness}) + 7.4.$$

This relationship between length and thickness is strong, and as a result, we can be confident that our estimates of original blade length are fairly accurate ($F = 84.569$, d.f. $= 1$, $p < .0005$, $r^2 = .602$). Although the relationship between the estimated original blade length and the actual length of points is a statistically viable way of measuring retouch ($F = 5.552$, d.f. $= 2$, $p = .011$), the practicality of this measure is questionable. Due to the fact that el-Khiam points were hafted, as seen with their notching elements, estimates of the potential usable portion of the points must not include the length of the blade that is covered by the haft element. As a result, the original blade length estimation requires some tweaking to provide an estimate of the

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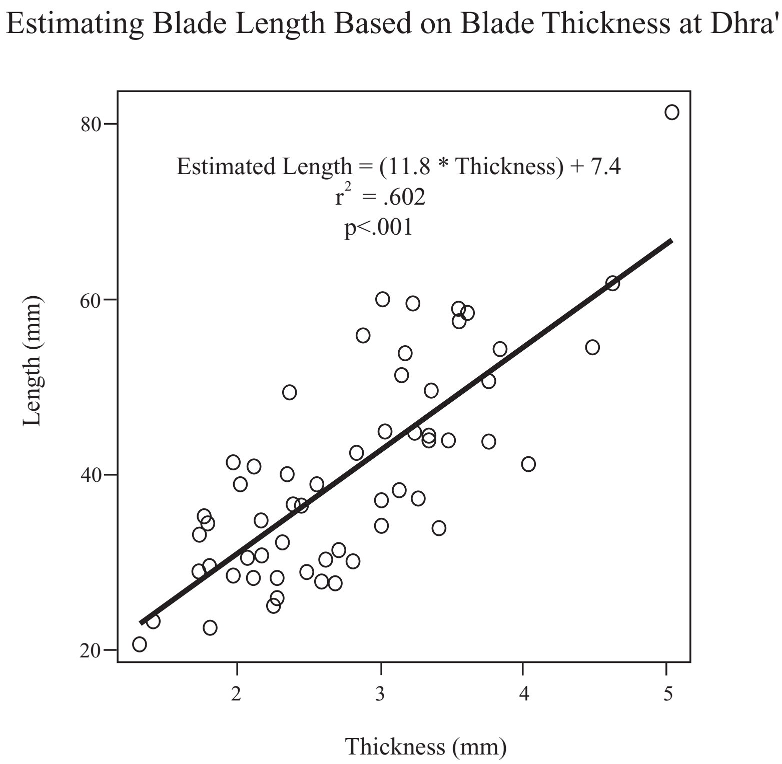

FIGURE 7.7. Regression analysis showing estimation of blade length based upon thickness values.

usable bit length.The el-Khiam curation index (EKCI) is calculated by quantifying the amount of bit that is lost through use and retouch (Figure 7.8). In this index, by subtracting the hafted portion of the blade (from the top corner of the notch to the base) from the estimated original blade length, a measure of bit length is devised:

Estimated Bit Length = Estimated Blade Length − Haft Element.

To calculate the amount of used bit length on a point, the maximum length of the point from the tip to the base is recorded (Figure 7.8a). As with the estimated bit length measurement, the haft element length (from the top corner of the notch to the base) is subtracted

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from the length of the point. The resulting number is the length of the bit that has not been removed:

Unused Bit Length = Total Length − Haft Element.

Because curation is the relationship of realized to maximum potential, the EKCI is the ratio of realized to maximum potential. To calculate this index, the unused bit length is subtracted from the estimated bit length, which is the length of the bit that has been removed by retouch (Figure 7.8b). This number is then divided by the maximum potential bit size, here represented as the estimated bit length:

EKCI = (Estimated Bit Length − Unused Bit Length)/ Estimated Bit Length.

The resulting number is the EKCI value (Figure 7.8c), ranging from a minimum amount of curation (0) to the maximum potential of the hafted el-Khiam point being realized (1). Due to possible slight errors in estimating the original blade length, some points can score in negative numbers based on this equation. In these rare cases, the value is rounded up to the lowest possible curation score of 0.

Experimental Verification of the El-Khiam Curation Index

To determine whether or not the EKCI actually quantifies retouch intensity, a number of experiments were conducted. A sample of el-Khiam points was initially manufactured and hafted to wooden handles. The EKCI for each point was measured prior to the points being used. Once these measurements were recorded, each point was used to perform a variety of leatherworking activities ranging from puncturing to scraping. Once the working edge of the points became dull or the tip of the bit snapped during use, the points were pressure-flaked to rejuvenate the edge as well as to resharpen the tip. After resharpening, the EKCI measurements were taken again. This process was repeated once more, giving a total of three EKCI measurements for each point, which accounts for two retouch events. A total of ten points were used to perform leatherworking experiments

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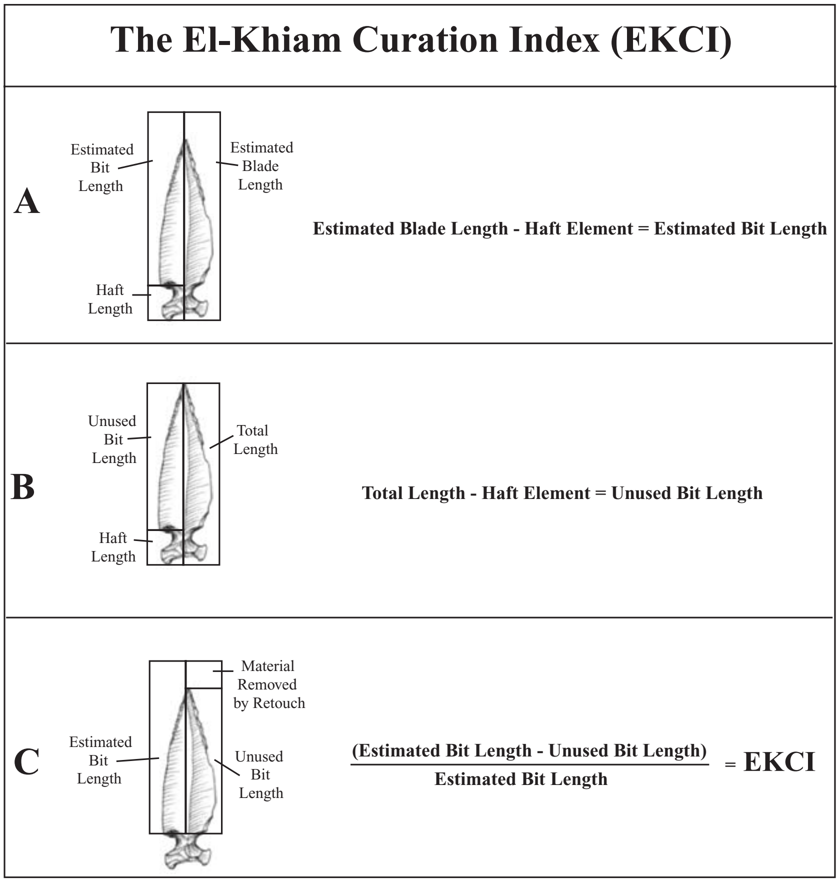

FIGURE 7.8. Schematic illustration showing method of calculating the el-Khiam index (EKCI).

in this fashion. Some of the experimental points were not resharpened as many times as others due to snapped bits that could not be rejuvenated.

The experimentally reduced assemblage had significant variation in the EKCI, with retouch values increasing with each subsequent stage of reduction ($F = 6.657$, d.f. $= 2$, $p = .005$). The EKCI value for each point increased each time it was retouched (Figure 7.9). Although none of the points have EKCI values that approach 1, this is to be expected from the nature of the measurements. For a score of 1, all of the bit must be removed, yet maintaining a tip is impossible once

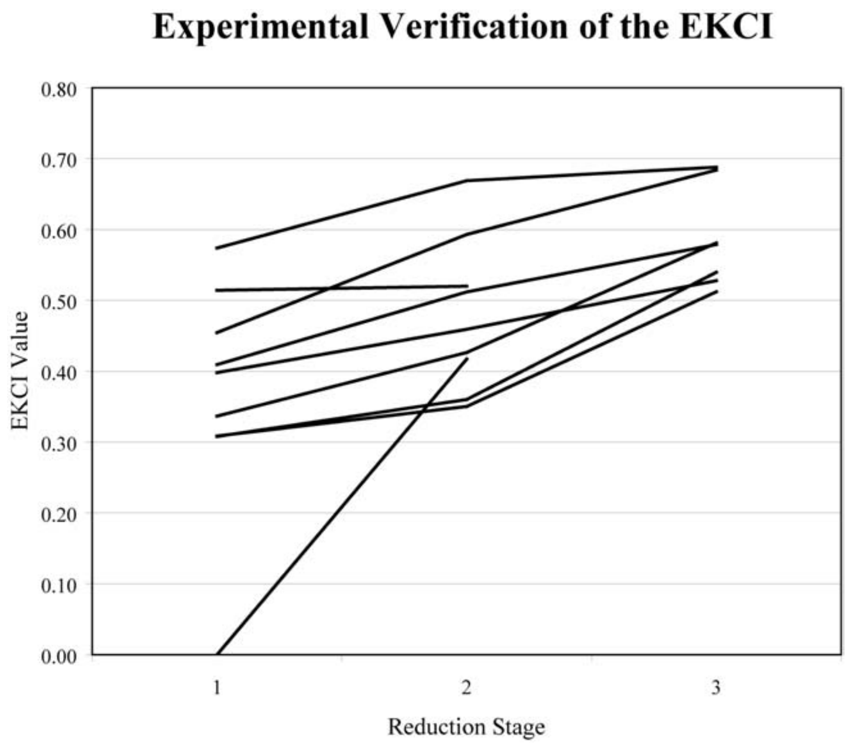

FIGURE 7.9. Experimental verification of the EKCI.

the available bit length is removed. As these data show, the EKCI is an effective measure of retouch intensity on el-Khiam points that are used for functions that produce minimal macroscopic use-wear, such as leatherworking.

RETOUCH AND THE DHRA' EL-KHIAM POINTS

A sample of el-Khaim points was taken from the 2004 excavation season at Dhra'. In all, 42 complete el-Khiam points were included in the sample. The EKCI was calculated for each of these specimens (Table 7.2). Based upon the EKCI values, the archaeological points at Dhra' were discarded at various stages of their use-life, with unfinished points scoring low on the EKCI. Other points being discarded with nearly half of the usable bit length removed did appear intensively retouched (Figure 7.10). None of the discarded el-Khiam points scored

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Table 7.2. Raw data from experimental assemblage

Lab ID	Length	Thickness	Estimated blade length	Haft length	Bit length	Estimated bit length	EKCI value
4876	36.97	1.93	30.17	13.86	23.11	16.31	0.000
4303	33.41	1.67	27.11	9.75	23.66	17.36	0.000
4458	40.40	2.28	34.30	15.01	25.39	19.29	0.000
4467	48.09	2.76	39.97	9.16	38.93	30.81	0.000
4737	37.18	2.48	36.66	8.97	28.21	27.69	0.000
4736	31.16	2.02	31.24	8.13	23.03	23.11	0.003
4829	43.53	3.07	43.63	20.98	22.55	22.65	0.004
5068	31.45	2.11	32.30	10.19	21.26	22.11	0.038
4711	25.38	1.65	26.87	6.51	18.87	20.36	0.073
4446	39.29	2.99	42.68	14.04	25.25	28.64	0.118
4332	31.02	2.29	34.42	7.97	23.05	26.45	0.129
4369	29.81	2.29	34.42	7.25	22.56	27.17	0.170
4296	22.94	1.78	28.40	5.50	17.44	22.90	0.239
4452	32.46	2.73	39.61	11.75	20.71	27.86	0.257
4974	27.93	2.39	35.60	6.57	21.36	29.03	0.264
4554	32.71	2.71	39.38	14.85	17.86	24.53	0.272
5046	29.27	2.57	37.73	7.00	22.27	30.73	0.275
4625	30.69	2.67	38.91	10.16	20.53	28.75	0.286
5167	32.25	2.85	41.03	10.49	21.76	30.54	0.287
4747	28.85	2.53	37.25	8.10	20.75	29.15	0.288
4866	24.01	2.08	31.94	5.68	18.33	26.26	0.302
4386	40.05	3.86	52.95	11.09	28.96	41.86	0.308
4996	23.36	1.98	30.76	6.80	16.56	23.96	0.309
5125	26.29	2.36	35.25	6.90	19.39	28.35	0.316
4787	24.01	2.01	31.12	10.09	13.92	21.03	0.338
5143	18.88	1.64	26.75	4.56	14.32	22.19	0.355
4650	23.13	2.20	33.36	5.89	17.24	27.47	0.372
4456	19.41	1.77	28.29	4.53	14.88	23.76	0.374
4531	23.87	2.30	34.54	6.19	17.68	28.35	0.376
4523	27.15	2.70	39.26	7.18	19.97	32.08	0.377
4565	37.93	4.11	55.90	8.48	29.45	47.42	0.379
4951	32.70	3.44	47.99	8.21	24.49	39.78	0.384
4529	23.60	2.27	34.19	6.74	16.86	27.45	0.386
4325	25.86	2.53	37.25	9.54	16.32	27.71	0.411
4392	17.72	1.61	26.40	5.65	12.07	20.75	0.418
5194	29.05	2.61	38.20	16.49	12.56	21.71	0.421
4401	30.01	3.05	43.39	11.99	18.02	31.40	0.426
4877	18.45	1.82	28.88	5.94	12.51	22.94	0.455
4992	26.02	2.68	39.02	10.91	15.11	28.11	0.463
4433	18.03	1.84	29.11	5.40	12.63	23.71	0.467
5070	26.34	2.74	39.73	11.41	14.93	28.32	0.473
5035	18.68	1.76	28.17	8.21	10.47	19.96	0.475

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over .5 on the EKCI, suggesting that the points were not retouched as much as they might have been. Because the settlement of Dhra' is located within 30 m of a large flint source, the abundance of raw materials may have allowed the people at Dhra' to discard their points with usable bits remaining. The tasks for which the points were used, as fine tools associated with leatherworking, likely necessitated a sharp and narrow tip that would have been difficult to maintain when the bit became short.

It is important to note the differences between the EKCI values for the archaeological points and the experimentally produced points. The measurements for the experimental sample averaged .36, .48, and .59 at the first, second, and third retouch stages, respectively, whereas the Dhra' assemblage averaged .27 with no values over .47. The variation of these measurements seems to be attributable to the differences in skill of the researcher when compared with the skill of the PPNA el-Khiam point manufacturers in maximizing the amount of usable bit from a given blade during the primary manufacturing stage. Although the exact values from the archaeological points cannot be used to correspond with specific reduction events from the experiments, the EKCI values do accurately differentiate points throughout their use-life at Dhra'.

DISCUSSION

Among other things, this study shows that measures of curation may not be universally applied to all tool forms. Other researchers have noted this as well (Andrefsky 2006; Clarkson 2002; Eren and Prendergast, this volume; Wilson and Andrefsky, this volume). One universal in studies of retouch intensity, however, is the fact that all measurements of curation must conform to how the tool morphology changes through use and retouch, which is guided by the artifact's form, function, and context (MacDonald, this volume).

One consequence of researchers independently developing curation indices that are context-specific is the problem of comparing artifacts or assemblages with varying contexts. One simple way of doing this is to quantify our curation indices in a standardized way. We have followed work by Kuhn (1990), Clarkson (2002), and Andrefsky (2006; this volume), among others, that quantifies curation between

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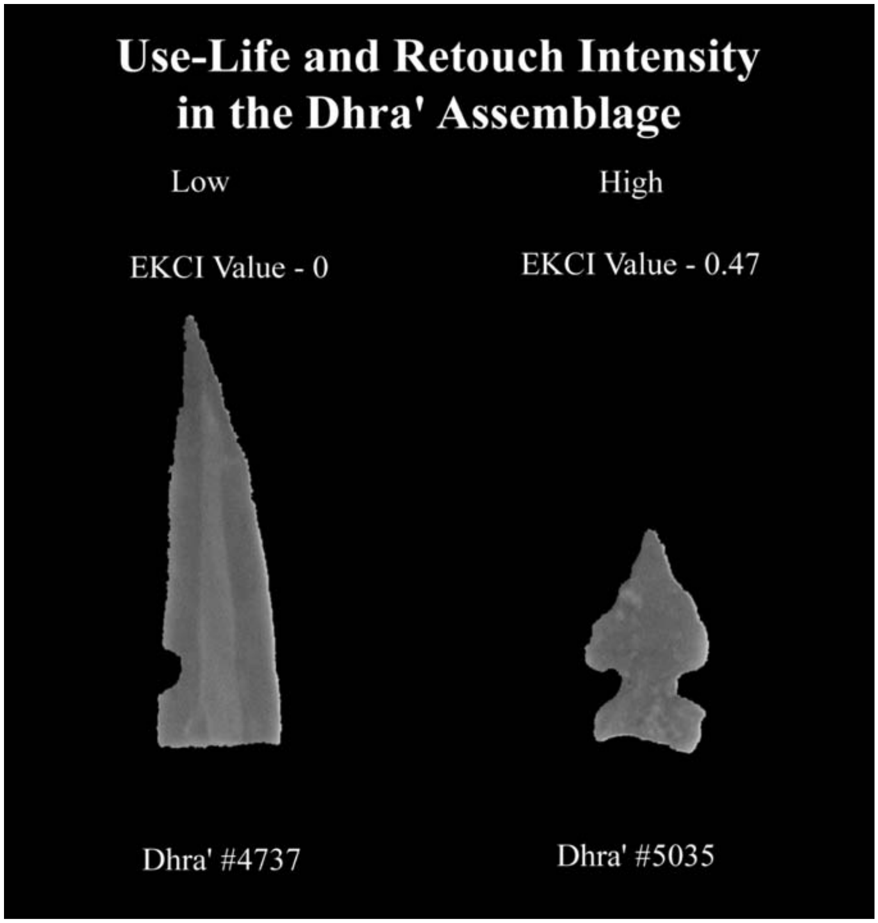

FIGURE 7.10. Examples of Dhra points with low and high EKCI values.

the values of 0 and 1. We also realize that not all indices are created equal, and there may be distributional differences in the indices that do not fit a normal bell curve from 0 to 1. In these cases it is up to the author to explain the expected range of variation in the assemblage. For example, it is impossible for the EKCI to have a value of 1, as this would mean the entire bit was removed. El-Khiam points with their entire bit removed are not considered complete points, though values of 1 are possible with other curation indices (e.g., Andrefsky 2006). If authors are explicit with the expected ranges between 0 and 1 and how they correspond with low and high retouch intensity, we

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can start to compare retouch on artifacts that have little, if anything, to do with each other in terms of form, function, or context.

Lithic analysts can compare el-Khiam points that served as perforators at PPNA sites to side scrapers at Mousterian sites to hafted bifaces that were used as knives at sites in North America. Using a common language, ranging from low to high retouch intensity, researchers can then look to other variables to explain possible similarities and differences in retouch intensity, such as raw material availability, site type, and transport costs. The important thing to remember, however, is that each of those artifact types must have retouch intensity measured and tested with an independent index that is context-specific, rather than one index being used to measure all of them. Just because measures of curation must be developed for specific forms, functions, and contexts does not mean that we cannot compare retouch intensity on artifacts that vary in any of these attributes. This is a quantitative matter of scaling different measures from low to high so that such measures are comparable across different tool forms and different indices.

CONCLUSIONS

Based on the form, function, and archaeological context, we were able to devise a measure of retouch intensity, the EKCI, that provides a tool for researchers working in the Near East on PPNA assemblages. In order to better understand the function of el-Khiam points, controlled experiments were performed to determine relative density of the contact material, which could affect use and retouch patterns. It was shown that el-Khiam points were likely used to pierce and scrape soft materials such as leather. The EKCI was then devised, measured, and tested. Experimental replication showed that the EKCI was an accurate measure of retouch intensity, and application of the EKCI to the lithic assemblage at Dhra' reaffirmed the EKCI's utility for analyzing PPNA archaeological assemblages. This study has introduced a baseline technique with which future work can be compared using a standardized retouch intensity measurement. Although this curation index is effective for el-Khiam points, it may not be applicable to other hafted point types, which highlights the need for independently developed measures of retouch that accounts for form, function, and context of the artifacts rather than attempting to generate universal measures of curation.

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