ARCTIC
VOL. 76, NO. 4 (DECEMBER 2023) P. 445–463
https://doi.org/10.14430/arctic79001

Unstitching the Past: An Experimental and Microwear Investigation of Dorset (Paleo-Inuit) Needles from the Foxe Basin Region

Matilda Siebrecht,[1] Annelou van Gijn,[2] Susan Lofthouse,[3] Elsa Cencig [3] and Kathryn Kotar[4]

(*Received 2 February 2023; accepted in revised form 4 October 2023*)

ABSTRACT. For Paleo-Inuit cultures, needles are arguably one of the most important artefact types, as they were used to create warm, waterproof clothing that is essential for survival in Arctic environments. This, in combination with the prevalence of needles within archaeological collections, has prompted many researchers to the topic of Paleo-Inuit needles. However, the majority of their studies have approached the material using traditional, typological methodology. A pilot study conducted by Siebrecht et al. (2021) demonstrated that, while needles from several Dorset Paleo-Inuit culture (c. 800–1300 AD) sites in the Foxe Basin region were previously considered as typologically identical, microwear analysis highlighted variation in how they would have been made and used over time and across sites. The pilot study also noted variation, across sites, in certain typological attributes, such as needle eye shape, distal end shape, and cross-section shape. The present study aims to expand on these discoveries by considering possible reasons for variability in the attribute of needle cross-section shape. Methodologically, we use microwear analysis, experimental archaeology, and ethnographic collaboration. With this approach, we were able to explore Dorset needle making and sewing practices in more detail than has been possible in prvevious, purely typology-focused studies. Our results showed no observable pattern between cross-section shape and the material being sewn but may reveal links between needle size and the material being sewn, a correlation in different polish types and the duration of needle use, as well as insights into the possible sewing techniques used by Dorset groups. Our study thus offers a fresh perspective on this topic and points to new directions for this area of Arctic archaeological research.

Keywords: Dorset Paleo-Inuit; microwear analysis; experimental archaeology; needles; organic material culture; ethnographic collaboration

RÉSUMÉ. Chez les cultures paléo-inuites, les aiguilles sont vraisemblablement les types d'artefacts les plus importants parce qu'elles servaient à créer des vêtements chauds et imperméables, essentiels à la survie dans les milieux arctiques. Ceci, allié à la prévalence des aiguilles faisant partie des collections archéologiques, a incité de nombreux chercheurs à se pencher sur le sujet des aiguilles paléo-inuites. Toutefois, la plupart des études ont abordé le matériel au moyen d'une méthodologie typologique traditionnelle. Une étude pilote réalisée par Siebrecht et al. (2021) a permis de démontrer que même si les aiguilles de plusieurs sites de la culture paléo-inuite Dorset (vers 800 à 1300 A.D.) se trouvant dans la région du bassin Foxe étaient antérieurement considérées comme typologiquement identiques, l'analyse des micro-usures a permis de détecter des variations dans la façon dont elles auraient été fabriquées et utilisées au fil du temps et des sites. L'étude pilote a également permis de détecter une variation, dans les sites, de certains attributs typologiques, comme la forme du chas de l'aiguille, la forme de l'extrémité distale et la forme de la coupe transversale. La présente étude vise à approfondir ces découvertes en considérant les raisons possibles derrière la variabilité de l'attribut de la forme de la coupe transversale des aiguilles. Sur le plan méthodologique, nous recourons à l'analyse des micro-usures, à l'archéologie expérimentale et à la collaboration ethnographique. Cela nous a permis d'explorer la fabrication des aiguilles et les méthodes de couture de la culture Dorset plus en détail que ce qu'il était possible de faire dans le cadre d'études antérieures purement axées sur la typologie. Nos résultats n'ont pas permis de déceler de tendance observable entre la forme de la coupe transversale et le matériau cousu, mais ils pourraient révéler des liens entre la taille de l'aiguille et le matériau cousu, une corrélation entre les divers types de polis et la durée de l'utilisation des aiguilles de même qu'un aperçu des techniques de couture susceptibles d'avoir été utilisées par les groupes de la culture Dorset. Cette étude offre une nouvelle perspective qui façonnera les approches futures en matière d'interprétation de la recherche archéologique dans ce domaine.

Mots-clés : paléo-inuit Dorset; analyse des micro-usures; archéologie expérimentale; aiguilles; culture matérielle organique; collaboration ethnographique

Traduit pour la revue *Arctic* par Nicole Giguère.

[1] Corresponding author: Arctic Centre/Groningen Institute of Archaeology, University of Groningen Aweg 30, 9718 CW Groningen, The Netherlands; matilda.siebrecht@gmail.com
[2] Faculty of Archaeology, Leiden University, Einsteinweg 2, 2333 CC, Leiden, The Netherlands
[3] Avataq Cultural Institute, 4150 Saint-Catherine Street West, Westmount, Quebec H3Z 2Y5, Canada
[4] Department of Anthropology, McGill University, 3460 McTavish Street, Montreal, Quebec H3A 0E6, Canada

INTRODUCTION

Needles are a frequent find throughout the Dorset cultural time frame (c. 800 – 1300 AD). Our previous study (Siebrecht et al., 2021) of needles from different Dorset sites in the Foxe Basin revealed that, while these needles were typologically identical across the sites, we could observe variations through time and space in certain macro- and microscopic elements. For example, we observed differences in the cross-section and proximal end shapes of the needles, and our microscopic analysis of the manufacturing and use-wear traces revealed variations in polish types. The present paper aims to expand on this discovery and suggest possible explanations for this variability by means of a combined approach of experimental archaeology, microscopic analysis, and collaboration with craftspeople from local Inuit communities.

Archaeologists who want to understand what lies behind morphological variation within one typological category, generally work from the assumption that these variations relate to technological choices made during the manufacturing process (Lemonnier, 1993). These choices may result from practical constraints posed by the raw material or the tools at the creator's disposal; from variations in individual *chaînes opératoires* (operational sequences) during the manufacturing process; or from the function envisaged for the completed object (LeMoine, 1994). It is this final perspective that we wish to explore further in the present paper. In modern sewing technology, users select needles of different shapes and sizes for use on different materials or for employing different techniques. Consequently, the choices relating to the shape and size of a needle during manufacture are often dictated by the material that it will be used on once completed (Knight, 2012). Such specialised needle styles may also have been required for particular sewing tasks in past Paleo-Inuit sewing traditions. In order to investigate this hypothesis, we must first explore, based on the archaeological collections, which materials were being sewn by which needles in the archaeological collections.

Experiments conducted by researchers such as Maigrot (2005), LeMoine (1994), Buc (2011), and Van Gijn (2006; 2007) have shown that variations in use-wear, such as striation depth and thickness, and brightness and linkage of polish, can be directly linked to the materials on which bone tools were used. For example, Maigrot (2005) demonstrated that tools made from different raw materials had been used in different technological practices: ivory tools were used for woodworking, antler tools for agricultural processes, and bone tools for domestic activities. LeMoine (1994) showed that differences could be observed in the use-wear traces created on needles used to sew fresh versus dried hides and hides with hair versus without. In this paper we use the terms "hide" and "skin" interchangeably. Similar experiments conducted by Buc (2011) revealed differences in the polish attributes created on piercing tools used on skins versus plant rushes. Additionally, experimental research and microwear analysis conducted at the Leiden University Laboratory for Artefact Studies in the Netherlands has demonstrated that bone tools used on different material types exhibit different patterns of use-wear traces (Van Gijn, 2006, 2007). Based on these and other related research projects (cf. Olsen, 1988; D'errico, 1993; Gates St-Pierre, 2007; Bradfield, 2015), it is widely accepted that different contact materials can be interpreted based on the use-wear traces they leave behind. For example, materials such as leather, wool, and other forms of textiles create traces on the surfaces of the needles used to sew them. To expand on existing research, we aim to explore how further experimentation focusing on the unique combination of materials from Arctic contexts could allow a more detailed investigation of these traces, specifically in relation to specialised Paleo-Inuit sewing practices. Therefore, we ask: how can methods commonly employed in the analysis of osseous materials (specifically, microwear analysis and experimental archaeology) contribute fresh insights into the specific material and cultural contexts of Paleo-Inuit sewing practices?

In the current understanding of sewing practices in Dorset culture, skins of hunted animals were the primary sewing materials, including terrestrial species, such as fox (*Vulpes lagopus*) and caribou (*Rangifer tarandus*), and maritime species, such as seal (*Phoca vitulina* and *Erignathus barbatus*). There are several differences in properties between terrestrial versus maritime species hides linked to adaptations to the immediate environment, such as increased oiliness to assist with movement through water, or a fluffy underlayer to assist with body warmth on land. These differences could arguably create varying use-wear traces on sewing needles. We know from ethnographic records and present-day practices that Inuit people have always considered the properties of hides in their decisions around what purposes they intend the finished products to serve. For example, seamstresses use seal skin waterproof clothing, whereas they favour caribou skins for its warmth and insulation (Issenman, 1997; Meeks and Cartwright, 2005; Osborn, 2014). If we therefore assume that Dorset clothing makers made choices about which material to sew based on the properties of the different skins, we can go one step further and suggest that the tools used to sew the skins were also made in light of these properties. For example, the tool makers may have considered certain needle shapes or sizes more efficient or appropriate depending on the species of the skin being sewn. Similar reasons for tool choice could be linked to the way the skin was prepared (for example, with or without fur) or to the thickness of the final scraped skin. Thus, choices made during the manufacture of the needles in these cases would be a direct result of practical restrictions or limitations of the materials they were used on.

Our aim in the present study was to investigate whether it is possible to see any correlation between the morphological characteristics of Dorset needles and the material on which they were used, and what this can tell us about Dorset needle making and sewing practices. To this end, we first had to determine whether different materials (in this case skins from maritime versus terrestrial Arctic species) create observably different use-wear traces on the needles used to sew them. We therefore used experimental archaeology to sew a variety of skin types using replica needles, which we then examined through use-wear analysis. We then compared the resulting observable traces with traces identified on needles from the archaeological collections. This framework allowed us to answer the following research questions:

- Is it possible to differentiate between needles used to sew skins from maritime versus terrestrial mammals based on experimentally created use-wear traces?
- Are there any observable patterns in the archaeological Dorset (Early – Late) collections linking comparable use-wear traces with certain needle shapes and sizes, or with any other factors?
- What can the presence of such patterns, in combination with the traditional knowledge and experience of Inuit seamstresses, tell us about Dorset needle making and sewing practices?

METHODS AND MATERIALS

The methodological framework for the present study is divided into three parts:

- microwear analysis of a collection of replica needles used for sewing experiments.
- comparison of the results of this analysis with microscopic analyses of needles from archaeological collections of artefacts originating in the Foxe Basin region.
- a discussion of the results of these analyses as part of a sewing workshop conducted in the northern Foxe Basin with experienced Inuit seamstresses.

We undertook all microscopic analyses using two levels of magnification. We used a low power AM7115MZT Dinolite microscope (10 – 120x magnification) to observe morphological characteristics of all the needles, such as cross-section shape and the level of rounding visible in the perforation. For identification of use-wear traces on archaeological objects, we used a high power Olympus BX51 metallographic microscope (100 – 1000x magnification) with a SC50 camera attachment, while, for use-wear analysis of the experimental objects, we used a high power Leica DM 1750 M metallographic microscope (100 – 1000x magnification) with a Leica MC120 HD camera attachment. Our use of two different high power microscopes related to the location of our analyses: the Olympus is a portable microscope we used while travelling to view the different archaeological collections, while the Leica is situated in the Leiden University Laboratory for Artefact Studies, and we therefore used it for the experimental portion of the research project. To more accurately identify the formation of use-wear traces, we analysed and photographed all of the experimental needles both before and after use.

Experimental Analysis

In order to ascertain the possibility of differentiating between needles used to sew maritime versus terrestrial skin types, we used experimental archaeology combined with use-wear analysis to investigate different patterns in use-wear traces created on the surface of a collection of experimental needles. We created needles using Dorset-style tools made from flint sourced from France and the Netherlands. We used replica burins, based on examples from a range of Dorset sites (cf. Stenton and Park, 1998; Desrosiers and Sørensen, 2016), to create grooves in the bone surface, which could then be snapped completely to create a needle preform (the initial, unfinished shape of the needle) and to perforate the needle eye. We then used replica scrapers, based on examples from a range of Dorset sites (cf. Stenton and Park, 1998; Desrosiers and Sørensen, 2016), to further scrape the preform down to the finished shape and size. These needle-making techniques have been well documented in both archaeological and ethnographic studies (cf. Gelvin-Reymiller and Reuther, 2010; Sloan, 2014; Monchot et al., 2016). Although we attempted to create a relatively standardised set of needles in terms of form, the final collection included some variation. We did not create any particular cross-section shape for this stage of the project, as the central focus of the experiments for which these replicas were used was to provide a reference for the use-wear created on the surface.

We manufactured the needles from a range of materials found in Arctic contexts: seal bone (*Phoca vitulina*), caribou bone (*Rangifer tarandus*), bird bone from both Snow Goose (*Anser caerulescens*) and Common Eider (*Somateria mollissima*), caribou antler, and walrus ivory (*Odobenus rosmarus*). None of the osseous materials were pre-processed (for example, through boiling or soaking) before being made into needles. Apart from the seal bones, which came from Wadden Sea region (The Netherlands), we sourced all raw bones and ivory from the Foxe Basin region (Canada). We sourced the caribou antler from the northern USA (a more specific provenance is unknown); it came from one sample that had been in storage for several years. Although the antler appeared untreated, it is important to note here that results relating to the replica needles from this particular material may have been influenced by the specific sample, rather than by antler as a material in general. The skins we used the experimental needles on are also native to Arctic contexts or from comparable species: seal skin (both untanned, with and without fur, and tanned, with and without fur), caribou skin (both untanned with and without fur, and tanned without fur), and fox skin (tanned with fur) (*Vulpes lagopus*). We sourced all seal and caribou skins from the Foxe Basin region, and the fox skin from the Netherlands.

A group of participants with a range of sewing experience used the experimental needles for varying amounts of time. They defined the time of use and their experience level based on their own perceptions (see Table 1 for times and experience levels associated with all experimental needles). Because of travel restrictions imposed during the pandemic, it was impossible to interact directly with Inuit seamstresses during the early stages of the project. Consequently, participants in this first stage of experimentation were non-Inuit. Participants did not use awls during the sewing experiments. Ethnographic accounts of historic Inuit sewing practices describe people using bodkins or awls to pierce an initial hole in the materials being sewn (cf. Balikci, 1970). However, whether or not Dorset groups used awls is still a matter of some debate. When analysing objects from the Dorset sites included in this paper that had been labelled as awls based on their shape and size (or could possibly be interpreted as such), we found that these objects did not demonstrate any use-wear associated with initial piercing. Through use, traces such as circumferential or parallel striations (meaning striations running circumferentially around or parallel to the length of the awl) are usually created on the pointed tips of the awls, while traces of handling polish would appear towards the non-pointed ends. We identified none of these traces on the awls in the assemblages we analysed. Investigation of a wider range of sites is required to explore this topic further. But, based on the absence of archaeological evidence for the use of awls in the assemblages relevant to this study, we decided not to use them for the experimental stage of the project.

In addition to monitoring the more quantifiable data of stitch type, sewing time, and breakage points on any broken needles, we also encouraged participants in the sewing experiments to document their experience in terms of ease of sewing, particular sewing style used, and any other information they felt was pertinent to the study. The raw, experimental data from these experimental observations are freely available from the internal database at the Leiden University Laboratory for Artefact Studies. Stitch types adhered to those documented in ethnographic accounts and archaeological studies, in particular overcast stitching and running stitches (Balikci, 1970; Oakes, 1988; Ewing and Darwent, 2018). Several of the participants used a makeshift thimble while sewing, created from a piece of skin, as described in several ethnographic accounts (Lyon, 1824; Balikci, 1970). Wherever possible, to avoid contamination of use-wear results from contact with multiple skin types, participants made this thimble from the same material as that being sewn. However, three needles were also used

TABLE 1. Overview of the primary quantitative results of the sewing experiments plus sewing experience level.

Number	Material of needle	Material used on (skin type)	Duration (minutes)	Polish type	Sewing experience
4055	cow bone	tanned seal without fur	33	None	none
4056	cow bone	tanned caribou without fur	41.3	A1	high
4057	cow bone	tanned seal with fur	60	A1	none
4058	seal bone	used on multiple skin types	10	A1	high
4059	seal bone	tanned caribou without fur	2.3	None	high
4060	seal bone	untanned caribou without fur	125	A1	intermediate
4061	seal bone	tanned seal without fur	60	None/A1	low
4062	seal bone	untanned seal with fur	195	None/A1	low
4063	seal bone	untanned seal with fur	59	A1	none
4064	goose bone	tanned caribou without fur	27	A1/A2	high
4065	goose bone	untanned caribou without fur	15	A1	low
4066	goose bone	untanned seal with fur	170	A2	low
4067	goose bone	tanned seal with fur	25	None / A1	none
4068	goose bone	tanned fox with fur	240	A2	high
4069	goose bone	untanned seal with fur	1	None	low
4070	duck bone	untanned seal without fur	38	A1	intermediate
4071	duck bone	untanned caribou with fur	140	A2	intermediate
4072	duck bone	untanned seal with fur	80	A2	intermediate
4073	duck bone	untanned caribou without fur	45	A1	intermediate
4074	duck bone	tanned caribou without fur	40	A2	high
4075	duck bone	tanned caribou without fur	60	A1 / A2	low
4077	duck beak	tanned seal with fur	2	None	intermediate
4078	duck beak	tanned seal with fur	5	None	intermediate
4079	caribou antler	untanned seal with fur	80	A1	low / intermediate
4080	duck bone (rib)	tanned fox with fur	10	None	low
4081	duck bone (rib)	tanned fox with fur	2	None	high
4082	duck bone (rib)	tanned caribou without fur	1.5	None	high
4085	caribou bone	tanned seal without fur	210	A1	low
4086	caribou bone	tanned caribou without fur	255	A2 / B	intermediate
4087	caribou bone	used on multiple skin types	140	A2	low and high
4088	walrus ivory	untanned seal without fur	60	A1	intermediate
4089	walrus ivory	untanned seal with fur	210	A2	intermediate
4090	walrus ivory	tanned caribou without fur	7	None	high
4091	walrus ivory	untanned caribou with fur	65	A1	intermediate
4093	walrus ivory	untanned caribou without fur	240	A2	intermediate
4094	walrus ivory	tanned seal without fur	30	None	high

FIG. 1. Map of the Foxe Basin region showing the archaeological sites used in the present study.

on multiple skin types in order to compare the use-wear traces created against needles used only on one skin type. To obtain as authentic a collection of experimental results as possible, we encouraged participants to re-sharpen and rework their needles as they progressed using the replica flint tools described above, and making sure to record any of these needle adaptations in their experimental observations.

Archaeological Comparison

Following these experiments and building on the preliminary analysis already undertaken in Siebrecht et al. (2021), we conducted a detailed analysis of needle collections from four Dorset sites in the Foxe Basin region of Arctic Canada, considering both the morphological characteristics and use-wear traces observed on the objects. These four sites are the Needle Point complex (NgFv-6, -7, -8, -9) on Rowley Island (Salliq), Kapuivik (NjHa-1) on Jens Munk Island (Kapuiviit), Qulliapik (JlGu-3) on Mansel Island (Pujjanaq), and Avvajja (NiHg-1) (Fig. 1).

The collections chosen from each site span a range of time periods within the greater Dorset cultural period (Table 2). It should be mentioned here that in this paper we use the term "Dorset" to refer to the later Paleo-Inuit cultures living across central Arctic Canada and Greenland between c. 800 BC – 1300 AD (Friesen and Mason, 2016; Ryan, 2016). The term "Tuniit" is often applied to this

TABLE 2. Number of needles analysed from each time period and site collection.

Site Name	Early – Middle Dorset (800 BC – 800 AD)	Late Dorset (800 – 1300 AD)
Needle Point		17
Kapuivik	27	
Qulliapik		22
Avvajja		80

culture. These two terms have very different histories of use, with Dorset being an archaeological term, and thus intrinsically linked with the colonial context of early European contact with Arctic populations, while Tuniit originates in Inuit oral histories (Martin, 2009). However, some debate still exists as to whether the two can be used interchangeably, as some researchers doubt whether Tuniit applies to the entire Dorset cultural range or only to the Late Dorset people who lived from ca. 800 – 1300 AD (Appelt et al., 2016; Friesen, 2022). To avoid confusion, we have decided to use the commonly employed archaeological cultural definition of Dorset to refer to the complete timespan of Dorset cultures.

The Kapuivik material we chose (excavated by Kotar as part of a field crew led by James M. Savelle in 2016) dates to the Early and Middle Dorset periods, and the Needle Point, Qulliapik, and Avvajja material (excavated by Lofthouse in 2004 and 2005, Cencig in 2017, and Graham Rowley in 1950, respectively) dates to the Late Dorset periods. Our pilot study (Siebrecht et al., 2021) demonstrated that the majority of the variations observed in the morphological and microscopic traces of the needles mainly correlated with a regional variance, while only some differences could be linked to time period. We therefore believe that including collections from different sub-periods within the wider Dorset cultural time frame has a minimal effect, if any, on the results of the present study.

Morphological aspects of the archaeological needle collections that we considered in the present study included needle size and cross-section shapes. When considering size, we decided not the measure the length of the needles, as most of the objects were broken, and comparison of length would not have provided any valid results. Consequently, we limited size measurements to needle width and thickness (Fig. 2). We always took these measurements at the widest/thickest part of the needle, and only from fragments that were complete enough to identify where this section of the needle would have been (i.e., we excluded from the data set pieces that were just the very end of the pointed tip). We used the observations of cross-section needle shapes that we had undertaken in the preliminary analysis from the pilot study (Siebrecht et al., 2021); these shapes included oval, quadrangular, hexagonal, lens-shaped, and diamond-shaped (Fig. 2).

In terms of use-wear, we focused on identifying the presence and directionality of striations and examining polish attributes. We determined which use-wear identifications were relevant for the study through

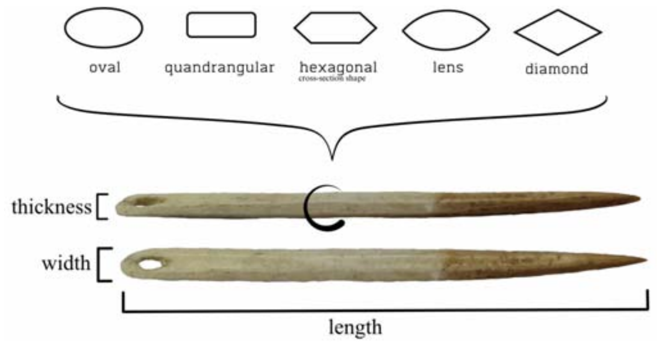

FIG. 2. Morphological aspects observed on each needle: size and cross-section shapes.

comparisons with existing literature on similar use-wear studies (cf. Olsen, 1988; D'errico, 1993; LeMoine, 1994; Maigrot, 2005; Van Gijn, 2006, 2007; Gates St-Pierre, 2007; Buc, 2011; Bradfield, 2015). We then created our own categorisations based on the traces observed in the archaeological collections listed above. Our choice to create our own descriptive categories was because of the unfortunate lack of any universal published standard of microwear traces. Several studies have tried to standardise the identification of use-wear traces and quantify the results of microwear analysis, which traditionally, has been very much focused on qualitative identification (cf. Grace, 1989; González-Urquijo and Ibánez-Estévez, 2003; Evans et al., 2014). However, the subjective nature of the analytical approach, combined with the wide range of variables that differ between each study (e.g., material type, cultural context, and material preservation) means that it is nearly impossible to achieve a standardised categorisation of all use-wear traces (Van Gijn, 2014a). Our definitions and terminology are associated with those used at the Leiden University Laboratory for Artefact Analysis (for examples, see Siebrecht et al., 2021; Aleo et al., 2023).

By "striations," we refer to the microscopic scratches created during the use of an object, which can be distinguished at higher levels of magnification from grooves created during manufacture. Striations can offer hints about the way in which an object was used, for example, the direction in which the object was moved against a material. In the case of needles, this directionality is generally either evident in the form of parallel striations (running parallel to the length of the needle) or circumferential striations (running perpendicular to the length of the needle). By "polish attributes," we refer to traces created after (relatively) prolonged contact with an external material, which is generally referred to as polish due to its visual similarity to the polish created on, for example, statues that have been rubbed multiple times in one location. Polish identification varies considerably depending on the object material and contact material. As such, for the present study, we have identified specific types. Our main categorisations include bright versus matte polish, which relates to the level of light reflection on the surface, and rough versus smooth polish, which relates to the observed texture of the polish. We also consider the level of linkage of the polish, which refers to the level of connectivity between different patches of polish. We define these levels through a relative qualitative assessment of low, medium, and high. These categories are based on identification employed at the Leiden University Laboratory for Artefact Studies.

The majority of the site collections we drew from did not undergo significant post-excavation treatment that would affect the identification of use-wear traces. However, several of the objects from the Avvajja collection excavated by Graham Rowley in 1950 had some kind of preservative added to the surface, which obscured any relevant use-wear traces. The exact material used as an additive is undocumented, and we did not attempt to remove it for the present analysis in order to avoid further contamination of the use-wear through any additional rubbing actions on the needle surface. If we considered the additive too thick to allow for a valid interpretation of use-wear, we classified observations for that object as "not identifiable." The issue of post-excavation treatment is an important point to consider in any microwear study. However, it is generally clear if certain traces have been more recently added to an object, so any objects showing evidence of contamination can be removed from the analysis, as we did for the present study.

One of the most important variables we monitored during the experimental stage of the analysis was the duration of use of each needle, which we also wished to investigate during the archaeological analysis. As we obviously do not know the duration of use for the archaeological needles, we instead used categories of relative distinctions based on the level of rounding observed in the eye of the needle (Fig. 3). We determined our classifications of low, medium, and high levels of rounding based on visual comparisons. Those archaeological objects with the least level of rounding were deemed to have low levels, those with the most rounding have high levels, and objects at the mid-point along the relative visual scale between the two have medium levels. These definitions are naturally subjective, as they are based on our intuitive observations of the objects and our experience of the effect of use on similar objects from comparative reference collections (cf. Van Gijn, 2006, 2014a). We worked on the assumption that objects with a higher level of wear and rounding in the needle eye were likely used for the longest time. Experiments from other studies have demonstrated that extended use of bone tools creates a more rounded surface, in the same way that, for example, beads worn for a longer period of time are significantly more rounded within and around the perforation, also often making the perforation or hole bigger as a result (for further details, see Van Gijn, 2006, 2014b). In light of these observations, we compared the level of rounding (and thus, the assumed duration of use) with the type of polish identified on the majority of the needle surface to investigate whether there are any links between the polish type and duration of needle use.

FIG. 3. Examples from the archaeological collections showing the different levels of rounding classified in the present study.

Several needles from the Avvajja collection had their catalogue number attached to the object with string tied through the eye of the needle. According to the curator, this string was likely added very soon after their original excavation in 1950. We therefore did not document the level of rounding for objects on which the string obscured too much of the needle eye and instead classified them as unidentifiable. However, because, in the majority of the objects, a range of rounding levels was still visible, we decided that the relative categories of low, medium, or high rounding remained valid and applicable to the present analysis.

Arctic Sewing Workshops

Discussing sewing technology in collaboration with modern Inuit populations is an important way to gain a greater understanding of how needles may have been used in the past. For this reason, the first author conducted sewing workshops with three experienced Inuit seamstresses in Igloolik, a town located in the northern Foxe Basin. The aim of this workshop was to gain insights from traditional knowledge holders who still sew skins from Arctic species on a regular basis about the different possibilities associated with needle shape and size in relation to materials being sewn. We created a new set of experimental needles for the seamstresses made from caribou bone and walrus ivory. In order to ensure that the needles accurately represented the size and different cross-section shapes of the archaeological objects, we used modern metal tools to make the needles. We did not conduct any use-wear analysis on these objects; they were intended to serve as a topic of discussion among the seamstresses on the characteristics of the needles, how they performed on the various materials, and how they compared to modern and ancient needles.

Preliminary Observations

Certain observations were immediately apparent during early stages of the analysis that may affect the interpretation of our results. These merit elucidation. First, although there was some visible variation in the size and shape of the archaeological needles (as demonstrated in Fig. 4), the average size of these objects was significantly smaller than the experimental sets of replica needles (i.e., the set(s) used in our use-wear analyses and those used in the Igloolik workshops).

As the first stage of experimental analysis was intended to create use-wear, we did not consider it necessary to replicate the exact shape of needles. While the same could be said of needle size, size differences between replicas and archaeological artefacts could have affected certain observations made during the experiments and should be kept in mind when considering our results. In contrast, we took great care to replicate those needles used in the sewing workshops as accurately as possible, especially in cross-section shape, but also in terms of the size. However, as can be seen in Figure 4, the objects were on average still larger than the archaeological collections.

Second, the surface of the experimental needles demonstrated a significantly more uneven micromorphology, with large grooves and ridges from the manufacturing process, compared to the generally flat overall micromorphology observed on the archaeological needles. Manufacturing traces, such as scraping traces, can be observed on the archaeological needles. However, they are not as visually prominent as those on the experimental needles. Since we analysed and photographed all experimental needles before use in order to accurately identify the formation of microwear, this uneven micromorphology did not affect identification of use-wear in our study. Still, we believe this disparity is worth considering.

Finally, during the first stage of experimental sewing, we measured the usage of each needle in terms of duration of time. While duration is the common unit of measurement in experimental studies, it may have been more appropriate in the present study to record the number of stitches made, rather than the time taken in total. Some of the experimental sewers were more adept at piercing their hides than others regardless of the needle being used, and so, in the same amount of time, they were able to create more stitches, and thus more use-wear on the needle surface.

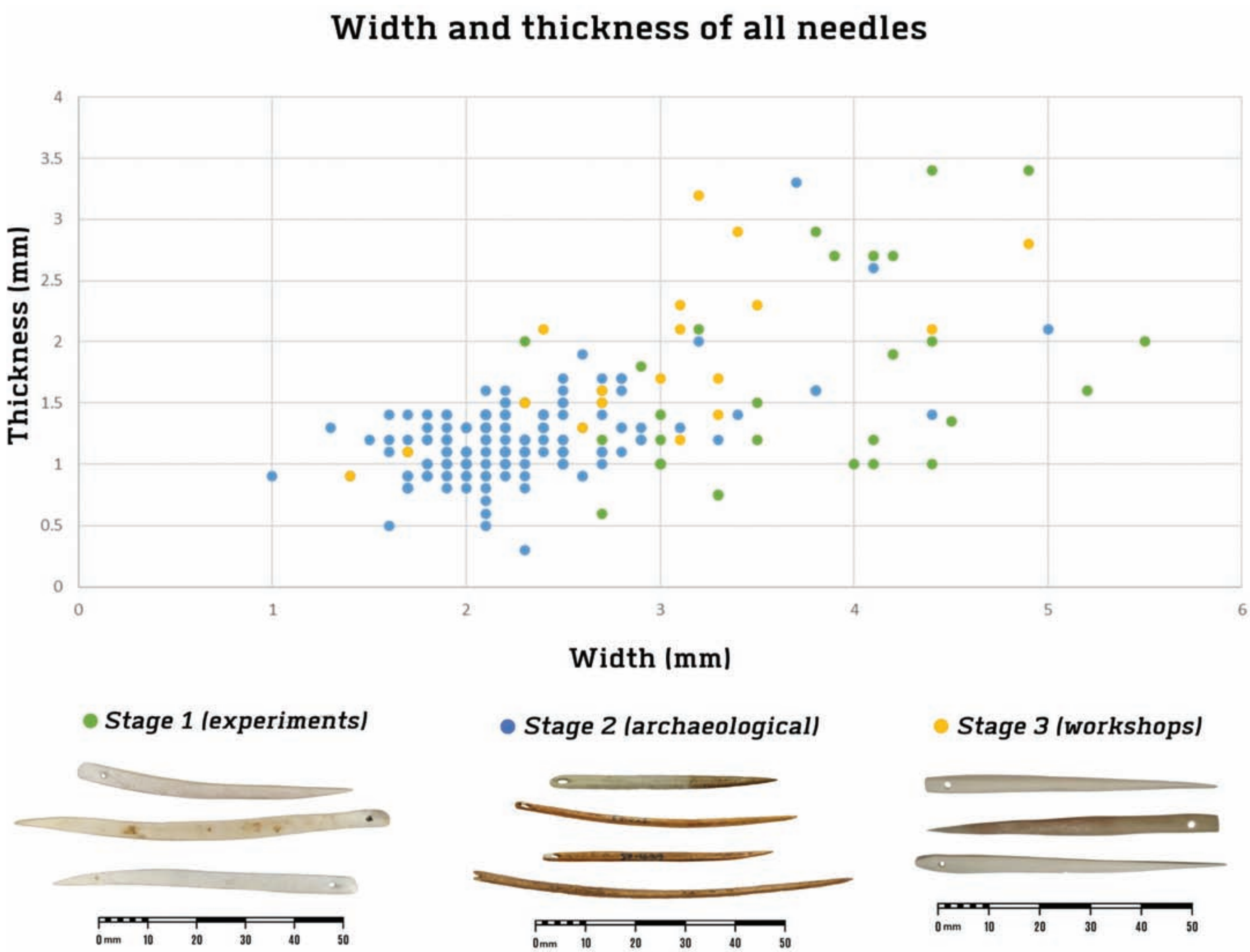

FIG. 4. Graph displaying needle sizes in three analysis stages of the study: 1. experimental sewing, 2. archaeological analysis, 3. Inuit seamstress workshops. Bottom left: experimental replicas used in stage 1. Bottom centre: examples of needles discovered at the Dorset sites used in stage 2 (top needle from Needle Point [NgFv-8] courtesy of Susan Lofthouse, remaining needles from Avvajja [NiHg-1] courtesy of the Museum of Archaeology and Anthropology in Cambridge, UK). Bottom right: examples of the replica needles used during the sewing workshops in Igloolik (stage 3).

RESULTS

Experimental Analysis

Several needles were broken during the experiments, and certain bone types, for example, bird rib bones, proved ineffective for sewing, often splitting or bending after only one or two stitches. Similarly, the caribou antler needles could not be worked down to a small enough shape while remaining sturdy enough to be pushed through the material. The only caribou antler needle which could be successfully used, for 80 minutes, demonstrated no observable use-wear during microanalysis, which we considered unusual.

Table 1 outlines the main quantitative results of the sewing experiments and includes the level of sewing experience of those using each needle, as classified by each individual participant.

A microwear analysis of the experimental needles corroborated results of similar microwear studies of osseous materials, such as those by LeMoine (1994) and Buc (2011). For example, we observed variation in the fineness of striations on needles used on skins with fur versus skins without fur, as also described in LeMoine (1994). Additionally, the hardest material, which was the tanned seal skin without fur, created polish only on the top ridges of the microscopic morphology, by which we mean the peaks of the microscopic ridges on the needle surface. In contrast, the softest skin, which was the tanned caribou skin without fur, created a significantly smoother polish, with a higher degree of linkage across all topographic levels of the needle surface (i.e., the soft skin matrix created polish on both the ridges and valleys of all micro-surfaces) (Fig. 5). LeMoine (1994) also noted these correlations in polish creation and the relative hardness of the skin (i.e., a hide's pliability according to relative comparisons with other skin types). Further, the twisting motion used by many of the participants to facilitate piercing the skin with the needle was evident in the presence of circumferential

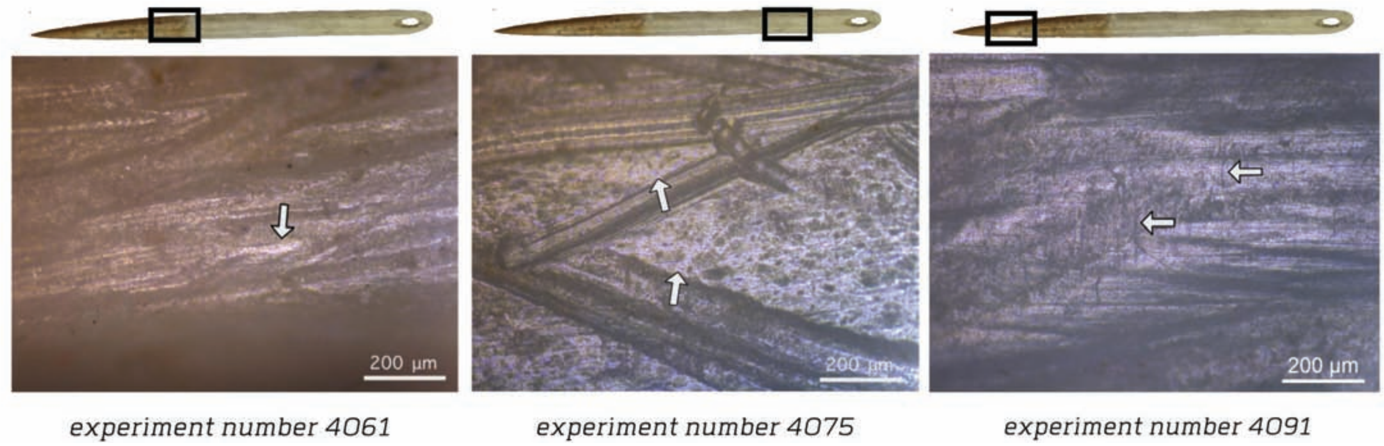

FIG. 5. Examples of traces observed that correlate with previous studies (e.g., Buc, 2011). Left to right: polish on top areas of micro-morphology on needles used to sew tanned seal skin without fur; smooth and highly linked polish on needles used to sew tanned caribou skin without fur; circumferential striations created when twisting the needles during sewing. Graphics above each image show the area photographed and orientation of the needle.

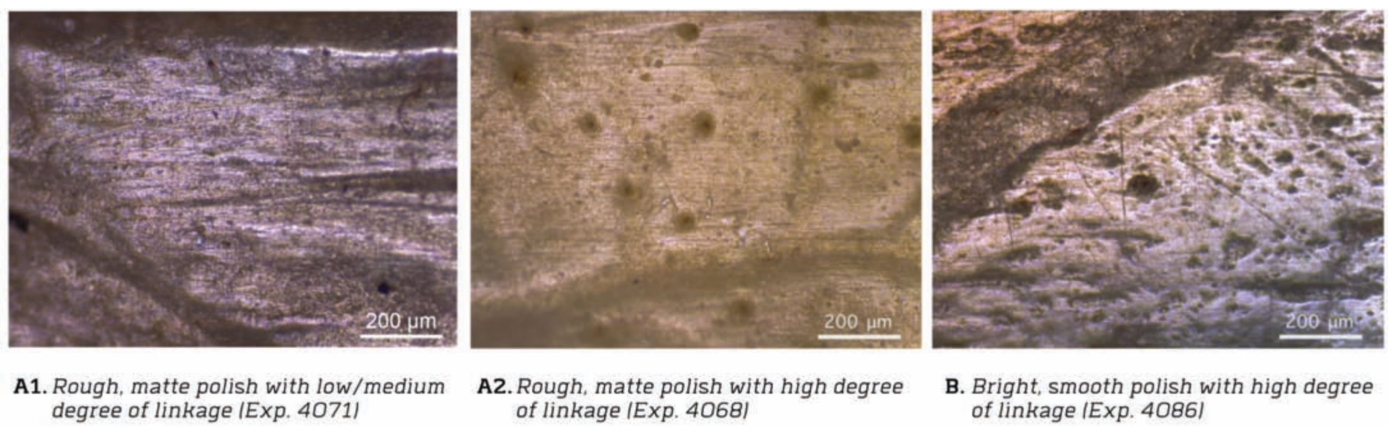

FIG. 6. Examples of the different polish types seen on the collection of experimental needles based on the observed attributes.

traces on 19 of 36 experimental objects (example shown in Fig. 5). Other experiments have also noted such traces (cf. Buc, 2011), and these were also evident on 50% of the needles from the archaeological collections in the present study. We observed participants' resharpening of needles through the elimination of certain patches of use-wear by fresh manufacturing traces.

When investigating the variation in polish attributes observed on the experimental needles, we were able to categorise these into three broad polish types (Fig. 6):

- A1. Rough, matte polish with a low-to-medium degree of linkage.
- A2. Rough, matte polish with a high degree of linkage.
- B. Bright, smooth polish with a high degree of linkage.

We only observed the last polish type on one replica needle, used on tanned caribou skin without fur, but we considered it distinct enough, in terms of polish attributes, to warrant a separate category.

Apart from this example of a polish type correlating to a particular skin type (i.e., type B on the needle used to sew tanned caribou without fur), it was unfortunately not possible to differentiate between traces created when sewing hides from terrestrial versus maritime species. However, to further investigate the presence of type B polish on the needle used to sew tanned caribou without fur, we looked at the possible influence of other experimental parameters on the formation of polish attributes. When comparing the different durations of use for each object, we observed that, in instances when use-wear was visible and when used for long enough before breaking, needles used on the tanned caribou without fur were used for a significantly longer duration than needles used on other materials. We therefore looked to see whether there was any link between duration of use and polish type on the other experimental needles. We observed that type A1 polish was more prevalent on needles used for less than 100 minutes, while type A2 polish was more prevalent on needles used for more than 100 minutes (Fig. 7).

Archaeological Comparison

We also observed signs of needle resharpening and reworking in the archaeological collections. Several objects showed evidence of eyes being remade, with a

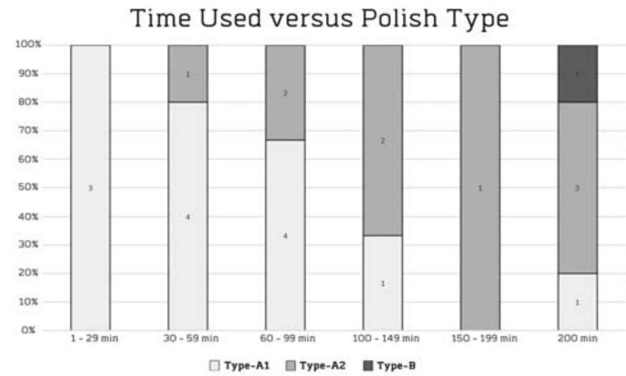

FIG. 7. Comparison of polish types identified on the experimental replicas with the duration of use in minutes.

broken section of the eye still visible on the proximal end. Additionally, some objects were significantly shorter than average, thus suggesting that the distal end had also been resharpened at some point in the needle's use-life.

When we compared polish types on the archaeological needles, we observed a similar variation in polish types to those we had established through our experimental analysis (see Fig. 8). In the archaeological collections, significantly more objects demonstrated the type B polish than among our experimental replicas.

As with our experimental analysis, we also investigated the link between these different polish types and duration of use (identified through the proxy of low, medium, and high levels of rounding in the needle eyes, as described above). Figure 9 shows the results of this comparison. The majority of objects demonstrating type A1 polish also had a low or medium level of rounding around the needle eye, suggesting they were used for a shorter duration of time. Similarly, no objects with a low level of rounding around the eye demonstrated type B polish. Instead, the majority of archaeological needles showing a high amount of rounding around the eye, and which were therefore likely used for a longer duration, had type B or type A2 polish. We observed the highest percentage of type B polish on needles with a higher level of rounding in the eye, and all needles demonstrating type B polish had medium or high levels of rounding of the eye. Type A2 polish was the most prevalent across all needles and within each level of rounding.

We identified no observable patterns linking a particular cross-section shape with a particular polish type. When comparing the size of archaeological needles against observed polish type, no clear pattern was visible between needle thickness and polish type. However, when looking at needle width, there did appear to be a link (Fig. 10): needles demonstrating type A1 polish were wider than those demonstrating type A2 polish, which, in turn, were wider than those demonstrating type B polish.

In order to investigate this point further, we also compared the size of the needles with their cross-section shapes. Figure 11 shows the results of this comparison.

Arctic Sewing Workshops

When presented with the experimental needles created specifically for these workshops, which were the same average size, and demonstrated the same variety of cross-section shapes observed in the archaeological collections, workshop participants were asked to choose which needles they would pick to sew different skin types. These choices revealed that needle size was a more important consideration than cross-section shape. Participants explained that they were looking for the thinnest needles, as these are necessary when creating traditional Inuit stitches, such as waterproof stitches. This particular stitch involves pushing the needle within the internal layers of a hide, rather than piercing it completely through, so that no holes are created in the outer layer of the waterproof garment (Issenman, 1997; and demonstrated during the workshop).

Workshop participants also demonstrated the traditional Inuit sewing method, where the needle is held between the middle finger and thumb and pushed with the first finger towards the user through the skin in a single motion. This method has been documented in ethnographic accounts of sewing with bone needles from other contexts (Lyon, 1824; Oakes, 1988). However, when the participants attempted to implement this technique using the experimental needles, these instantly broke. This did not correlate with our experiences from the experimental part of the study,

FIG. 8. Examples of different polish types identified on the archaeological needles.

and indeed the seamstresses found that the only way to successfully pierce the skin was by using the twisting and forward-pushing motion more commonly employed by Qallunaat (non-Inuit), which we had also used in our experiments.

DISCUSSION

Patterns in Use-Wear Analysis

Our study aim was to determine whether variations observed in needle morphology, specifically in the cross-section shape, could be linked with the observed use of needles, focusing on their use when sewing skin types of different species. Our results show it is unlikely that distinctions between needles used on the skins of maritime or terrestrial species can be drawn based solely on use-wear traces evident on the surface of the needles themselves. Although the decision to make needles with a particular cross-section shape may have been intentional in the past, we cannot say, based on the present study, whether this variation in morphology was directly linked to use on different materials (i.e., a maritime or terrestrial skin types). However, if we instead consider other possible patterns in use-wear, the results suggest some interesting interpretations.

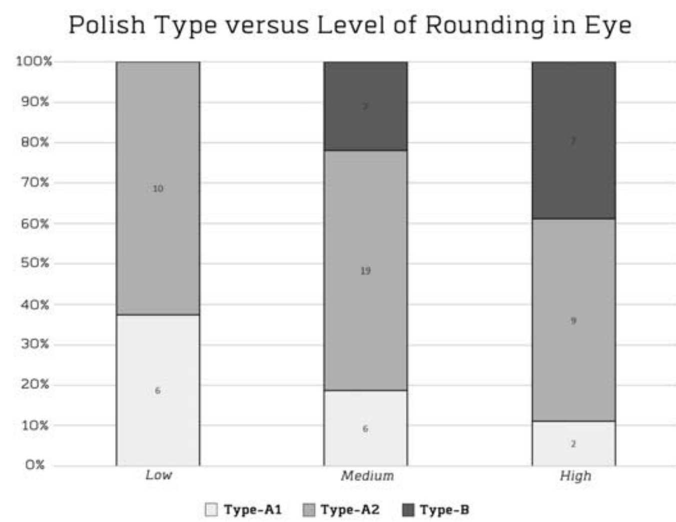

FIG. 9. Comparison of polish types identified on the archaeological needle collection with level of rounding observed in needle eyes.

The first of these relates to the correlation between polish type and duration of use of the needles. Our hypothesis, based on the results, is that the three polish types could represent increasing duration or intensity of use. This hypothesis was first suggested by the apparent link between type B polish and the experimental needles used on tanned caribou skin without fur. We observed that those needles were used for significantly longer than

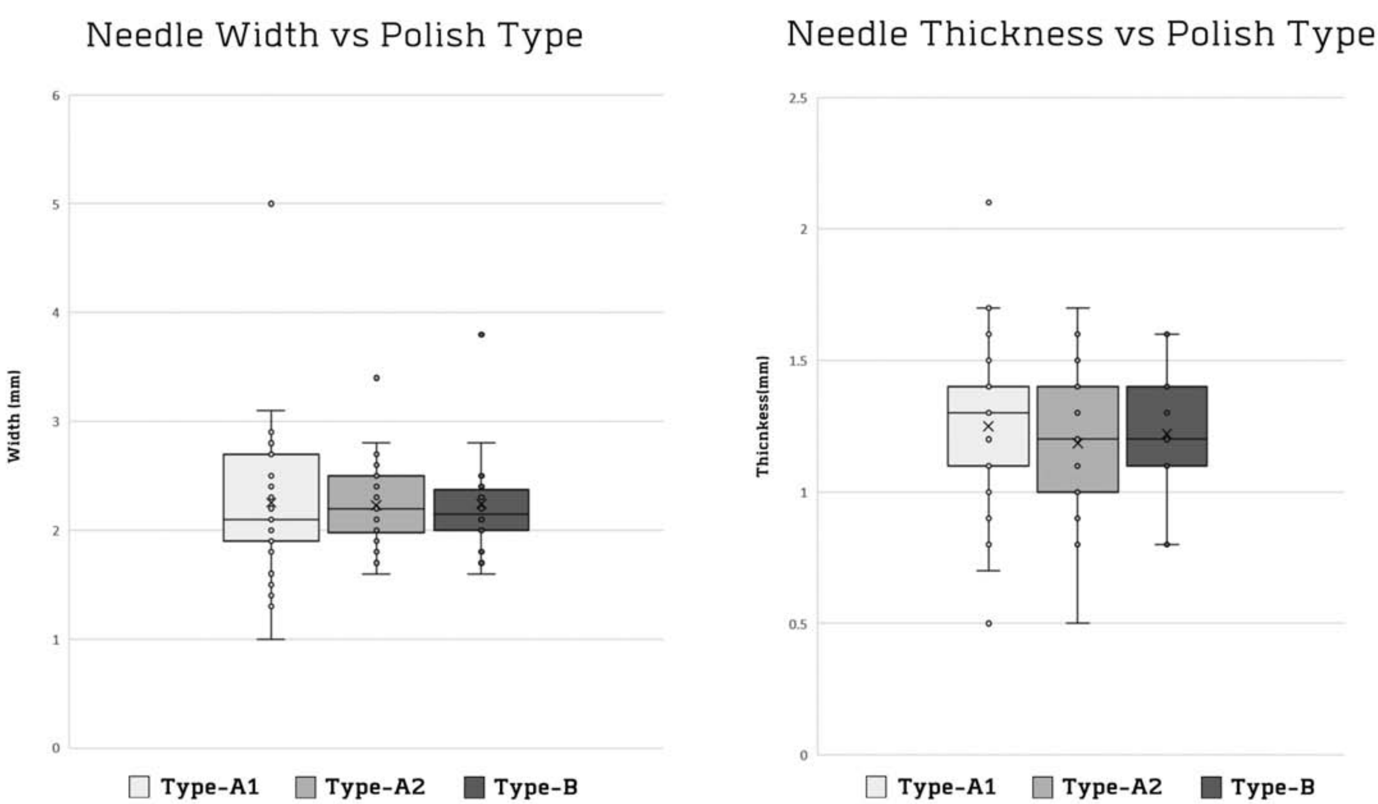

FIG. 10. Comparison of needles from the archaeological collections by polish types against width and thickness..

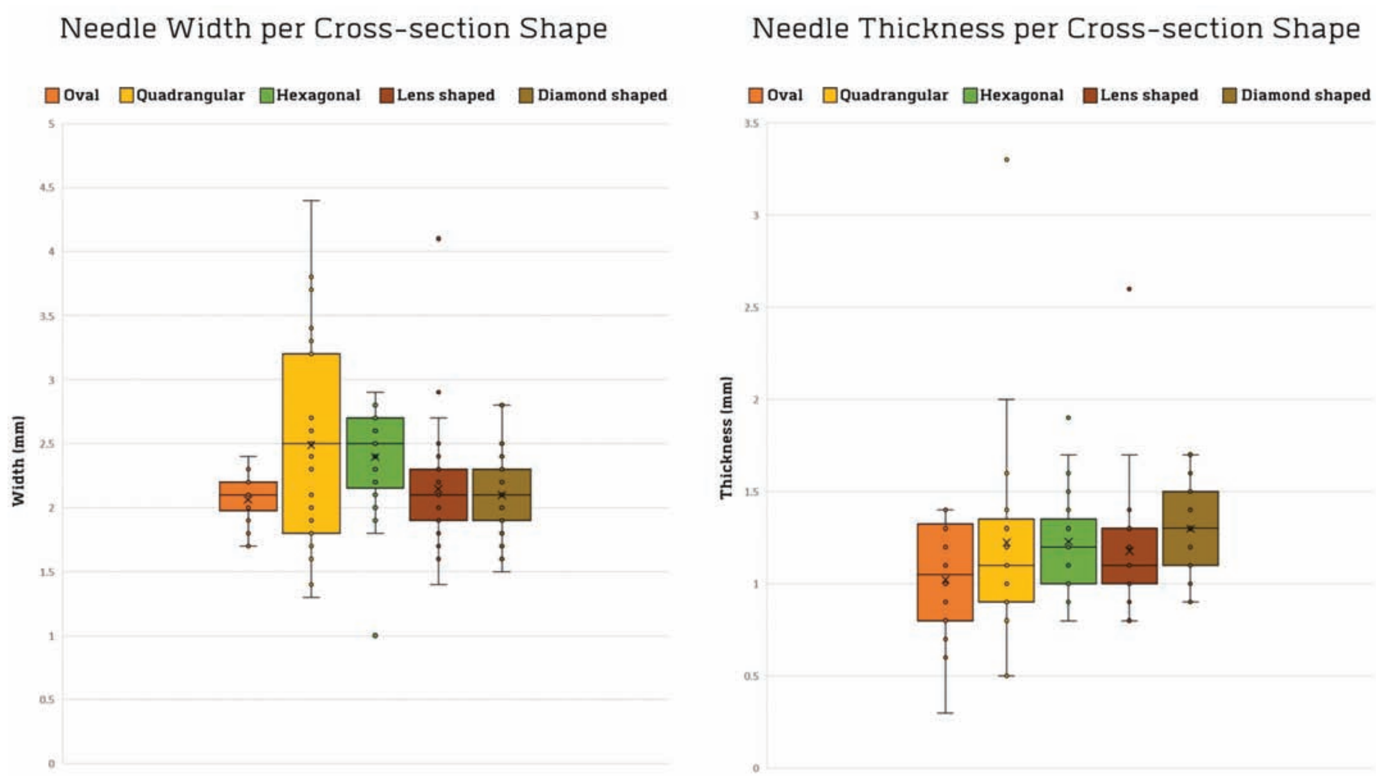

FIG. 11. Comparison of needles from the archaeological collections by cross-section shapes against width and thickness.

those used on other materials. This could suggest that type B polish is associated with a longer duration of use, rather than with a needle's use on a particular skin type. To investigate this hypothesis further, we drew comparisons between the duration of experimental sewing and the polish type observed on needles. Results from our experimental analysis reveal a correlation between increased duration of use and different polish type categories, with type A1 polish more often created on needles used for less time, and type A2 polish more often created on needles used for longer (Fig. 7). Therefore, we suggest that type A2 polish is a development of type A1 polish that occurs after a longer period of use, observable in the increased linkage of the polish between types. That type B polish may be a further development (observable through increased linkage as well as the formation of a brighter and smoother polish) does correlate with the results shown in Figure 7. Given that we only observed evidence of type B as a further development on one of our replica needles, a larger experimental dataset is needed to fully investigate this suggestion. Nonetheless, we were able to explore the hypothesis further through the results of the archaeological analysis. In this case, the results of the comparison between duration of use (identified through the visible level of rounding in needle eyes) and polish type revealed a similar pattern to that observed in the experimental analysis, where type A1 polish was more often associated with a low level of rounding, type A2 polish with a medium level of rounding, and type B with a higher level of rounding. Based on these results, we suggest that the A1, A2, and B polish types observed on both the experimental and archaeological objects represent a progression in duration or intensity of use.

The second interesting result relates to the correlation between use-wear traces and needle size. Lyman (2015) suggested that larger needles may have been specifically made and used to sew thicker hides. We wished to explore this idea further and see whether a link could be drawn between the thickness and width of a needle, and use-wear traces that could be linked with thicker hides, such as the traces observed on our replica needles used on tanned seal skin without fur (Fig. 5). If we consider the results of the experiments in light of the polish observed, contact with this thicker and harder hide seems to demonstrate a slower buildup of polish over time across the complete micromorphology of the needle surface, with polish areas focused only on the top layer of the surface morphology. That is, it took a longer time for the same polish type to develop on needles used to sew thicker or harder hides than on those used to sew thinner or softer hides. Consequently, these thicker needles may demonstrate polish attributes that suggest they had been used for less time, even if this were not the case, due to the thicker/harder nature of the contact hide. According to our hypothesis of polish development being linked to duration of use, we would therefore expect that larger needles (if they were used to sew thicker skin) would be more likely to demonstrate the polish type associated with the least time used: type A1. The results outlined in Figure 10 show that, indeed, needles with type A1 polish were wider than those with type A2 polish, which were consequently wider again than those with type B polish. According to our hypothesis that these three polish types represent a progression in duration of use, this could suggest one of two things, or both:

- that wider needles were generally used for a total shorter period of time.
- that wider needles were generally used to sew thicker hides (which we can see, from our experiments, creates a slower buildup of polish on needles over time).

The second possibility could suggest that hide thickness had more influence on the choice of needle than the species to which the hide belonged, and that, in general, larger needles may have been preferred for thicker hides and vice versa.

To investigate this idea further, we also compared the different cross-section shapes against needle size to see whether certain cross-section shapes correlated with larger needle widths and thicknesses (Fig. 11). From the results, it is indeed possible to see some patterns emerge from this comparison. Focusing on thickness, we can see that cross-sections with sharper edges (i.e., shapes with a higher number of edges, such as hexagonal and diamond-shaped) are generally thicker than smoother shapes such as oval- and lens-shaped cross-sections. In order to sew thick leather in modern sewing practices, a thicker metal needle is required. Interestingly, these specialised leather needles also have a triangular cross-section towards the tip, in contrast to standard sewing needles, which are generally circular. For a similar reason, cross-sections on bone needles with more edges may have been preferred when sewing thicker skins. This could also explain why the cross-section shape with the most edges (hexagonal) is generally wider than all other shapes. We cannot draw any solid conclusions about those needles with quadrangular cross-sections from the present study however, as there are too few data points spread over too wide an area.

Inuit Seamstresses Workshops

Our experiments predominantly focused on variables in needle morphology that could be influenced by practical restrictions or limitations of the materials being sewn. However, there is also the additional variable of culturally or socially defined restrictions on material use. Ethnographic accounts demonstrate certain cultural taboos associated with sewing practices. For example, Balikci (1970) describes yearly sewing camps in the winter months, when fresh garments were prepared for the year, during which time no hunting could be undertaken. Conversely, Oakes (1988) describes how no sewing could be undertaken while hunting trips were underway. Culturally influenced rules therefore surrounded historic Inuit sewing practices in addition to any possible restrictions imposed by the physical properties of the materials being used and sewn. Similar external factors may also have influenced the choices made by Dorset needle makers during manufacture. Thus, we could expect that the link between a needle's final shape and size and the material it was used on was based as much on social factors as practical, material-based ones. We therefore considered collaboration with Inuit seamstresses a vital part of our study, as this would allow us to explore an extra dimension of our methodological framework together. The results of these sewing workshops in Igloolik provided invaluable observations.

First, the importance of needle size was established early on, as the seamstresses explained that smaller needles were favourable when creating the waterproof stitch. Even without these specialised waterproof stitches, small seams were (and still are) preferred, as it is essential to avoid any gaps around the stitching in order to create warm and weatherproof clothing. We examined historic Inuit seal skin and caribou-skin clothing from various regions, including Davis Strait (1800–25), West Greenland (1850–89), and Tasiilaq (1890–1925), and observed the tight seams visible in the stitching, which would likely have required the use of very thin needles. Figure 12 shows some examples.

Considering the maritime subsistence and environmental context of Dorset groups, we can assume that similar waterproof stitches and tight seams would have been preferred, and thinner needles may have been required. Hoffman (2002) has suggested that Dorset needles could be made as thin as they were because of the gouging technique used to create the eye, compared with the drilled holes from earlier and later cultures, which require a wider surface area. The elongated groove created through this action would also have allowed the thread to lie as flat as possible against the needle surface, thus preventing any excess widening of the hole during passage of the thread (Osborn, 2014). However, although the archaeological objects are very thin, Dorset needles are generally still wider and thicker than needles from the later Thule culture, the ancestors of current Inuit populations (Issenman, 1997).

This observation relates to the second result from the workshop discussions, which is the contrast between Inuit vs Qallunaat (non-Inuit) sewing methods and how this is possibly affected by the size of the needles used. When comparing Dorset needles with those from Thule Inuit sites and historic Inuit ethnographies, those from the latter two groups are shorter but also straighter and more compact, and therefore likely stronger and able to withstand more pressure when being pushed through the skin compared to the longer, curved, and arguably more delicate Dorset needles. This does not mean Inuit bone needles would never have broken; on the contrary, several ethnographic accounts have described the frustration felt by historic Inuit seamstresses when bone needles "frequently" broke (Balikci, 1970:13). However, during the workshop, the breakages that occurred using the Inuit sewing method usually involved only the tip of the needle breaking off before it even had a chance to pierce the skin. In contrast, breakages that occurred during the preliminary sewing experiments (conducted by non-Inuit and so using the Qallunaat twisting sewing technique)

FIG. 12. Examples of stitching observed on historic Inuit clothing housed at the Wereldmuseum, Leiden. Item number, location, and date clockwise from top left: 380-1904a (Davis Strait 1800–25), 690-30 (West Greenland 1850–1889), 2085-2 (Tasiilaq 1890–1925), and 690-35 (West Greenland 1850–89).

were more comparable with the breakage patterns observed on the archaeological tools, with the point of breakage distributed more evenly across the length of the needles. While discussing this during the workshop, modern Inuit seamstresses considered the comparatively long size and delicacy of Dorset needles (especially compared to the shorter and more compact Inuit bone needles) as impossible to use for creating tight seams and waterproof stitches. The design of Dorset needles thus appears to be incompatible with the traditional Inuit style of sewing, as the needles would instantly break when this technique was applied, which was not the case when twisted using the Qallunaat method.

This conclusion leads us to an interesting side point of discussion related to the investigation of sewing technique. Generally, investigations of different Dorset technological traditions have in some way involved the use of ethnographic analogy through comparisons with accounts of historic Inuit technologies. Using ethnographic analogy to understand past cultures is contentious and has long been a topic of debate in archaeological research due to its inherently colonial attitudes to modern Indigenous cultures (de Leeuw et al., 2012), its focus on a direct historical approach (Currie, 2016), and its biased research focus (González-Urquijo et al., 2014). However, the use of ethnographic analogy has remained prevalent in Arctic archaeological research. Although Dorset cultures are genetically distinct from the later Thule Inuit populations (Raghaven et al., 2014), the similarity in environmental context and resource availability to both groups have generally meant that studies focusing on Dorset rely heavily on analogies with historic Inuit ethnographies. This similarity in context fulfils one of the essential requirements of ethnographic analogy in archaeological research, according to Charlin and González-José (2018), and so, although there are issues with such a direct historical approach (Lyman and O'Brien, 2001), it is understandable why these recent cultures and their practices are regularly used as an analogy for Paleo-Inuit practices. However, the results of the present study suggest that this analogy may not be applicable to Dorset sewing practices. We are not proposing that such analogies should therefore never be used but wish to highlight the possibility that Dorset groups may have had alternative techniques or approaches, even if the objects employed are similar to those found in Thule Inuit or historic Inuit collections. The present study provides an interesting example of this, as Dorset needles could apparently not have been used with the Inuit method, which an ethnographic analogy with later Inuit groups would automatically assume.

One explanation for how it would have been possible to use the Inuit method with Dorset needles is through the use of awls, as mentioned in some ethnographic accounts of historic Inuit seamstresses (cf. Balikci, 1970). Using an awl would allow a needle to travel more easily through hide and could facilitate piercing using Dorset-style needles with the Inuit method without constant breakage occurring. As mentioned earlier, further microwear investigations into the presence of awls at Dorset sites is necessary to determine whether or not they were used by Dorset groups. However, a further argument to support the theory that they did not use awls is the presence of circumferential striations on just over half of the archaeological needles. We observed the same circumferential striations on a similar percentage of the experimental replicas, which were nearly all used with a twisting motion to initially pierce the hides. This observation suggests that Dorset people may indeed have used a twisting motion (similar to the Qallunaat method) to first get the needle through the skin, rather than using an awl or bodkin.

Directions for Future Research

Our study points to several directions for future research. The first relates to the experimental manufacturing process. One difference between our experimental replicas and the archaeological needles was the presence of clear manufacturing traces on the former, compared to limited presence on the latter. We suggest two possible reasons for this particular variation. First, the archaeological needles may have been used for a significantly longer time than those in our experimental collection, and therefore the surface of the needles would be naturally more worn down. This would also fit with our interpretation of type B polish as representing a longer duration of use, as that polish type was present on more objects in the archaeological collection than in our experimental replica collection. A second possibility is that the archaeological needles were further polished after being scraped into their final shape as part of the manufacturing process. This would make practical sense, as it would allow easier penetration of the hides. If needles were polished during manufacture, this would naturally have an effect on the polish observed following use, which would in turn affect the validity of our experimental comparisons, as our replica needles were not polished during manufacture. We therefore propose that, to expand our experimental dataset and allow for a wider range of steps in the archaeological manufacturing process, future experiments should incorporate experimental needles that have been polished as part of their manufacturing process.

We also noted potential inconsistencies between the success of needle materials used in our experiments versus evidence of successes from ethnographic and archaeological records. We used materials known from the archaeological and ethnographic records as raw materials likely used in needle manufacture when creating our experimental objects. However, as described earlier in the paper, some of these needles either did not work at all or broke/bent very soon after initial use, for example, those made from bird rib bones. Considering that smaller needles would likely have been preferred to create watertight stitches, it would be useful to experiment further with bird rib bones from a wider range of species, and perhaps with alternate *chaînes opératoires*. The ineffectiveness of the caribou antler needles and lack of observable use-wear traces was also surprising. However, one possible explanation for this anomaly may relate to the raw material sampling mentioned in the methodology, as certain properties of this sample may have influenced its efficacy and the creation of use-wear traces. Future research should therefore be undertaken using different caribou antler samples of varying freshness. More experiments are thus necessary to determine whether the inefficiency of our particular needles was due to manufacturing or user error, or to impracticalities of the material itself. Additionally, the environmental context surrounding the experiments could have played an important role. All of the sewing experiments were undertaken in Western Europe, with the majority happening in the Netherlands, which has a particularly humid environment. In contrast, Arctic climates are extremely dry, and therefore bones may react differently when worked and used in this environment compared to foreign environments (Maya Siluk Jacobsen, pers. comm. 2022). Ideally, future experiments should therefore be conducted at the original location in which the archaeological objects were discovered.

Evidence from both the experimental and the archaeological tools supports our hypothesis that different polish types are linked with duration of use. However, there are several alternative explanations for these polish types, which should also be investigated through further experimental study. For example, similarities exist between the type B polish described here and polish observed on experimental objects from other studies used on plant materials (cf. Buc, 2011). While plant fibres were used regularly by many cultures in the past, the environmental restrictions of Arctic contexts would have limited the availability of this resource for Paleo-Inuit cloth manufacture, and mention of these materials is also missing from ethnographic accounts. It is therefore unlikely that needles would have been regularly used to sew plant materials. However, ethnographic accounts describe how bone needles were often stored by being poked into a moss cushion inside a needle case (Oakes, 1988). This contact with the moss could then create the brighter, smoother polish associated with contact with plant materials in Buc

(2011) and with the type B polish identified in the present study, rather than being linked with duration of use. If a needle is used over a longer period of time, we can assume that it is put in and out of the moss cushion more often than those used for shorter periods. This could also explain an increased buildup of polish, associated with contact with moss, on those objects, in comparison to those demonstrating type A1 and type A2 polishes. Consequently, our hypothesis regarding progression of polish in relation to duration of use would still hold true. However, further experiments are required to investigate this idea further, for example, in a longer scale use-wear project where needles would be stored in moss cushions between sewing events.

Level of sewing experience should also be considered when interpreting the polish types observed in the present study. In our experimental section, we used the parameter of duration for each experimental needle, rather than number of piercings. For future experiments this should perhaps be altered, as, during experiments, we observed that participants with less sewing experience struggled for longer to get their needle through the skin for each piercing. Therefore, a more experienced sewer will likely make more piercings, putting the needle in more contact with the skin, in the same amount of time during which a less experienced sewer would make considerably fewer completed piercings. It is therefore logical to assume that a more experienced sewer might make more contact between the needle and skin within a shorter period of time. Therefore, a polish that might be considered representative of more contact with the skin would also be present on objects used for a short amount of time by a more experienced sewer. We could indeed see that type A1 polish is generally identified with objects that have been used both for a shorter amount of time or by less experienced sewers (Table 1). Future studies should carefully monitor the effects of sewing experience on the level of contact between needles and hides, and the consequent creation of use-wear traces. Additionally, as mentioned in the methodology, participants self-identified their level of sewing experience, which created a level of uncertainty around an already subjective category. Future experiments should attempt to provide a more objective way to gauge the level of sewing experience, and should also be specific as to the familiar sewing materials of each participant. For example, a less experienced sewer who has always worked with leather may still do comparable sewing work to a highly experienced sewer who rarely works with leather.

Finally, several of the most interesting results of the present study would benefit from a more detailed experimental investigation. For example, the link between larger needles with sharper edges and use with thicker or harder hides could be investigated further by using replica needles with different cross-section shapes on skin types of varying hardness or thickness. It would also be interesting to discuss the experiential aspects surrounding using replica needles of different shapes and sizes to, for example, see whether a particular cross-section shape is easier to use on a particular hide thickness, or with specific sewing techniques. Further collaboration with modern Inuit seamstresses would be an essential part of both this work and possible experimentation with the use of awls. This would be particularly useful in order to investigate the possible differences in sewing techniques described above by, for example, applying experimental archaeology and microwear analysis to compare use-wear on Dorset, Thule Inuit, and historic Inuit needles.

CONCLUSION

The results of the present study did not suggest any link between the morphological characteristics of Dorset needles and the type of skin (maritime or terrestrial) on which those needles were used. However, they do suggest that the choice of Dorset needle makers to create needles of different sizes and shapes could have been influenced by the thickness or hardness of the hides being sewn. The methodological framework implemented in this project, combining experimental archaeology, microwear analysis, and Indigenous collaboration, has allowed us to explore Dorset sewing and needle making practices in much greater detail than could be achieved through the classic typological approach more commonly applied to studies of Arctic material culture. Future investigations into this and other technological practices would benefit from a similar research framework in order to provide even greater insights into the daily life of Paleo-Inuit groups.

ACKNOWELDGEMENTS

The authors would like to thank all those who assisted in the implementation of this project. Many of the conclusions within the paper could not have been made without the input of Igloolik community members Rebecca Mikki, Susan Avingaq, and Mary Kunuk, who were kind enough to participate in our sewing workshops and offer their own opinions and experiences. Our experiments would not have been possible without the raw materials, which were kindly provided by Douglas Meyer, Rebecca Mikki, and the veterinarians at the Pieterburen Zeehondencentrum. The first phase of experiments were undertaken by Matilda Siebrecht and several students in the University of Groningen experimental archaeology group, without whose help the experimental dataset would not have been half so extensive: Jelke Take, Lotte Zanting, Sandra Coenen, Wiske Bruinsma, Anne Vrielink, and Rhea Buijs. Thank you also to the Avataq Cultural Institute, McGill University, and the Museum of Archaeology and Anthropology in Cambridge for allowing access to analyse the archaeological collections. And finally, our thanks to the Nunavut Department of Culture and Heritage for providing the research permit for the current project, to the Canadian Museum of Nature for granting funding for the Igloolik-based workshops, to the University of Groningen for providing the research bursary for Matilda Siebrecht, and to Professor Peter Jordan and Dr. Sean Desjardins for their supervision and comments when writing this paper.

REFERENCES

Aleo, A., Kozowyk, P.R.B, Baron, L.I, Van Gijn., A., and Langejans, G.H.J. 2023. The dynamic lives of osseous points from Late Palaeolithic/Early Mesolithic Doggerland: A detailed functional study of barbed and unbarbed points from the Dutch North Sea. PLoS ONE 18(8): e0288629.
https://doi.org/10.1371/journal.pone.0288629

Appelt, M., Damkjar, E., and Friesen, M. 2016. 33 Late Dorset. In: Friesen, M., and Mason, O., eds. The Oxford handbook of the prehistoric Arctic. Oxford: Oxford University Press. 783–806.
https://doi.org/10.1093/oxfordhb/9780199766956.013.36

Balikci, A. 1970. The Netsilik Eskimo. Boerne, Texas: Doubleday.

Bradfield, J. 2015. Identifying bone-tipped arrow types in the archaeological record of South Africa: The contribution of use-trace studies. Journal of African Archaeology 13(2):135–147.
https://doi.org/10.3213/2191-5784-10278

Buc, N. 2011. Experimental series and use-wear in bone tools. Journal of Archaeological Science 38(3):546–557.
https://doi.org/10.1016/j.jas.2010.10.009

Charlin, J., and González-José, R. 2018. Testing an ethnographic analogy through geometric morphometrics: A comparison between ethnographic arrows and archaeological projectile points from Late Holocene Fuego-Patagonia. Journal of Anthropological Archaeology 51:159–172.
https://doi.org/10.1016/j.jaa.2018.06.008

Currie, A. 2016. Ethnographic analogy, the comparative method, and archaeological special pleading. Studies in History and Philosophy of Science Part A 55:85–94.
https://doi.org/10.1016/j.shpsa.2015.08.010

De Leeuw, S., Cameron, E., and Greenwood, M. 2012. Participatory and community-based research, indigenous geographies, and the spaces of friendship: A critical engagement. The Canadian Geographies 56(2):180–194.
https://doi.org/10.1111/j.1541-0064.2012.00434.x

D'Errico, F. 1993. La vie social de l'art mobilier paleolithique. Manipulation, transport, suspension des objets on os, bois de cervides, ivoire. Oxford Journal of Archaeology 12(2):145–174.
https://doi.org/10.1111/j.1468-0092.1993.tb00289.x

Desrosiers, P., and Sørensen, M. 2016. 6 Paleoeskimo lithic technology. In: Friesen, M., and Mason, O., eds. The Oxford handbook of the prehistoric Arctic. Oxford: Oxford University Press. 153–174.
https://doi.org/10.1093/oxfordhb/9780199766956.013.16

Evans, A.A, Lerner, H., Macdonald, D.A., Stemp W.J., and Anderson, P. C. 2014. Standardization, calibration and innovation: A special issue on lithic microwear method. Journal of Archaeological Science 48:1–4.
https://doi.org/10.1016/j.jas.2014.03.002

Ewing, D.R., and Darwent, C.M. 2018. Sinew thread production and stitch properties in Arctic Alaskan clothing construction. Alaska Journal of Anthropology 16(2):1–23.
https://escholarship.org/content/qt4hc3g82n/qt4hc3g82n_noSplash_cf3dcd44128f68463295d298149ec53f.pdf

Friesen, M. 2022. Hunter-gatherer aggregations writ large: Economy, interaction, and ritual in the final days of the Tuniit (Late Dorset) culture. Journal of Anthropological Archaeology 67: 101437.
https://doi.org/10.1016/j.jaa.2022.101437

Friesen, M., and Mason, O. 2016. Introduction: Archaeology of the North American Arctic. In: Friesen, M., and Mason, O., eds. The Oxford handbook of the prehistoric Arctic. Oxford: Oxford University Press. 1–24.
https://doi.org/10.1093/oxfordhb/9780199766956.001.0001

Gates St-Pierre, C. 2007. Bone awls of the St. Lawrence Iroquoians: A microwear analysis. In: Gates St-Pierre, C., and Walker, R., eds. Bones as tools: Current methods and interpretations in worked bone studies. Oxford: BAR Publishing. 107–118.
https://doi.org/10.30861/9781407300344

Gelvin-Reymiller, C., and Reuther, J. 2010. Birds, needles, and iron: Late Holocene prehistoric Alaskan grooving techniques. Alaska Journal of Anthropology 8(1):1–22.
https://www.alaskaanthropology.org/wp-content/uploads/2017/08/akanth-articles_329_v8_n1_Gelvin-Reymiller-Reuther.pdf

González-Urquijo, J., and Ibáñez-Estévez, J.J. 2003. The quantification of use-wear polish using image analysis. First results. Journal of Archaeological Science 30(4):481–489.
https://doi.org/10.1006/jasc.2002.0855

González-Urquijo, J., Beyries, S., and Ibáñez-Estévez, J. 2014. Ethnoarchaeology and functional analysis. In: Marreiros, J., Gibaja Bao, J., and Ferreira Bicho, N., eds. Use-wear and residue analysis in archaeology. London: Springer. 27–40.
https://doi.org/10.1007/978-3-319-08257-8_3

Grace, R. 1989. Interpreting the function of stone tools: The quantification and computerisation of microwear analysis. Oxford: BAR Publishing.
https://doi.org/10.30861/9780860546085

Hoffman, B.W. 2002. Broken eyes and simple grooves: Understanding Eastern Aleut needle technology through experimental manufacture and use of bone needles. In: Frink, L., Shepard, R.S., and Reinhard, G.A, eds. Many faces of gender: Roles and relationships through time in Indigenous northern communities. Calgary: Calgary University Press. 151–164.
https://doi.org/10.2307/j.ctv6cfrqv.14

Issenman, B. 1997. Sinews of survival. Vancouver: University of British Columbia Press.
https://doi.org/10.59962/9780774856416

Knight, L. 2012. Handbook of sewing stitches: An illustrated guide to techniques and materials. Tunbridge Wells: Search Press Ltd.

LeMoine, G. 1994. Use wear on bone and antler tools from the Mackenzie Delta, Northwest Territories. American Antiquity 59(2):316–334.
https://doi.org/10.2307/281935

Lemonnier, P. 1993. Technological choices: Transformation in material cultures since the Neolithic. London: Routledge.

Lyman, L. 2015. North American Paleoindian eyed bone needles: Morphometrics, sewing, and site structure. American Antiquity 80(1):146–160.
https://doi.org/10.7183/0002-7316.79.4.146

Lyman, R., and O'Brien, M. 2001. The direct historical approach, analogical reasoning, and theory in Americanist archaeology. Journal of Archaeological Method and Theory 8(4):303–342.
https://doi.org/10.1023/A:1013736416067

Lyon, G. 1824. The private journal of Captain G.F. Lyon, of H.M.S. *Hecla*, during the recent voyage of discovery under Captain Parry. London: Thomas Davison.

Maigrot, Y. 2005. Ivory, bone and antler tools production systems at Chalain 4 (Jura, France): Late Neolithic site, 3rd millennium. In: Luik, H., Choyke, A., Batey, C.E., and Lougas, L., eds. From hooves to horns, from mollusc to mammoth. Manufacture and use of bone artefacts from prehistoric times to the present. Muinasaja Teadus, Vol. 15. Tallinn: Tallinn Book Printers. 113–126.

Martin, K. 2009. Stories in a new skin: Approaches to Inuit literature in Nunavut. PhD thesis, Centre for Comparative Literature, University of Toronto, Toronto, Canada.
https://www.collectionscanada.gc.ca/obj/thesescanada/vol2/002/NR81230.PDF

Meeks, N.D., and Cartwright, C.R. 2005. Caribou and seal hair: Examination by scanning electron microscopy. In: King, J., Pauksztat, B., and Storrie, R., eds. Arctic clothing. Montreal: McGill-Queen's University press. 42–44.
https://doi.org/10.1515/9780773573284-009

Monchot, H., Thompson, A., Patenaude, B., and Houmard, C. 2016. The role of birds in the subsistence practices of the Dorset peoples of Nunavik. Arctic Anthropology 53(1):69–83.
https://doi.org/10.3368/aa.53.1.69

Oakes, J.E. 1988. Copper and Caribou Inuit skin clothing production. PhD thesis, Interdisciplinary Studies, University of Manitoba, Winnipeg, Canada.

Olsen, S.L. 1988. The identification of stone and metal tools marks on bone artifacts. In: Olsen, S., ed. Scanning electron microscopy in archaeology. Oxford: British Archaeological Reports. 337–360.
https://doi.org/10.30861/9780860545798

Osborn, A. 2014. Eye of the needle: Cold stress, clothing, and sewing technology during the Younger Dryas cold event in North America. American Antiquity 79(1):45–68.
https://doi.org/10.7183/0002-7316.79.1.45

Raghavan, M., DeGiorgio, M., Albrechtsen, A., Moltke, I., Skoglund, P., Korneliussen, T., Grønnow, B., et al. 2014. The genetic prehistory of the New World Arctic. Science 345(6200): 1255832.
https://doi.org/10.1126/science.1255832

Ryan, K. 2016. The "Dorset problem" revisited: The Transitional and Early and Middle Dorset periods in the Eastern Arctic. In: Friesen, M., and Mason, O., eds. The Oxford handbook of the prehistoric Arctic. Oxford: Oxford University Press. 761–782.
https://doi.org/10.1093/oxfordhb/9780199766956.013.37

Siebrecht, M., Desjardins, S.P.A., Hazell, S.M., Lofthouse, S., Cencig, E., Kotar, K., Jordan, P.D., and van Gijn, A. 2021. Magnifying the differences: Investigating variability in Dorset Paleo-Inuit organic material culture using microscopic analysis. In: Wild, M., Thurber, B., Rhodes, S., and Gates St. Pierre, C., eds. Bones at a crossroads: Integrating worked bone research with archaeometry and social zooarchaeology. Leiden: Sidestone press. 51–72.
https://pure.rug.nl/ws/portalfiles/portal/593437556/9789464270068.pdf

Sloan, A. 2014. Spirituality and the seamstress: Birds in Ipiutak and Western Thule lifeways at Deering, Alaska. Arctic Anthropology 51(2):35–59.
https://doi.org/10.3368/aa.51.2.35

Stenton, D., and Parks, R. 1998. Ancient stone tools of Nunavut: An illustrated guide. Ottawa: Parks Canada.

Van Gijn, A. 2006. Ornaments of jet, amber and bone. In: Jongste, P., and Kooijmans, L.P.L, eds. Schipluiden: A Neolithic settlement on the Dutch North Sea coast c. 3500 cal BC. Leiden: Analecta Praehistorica Leidensia 37/38. 195–206.

———. 2007. The use of bone and antler tools: Two examples from the Late Mesolithic in the Dutch coastal zone. In: Gates St Pierre, C., and Walker, R., eds. Bones as tools: Current methods and interpretations in worked bone studies. BAR International Series 1622. 79–90.

———. 2014a. Science and interpretation in microwear studies. Journal of Archaeological Science 48:166–169.
https://doi.org/10.1016/j.jas.2013.10.024

———. 2014b. Beads and pendants of amber and jet. In: Theunissen, E., Brinkkemper, O., Lauwerier, R., Smit, B., and van der Jagt, I., eds. A mosaic of habitation at Zeewijk (the Netherlands): Late Neolithic behavioural variability in a dynamic landscape. Amersfoort: Cultural heritage Agency of the Netherlands. 119–128.