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Reviewed Article:

Examining the Physical Signatures of Pre-Electric Tattooing Tools and Techniques

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This paper presents the first experimental archaeological study to formally compare the physical characteristics of tattoos made on human skin using multiple pre-modern tools and tattooing techniques. Our project used eight tools fashioned from animal bone, obsidian,

copper, and boar tusk, along with a modern steel needle, to create tattoos on the leg of co-author Danny Riday. Those tattoos were created through four different traditional, pre-electric techniques consisting of hand poking, hand tapping, incision, and subdermal tattooing. We then documented the tattoos over a six-month period to compare the results. This process revealed clear physical differences between tattoos created using different tools and methods. The resulting data is then used to assess preserved tattoos from archaeological sites in the Andes and Greenland in order to test assumptions about how those marks were created.

> In considering our study results we must also acknowledge the high level of skill held by tattooists in many or most pre-modern societies. Cross-cultural data from historical and ethnographic accounts and traditional cultural knowledge demonstrate that those individuals worked with tools and techniques rooted in generational knowledge that was honed over time to achieve optimal desired results.

Introduction

Tattooing was practiced by human societies throughout the past and around the world. Archaeological evidence for this history is documented on ancient human remains and through trace wear evidence on artifacts, which demonstrate the practice existed in both the eastern and western hemispheres by the mid- to late fourth millennium BC (Deter-Wolf, 2022; Deter-Wolf, et al., 2021). Over recent decades, historical, anthropological, and archaeological research, as well as traditional cultural knowledge, have combined to greatly expand appreciation of tattooing as a significant and ancient cultural practice. Despite this interest and recognition, many details regarding the tattooing customs of pre-modern societies remain unclear.

An ongoing question in understanding the archaeological footprint of tattooing relates to the tools and methods used to apply those marks. No uniform, cross-cultural tool or technique was used to tattoo among historical societies, and before the introduction of electric tools, tattooing technologies and methods varied by both region and culture (Robitaille, 2015). This diversity also extends into the pre-modern era. To date most efforts at identifying tattooing tools in archaeological collections, and the tattooing techniques used by ancient societies, have relied predominately on intuition and cross-cultural historical or ethnographic evidence rather than replicable physical data. It is only recently that scientific approaches including microwear studies and elemental analysis have been employed in the evaluation and identification of ancient tattooing artifacts (e.g. Deter-Wolf, et al., 2021; Gates St-Pierre, 2018; Gillreath-Brown, et al., 2019; Kononenko, et al., 2016).

One potential approach to evaluating the tattooing tools and techniques used by pre-modern societies lies in examining the specific physical characteristics of tattoos on archaeological human remains. To date preserved tattoos have been recorded on naturally- and deliberately

mummified bodies from over 50 archaeological sites, located across 13 countries and five continents (Deter-Wolf, 2022). In describing those tattoos some archaeologists have used traits including the length, shape, and cross-section of preserved marks to propose that certain tools or methods were employed in their creation (e.g., Allison, et al., 1981; Lynnerup, 2015; Sjøvold, 2003; Van Dalen Luna, et al., 2018). Those efforts to date are not grounded in first-hand knowledge of either professional tattooists or traditional cultural practitioners, nor are they based on comparative physical data from actual tattoos created using the suggested methods.

Prior experimental tattooing studies have employed pig skin to document the development of microwear on tool surfaces (e.g. Garvin Arcos, 2016; Deter-Wolf and Clark, 2017; Gates St-Pierre, 2018; Gillreath-Brown, et al., 2019; Kononenko, et al., 2016), as well as to assess the raw suitability of various tool forms for tattooing (e.g. Deter-Wolf and Peres, 2013; Pászik, 2021). Professional tattooists and primitive skills enthusiasts have documented efforts using a variety of non-electric tools to tattoo human skin, but not performed formal comparisons of results between tool types or techniques (e.g., Faust, n.d.; Junker, 2010; Hall, 2016; Krutak, 2019; Meyer, 2015; Piedade, 2020; Reime, n.d.). Finally, numerous professional tattooists and indigenous practitioners across the globe work with non-electric and traditional tools on a daily basis. Those practices continually demonstrate the suitability of various implements and methods to create successful tattoos, but do not compare the results in controlled experimental settings. Ours is the first experimental archaeological investigation to focus on comparing the physical characteristics of tattoos on human skin using pre-modern tools and methods.

Herein we document tattoos created using eight different pre-electric tools and four tattooing methods. Through documentation during the tattooing process and over a six-month period, we compare the results in order to identify observable differences. Our findings reveal that there are discernable variations in tattoos created using different tools and techniques. This data may be applied to the study of preserved remains from archaeological and museum collections, as well as to analysis of historical imagery and traditions, to illuminate previously unknown aspects of the associated cultures.

Methods

Pre-electric tattooing broadly encompasses four major techniques: *Hand poking, hand tapping, incision*, and *subdermal tattooing*. *Hand poking* encompasses traditions in which the tattooing tool is held in a precision grip between thumb and fingers and applied directly to the skin (See Figure 1). This technique covers a wide variety of tool materials, point and hafting arrangements, and angles of application, including but not limited to the widely known *sak yant* and *tebori* traditions and modern “stick and poke” tattooing. Percussive *hand tapping* includes practices where tattooing points or combs are hafted at an angle to their handle and driven into the skin using a beater or mallet (See Figure 2). This technique is

widely recognized among the public as being synonymous with traditional, pre-electric tattooing, and was historically limited to the southern Pacific Rim and pockets of inland Southeast Asia (Robitaille, 2015). During *incision tattooing* (also known as "cut and rub" tattooing), the epidermis is shallowly sliced in a linear fashion, typically using a metal blade or lithic implement (See Figure 3). Pigment is then rubbed into the wound from the surface. *Subdermal tattooing* was historically restricted to the northern circumpolar region and portions of South America and includes practices in which pigment is introduced laterally through the skin between two punctures. In one form of this technique strongly associated with Inuit culture (*Inuttut Kakiornerit*, also known as "skin stitching"), a small eyed needle is used to pull pigment-infused thread or sinew beneath the epidermis (See Figure 4). The exit hole of one "stitch" may act as the entry point for the next, thereby creating a solid line. Within all of these techniques there exists considerable variation in terms of materials, hafting arrangements, and point groupings.

Tool/Material	Technique
White tailed deer bone point	Hand poking
Copper awl	Hand poking
Obsidian flake	Hand poking
Modern 7RL tattoo needle	Hand poking
Gannet bone point	Hand tapping
Boar tusk comb	Hand tapping
Obsidian flake	Incision
Gannet bone eyed needle	Subdermal

TABLE 1. LIST OF TOOLS AND TECHNIQUES USED IN THE EXPERIMENTAL STUDY.

Our study incorporated eight tests (See Table 1): Hand poking using a bone point, a copper awl, the minimally retouched tips of obsidian flakes, and a modern 7RL (round liner) tattoo needle; Hand tap tattooing with a single bone point and with a boar tusk comb; Incision tattooing with obsidian flakes; And subdermal tattooing with an eyed bone needle. All tools excepting the modern tattoo needle and boar tusk comb were fashioned by authors Riday and Deter-Wolf using ethically and sustainably sourced materials, including obsidian from Waihi, New Zealand, and bones from Australasian gannet and white tailed deer. Creation of tools used for subdermal tattooing was guided by Inuk tattooist and co-author Sialuk Jacobsen. The boar tusk comb was provided by Mokonuiarangi Smith of Henderson, New Zealand. All tools used in the experiment were crafted using traditional or pre-electric technologies wherever possible, to ensure continuity with archaeological materials. Prior to tattooing all tools except for subdermal stitching needles were sterilized using a standard medical autoclave. To avoid potential loss of tool integrity those thin and fragile bone needles were instead sterilized manually using 90% isopropyl rubbing alcohol.

In July 2021 eight identical patterns were tattooed on the leg of co-author Danny Riday (See Figure 5). The specific design, measuring 5.9 cm tall and a maximum of 2 cm wide, was crafted by Riday to include both individual and intersecting lines, as well as filled areas, to account for potential variations in results. Riday, a professional tattooist from Hamilton, New Zealand, had prior experience tattooing with non-electric tattooing including both the hand poke and incision techniques, and before to the experiment launch, practiced subdermal tattooing under guidance from Sialuk Jacobsen using a separate set of tools. Riday created all hand poked, incision, and subdermal tattoos during the study. Hand tapping was done by professional tattooist Mokonuiarangi Smith.

Each pattern was executed with a single tool type and technique. Much of each pattern was marked using modern, commercial black tattoo ink, while the terminal triangle in each motif was outlined and filled using a soot-based ink harvested from burning kauri tree resin mixed with powdered charcoal, alcohol, and coconut oil. This was done to examine possible variations between natural and commercially produced tattoo pigment.

The tattooing process lasted nearly 12 hours. Treatment following tattooing consisted of standard aftercare including regular cleaning with soap and water, avoidance of restrictive clothing, and regular application of natural healing ointment. Antibacterial cream was applied to the tattoos created with obsidian tools to address redness and early signs of potential infection.

The resulting tattoos were photographed using a Cainda Digital WiFi Microscope at magnifications of between approximately 50-200X. Documentation took place immediately after testing, followed by daily intervals for five days. Further documentation was conducted after two weeks, and then at monthly intervals over a six month period. The collected digital imagery was then examined to identify discernable variations in the physical characteristics of the tattoos, including the shape of individual wounds, edge profiles and terminal ends of lines, and coverage/patterning within filled areas.

Results

The natural pigment used in the experiment did not set well within tattoos due to complications involving the viscosity of the coconut oil diluent. As the pigment approached room temperature the oil congealed, separating from the alcohol and pigments and rendering the ink ineffective. Although this discovery was instructive, the resulting faint and/or incomplete tattoos were not suitable for comparison during the study.

Individual punctures created by hand poking with a bone point (See Figure 6) were initially visible under magnification as oblong wounds, with jagged edges present in areas where punctures overlapped. Punctures were mostly closed over within two weeks, and by two months most ink deposited within the epidermis had faded, leaving only subdermal

pigments. Under magnification, lines hand poked with the bone tool exhibit sinuous edges and some internal separation related to the proximity of separate punctures. Some lines exhibit thin tails at the end, where individual punctures are situated outside the main body. Filled areas exhibit stippling, with separate marks discernable both macroscopically and under magnification.

The hand poke copper awl (See Figure 7) resulted in narrow, linear wounds resulting from the shallow angle at which the tool was applied. The punctures exhibited clean edge profiles, with little evidence of tearing or jagged edges even in overlapping areas. Some wounds were still visible at the skin surface up to one month after tattooing. Healed lines created by the copper tool exhibit sharper edge profiles than those made with either bone or obsidian hand poke tools, although still show some internal separation. Filled areas were more solidly packed with pigment than obsidian or bone hand poke tools, but under magnification still show stippling and separate discernable marks. Line ends are generally rounded and of uniform thickness.

Tattoos created by hand poking with obsidian flakes (See Figure 8) exhibited short linear- to triangular punctures varying according to the profile of the flake tip. Individual wounds were largely closed over following one month, and by three months pigment had settled in to connect separate punctures, resulting in solidly filled lines. During tattooing the obsidian flake was wielded at an angle relative to the overall line, rather than in a linear fashion, to allow for more concentrated “stacking” of consecutive punctures. As a result of this technique, the edges of the lines are irregular. Filled areas healed to a lighter color relative to other hand poke tools and exhibit some cloudiness. Subsequent microscopic inspection of the obsidian tools revealed that minute flakes detached along the active edge during tattooing. Those may have become embedded in the tattoo, resulting in initial redness and minor inflammation during healing.

A modern 7RL steel tattoo is composed of seven separate steel points soldered in a circular arrangement. Unlike the other tested hand poke tools, all of which consisted of a single point, the clustering of the tines acts to wick and retain pigment, facilitating regular deposition into the skin. Under magnification this tool caused the least amount of trauma to the skin surface (See Figure 9), and by two weeks almost no visible breaches in the epidermis remained. Hand poked lines created with the modern steel tool were generally of consistent width, while solid areas were packed with ink, exhibiting minor clouding and no unpigmented areas.

The hand tapped single point bone tool created short, oblong to linear punctures with greater variation in orientation than any of the hand poke tools (See Figure 10). Visible bruising surrounding the design after tattooing faded within two weeks. During healing, surface wounds were sealed, and epidermal pigments largely absent within two months. Lines created with this tool were irregular, and exhibit a wider, more randomized distribution of

individual marks than the hand poked examples. Filled areas were dense with pigment and show little internal variability.

Tattoos created by hand tapping with the multi-pronged boar tusk comb (See Figure 11) also exhibit some variability in the orientation of individual punctures. Surface wounds remained visible as individual dots of pigment in the upper epidermis for less than two months. Lines were dark and solid, with some outlying marks and slightly clouded edges. Pigment settled into shaded areas over the initial three month period, resulting in overall dark fill with some cloudiness throughout.

Incised tattoos made with an obsidian flake (See Figure 12) exhibited the greatest amount of skin trauma, particularly at points where individual cuts intersected. Despite this initial effect, by two weeks surface wounds were mostly no longer visible, and pigment was beginning to disappear from the upper epidermis. Lines initially exhibited clean, strong edges with a few thin, oblique trails resulting from changes to the angle of the tool or placement of overlapping cuts. By six months the edges of lines had become more indistinct, with some fuzzing and fading present. All lines exhibit distinctive thinning at one or both ends, formed by changes in the depth of the tool over the course of the incision. It was not possible to fill a solid area using the incision technique, and overlapping cuts created during that effort formed a complicated intersection of wounds. As with the hand poked obsidian test, the incision tattoo exhibited redness early in the healing process potentially related to loss of minute flakes along the tool's cutting edge.

Subdermal tattooing with an eyed bone needle and pigment-infused thread (See Figure 13) initially resulted in lines of discrete, round- to oblong dots surrounding circular punctures. Evidence of individual punctures persisted at skin surface for over 3 months. During that time pigment settled into the area between the punctures, connecting some adjacent entry and exit points. After six months some separation remained visible in the lines. Lines exhibited variability in terms of width, particularly in "blown out" areas where the pigment was deposited too deeply and failed to encapsulate during healing. It was not possible to create solid, filled areas using the subdermal technique.

Discussion

The physical characteristics of tattoos recorded in this study provide a limited window into pre-modern practices and technologies. Variables including number of points, angle of hafting, and the shape of a tool's distal tip all may affect traits such as edge profile and pigment coverage within filled areas. In addition, certain observable qualities including stippling and internal separation of lines might be reduced by extended or repeated tattooing sessions. Finally, the duration of our project does not account for taphonomies that might affect the physical characteristics of tattoos preserved in the archaeological record, such as cultural or natural mummification processes, and centuries of exposure or weathering.

In considering our study results we must also acknowledge the high level of skill held by tattooists in many or most pre-modern societies. Cross-cultural data from historical and ethnographic accounts and traditional cultural knowledge demonstrate that those individuals worked with tools and techniques rooted in generational knowledge that was honed over time to achieve optimal desired results. In traditional *Inuttut Kakiornerit*, for example, the sewing skills of Inuit women aided in creation of consistent, solid lines without blown out areas such as we encountered.

Despite the caveats outlined above, data collected during our study provides a framework for an informed evaluation of tattoos on archaeological remains, including examples from South America and Greenland. Preserved tattoos are found on hundreds of mummies at archaeological sites in the Pacific coastal deserts of Peru and Chile (Deter-Wolf 2022). Archaeologists have previously claimed that ancient Andean tattoos were made via subdermal, incision, or hand poking techniques based on observed traits, but not presented specific physical evidence or comparative data through which to test their hypotheses (e.g., Allison, et al., 1981; Van Dalen Luna, et al., 2018). Microscope imagery of a preserved tattoo from the site of Ancón, Peru recorded by the senior author in the collection of the Peabody Museum of Archaeology and Ethnology, Harvard University provides an opportunity to evaluate such claims using our project data (See Figure 14). The comparison reveals that this tattoo, consisting of a stepped fret motif with adjacent circles rendered in negative within a filled black wristband, was not made using either incision or subdermal techniques. Based on the visible stippling of the filled area and comparison of edges to interior space, our data suggests that the design was hand poked in two steps, first outlined with a single point tool and then filled in.

This conclusion does not categorically indicate that subdermal and incision methods were never used for tattooing in ancient Andean societies, but instead reiterates that pre-electric tattooing technologies within a given historical or ancient culture were not necessarily monolithic. Just as contemporary tattoo artists use a variety of needle arrangements to address specific lining and shading needs, different tool forms and/or techniques were likely used in the past to achieve different desired effects.

One example of the incorporation of multiple techniques is exhibited in tattoos preserved on the mummies from Qilakitsoq, Greenland (Hansen, et al., 1991). No discernible differences in the physical character of the tattoos appear in illustrations of those mummies (See Figure 15; e.g., Kapel, et al., 1991). However, direct investigations by author Sialuk Jacobsen have identified that the lines on the forehead of Mummy 5 from Qilakitsoq are approximately 300% thicker than other tattoos in the group. Broad lines also appear historically in chin tattoos of Inupiaq and Inuviaaluk women photographed in Canada's Northwest Territories and northern Alaska. Those tattoos include a broad central line measuring 3-5 mm in width, which in the case of Inupiaq women is flanked to either side by thinner lines (See Figure 16).

Although many *Inuttut Kakiornerit* are indeed created through subdermal tattooing, the results of our study and further personal experimentation by Sialuk Jacobsen demonstrate that creating thick lines is not likely to have been accomplished in this manner. Although additional microscope imaging is required to evaluate the specific physical traits of tattoos on the Qilakitsoq mummies, based on this study we suggest that thick lines seen on Mummy 5 and in traditional Inupiaq and Inuviaaluk tattoos were created by hand poking with a bone, iron, or later steel needle rather than through subdermal methods.

Conclusions

By combining experimental study, systematic analysis, and practitioner knowledge, our investigation presents a new data set for evaluating the tools and methods used to create tattoos in pre-modern societies. These results have already provided some insights into the details of tattooing practices in both the Andes and Greenland, and by comparing the physical characteristic of tattoos preserved on human mummies with actual tattoos created using pre-modern tools, scholars may gain further insights into cultures from across the globe. The data presented here also extends beyond the academic realm, and we hope will support efforts of indigenous practitioners and scholars working to better understand their own historical practices in their places of origin.

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Keywords tattoo
interpretation

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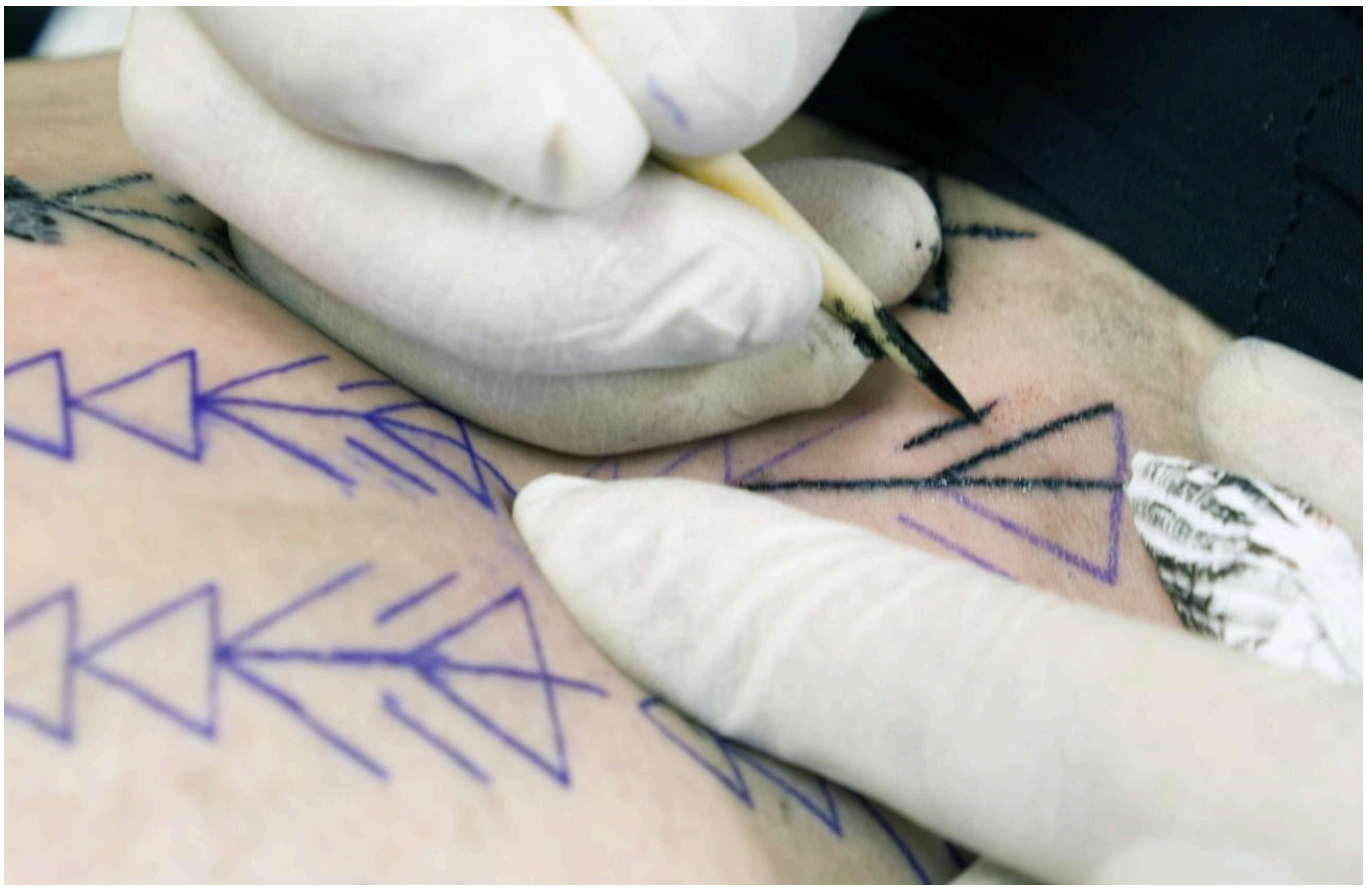

FIG 1. HAND POKE TATTOOING DURING THE STUDY USING A DEER BONE POINT. PHOTO BY CANDICE NEL

FIG 2. HAND TAP TATTOOING DURING THE STUDY USING A BIRD BONE POINT HAFTED TO A WOODEN HANDLE AND APPLIED BY STRIKING WITH A WOODEN BEATER. PHOTO BY CANDICE NEL

FIG 3. INCISION TATTOOING DURING THE STUDY USING AN OBSIDIAN FLAKE. PHOTO BY CANDICE NEL

FIG 4. SUBDERMAL TATTOOING DURING THE STUDY USING AN EYED BIRD BONE NEEDLE PULLING PIGMENT INFUSED THREAD. PHOTO BY CANDICE NEL

FIG 5. COMPLETED TATTOOS, THE DAY THEY WERE CREATED (LEFT) AND AFTER SIX MONTHS OF HEALING (RIGHT). UPPER ROW, LEFT TO RIGHT: SINGLE BONE POINT HAND TAPPED; COPPER AWL HAND POKED; OBSIDIAN INCISED; BONE NEEDLE SUBDERMAL. LOWER ROW, LEFT TO RIGHT: BOAR TUSK COMB HAND TAPPED; MODERN STEEL NEEDLE HAND POKED; BONE POINT HAND POKED; OBSIDIAN HAND POKED. PHOTOS BY DANNY RIDAY

FIG 6. BONE POINT HAND POKED TATTOOS UNDER MAGNIFICATION, ON DAY 1 (TOP), AT 3 MONTHS (MIDDLE) AND AT 6 MONTHS (BOTTOM). PHOTOS BY DANNY RIDAY

FIG 7. COPPER AWL HAND POKED TATTOOS UNDER MAGNIFICATION, ON DAY 1 (TOP), AT 3 MONTHS (MIDDLE) AND AT 6 MONTHS (BOTTOM). PHOTOS BY DANNY RIDAY

FIG 8. OBSIDIAN FLAKE HAND POKED TATTOOS UNDER MAGNIFICATION, ON DAY 1 (TOP), AT 3 MONTHS (MIDDLE) AND AT 6 MONTHS (BOTTOM). PHOTOS BY DANNY RIDAY

FIG 9. MODERN STEEL 7RL NEEDLE HAND POKED TATTOOS UNDER MAGNIFICATION, ON DAY 1 (TOP), AT 3 MONTHS (MIDDLE) AND AT 6 MONTHS (BOTTOM). PHOTOS BY DANNY RIDAY

FIG 10. HAND TAPPED SINGLE POINT BONE TOOL TATTOOS UNDER MAGNIFICATION, ON DAY 1 (TOP), AT 3 MONTHS (MIDDLE) AND AT 6 MONTHS (BOTTOM). PHOTOS BY DANNY RIDAY

FIG 11. HAND TAPPED BOAR TUSK COMB TOOL TATTOOS UNDER MAGNIFICATION, ON DAY 1 (TOP), AT 3 MONTHS (MIDDLE) AND AT 6 MONTHS (BOTTOM). PHOTOS BY DANNY RIDAY

FIG 12. OBSIDIAN FLAKE INCISED TATTOOS UNDER MAGNIFICATION, ON DAY 1 (TOP), AT 3 MONTHS (MIDDLE) AND AT 6 MONTHS (BOTTOM). PHOTOS BY DANNY RIDAY

FIG 13. SUBDERMAL BONE NEEDLE TATTOOS UNDER MAGNIFICATION, ON DAY 1 (TOP), AT 3 MONTHS (MIDDLE) AND AT 6 MONTHS (BOTTOM). PHOTOS BY DANNY RIDAY

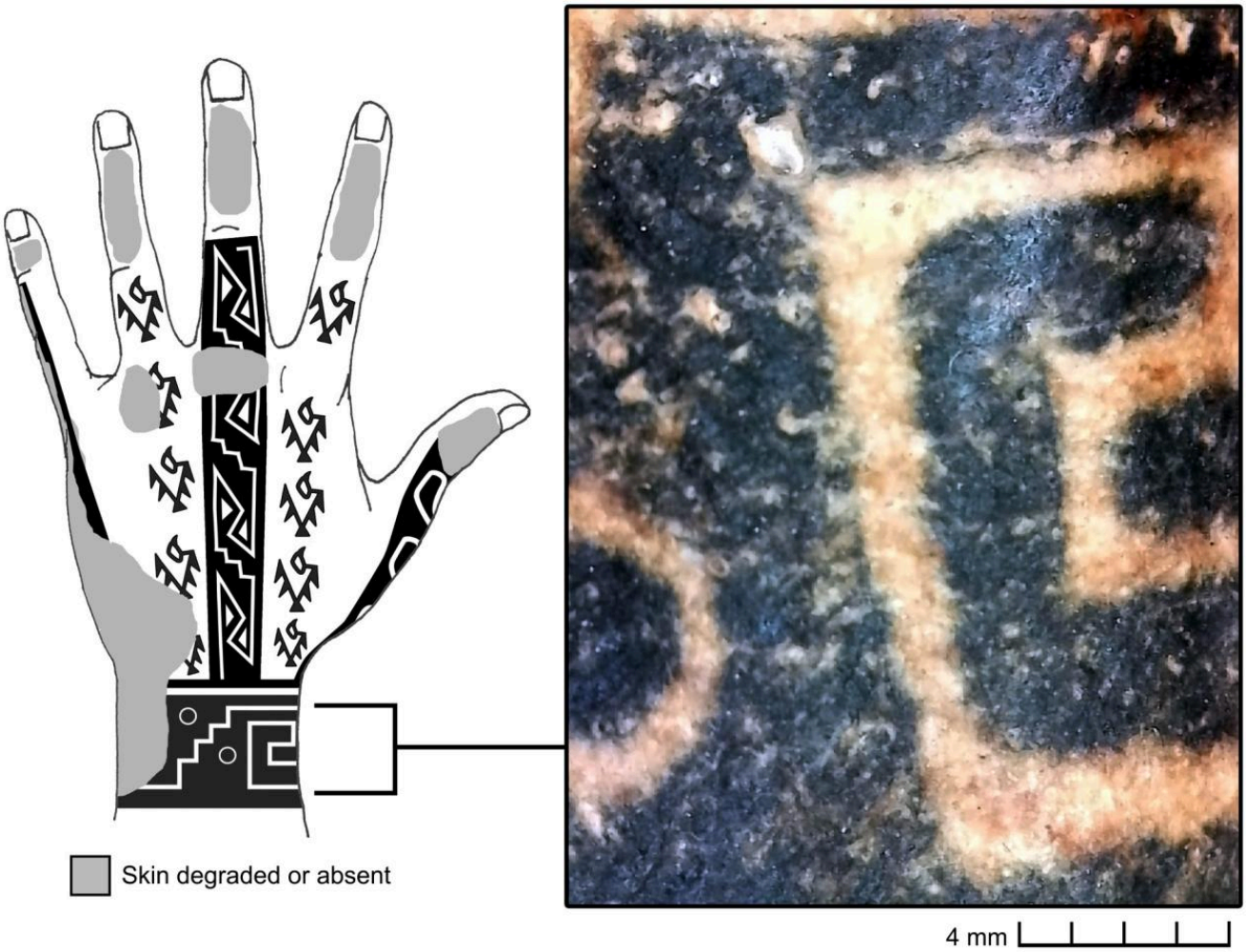

FIG 14. MICROSCOPE DETAIL OF PRESERVED PRE-COLUMBIAN TATTOO FROM ANCÓN, PERU. IMAGES BY AARON DETER-WOLF FROM THE COLLECTION OF THE PEABODY MUSEUM OF ARCHAEOLOGY AND ETHNOLOGY, HARVARD UNIVERSITY, 87-61-30/54485. PHOTO AND DRAWING BY AARON DETER-WOLF

FIG 15. LINE DRAWINGS OF TATTOOS ON MUMMIES 3, 4, AND 5 FROM QILAKITSOQ, GREENLAND. DRAWINGS SUCH AS THESE DO NOT ACCURATELY REFLECT PHYSICAL VARIATIONS PRESENT IN THE PRESERVED TATTOOS. REDRAWN AFTER KAPEL ET AL. 1991 BY AARON DETER-WOLF

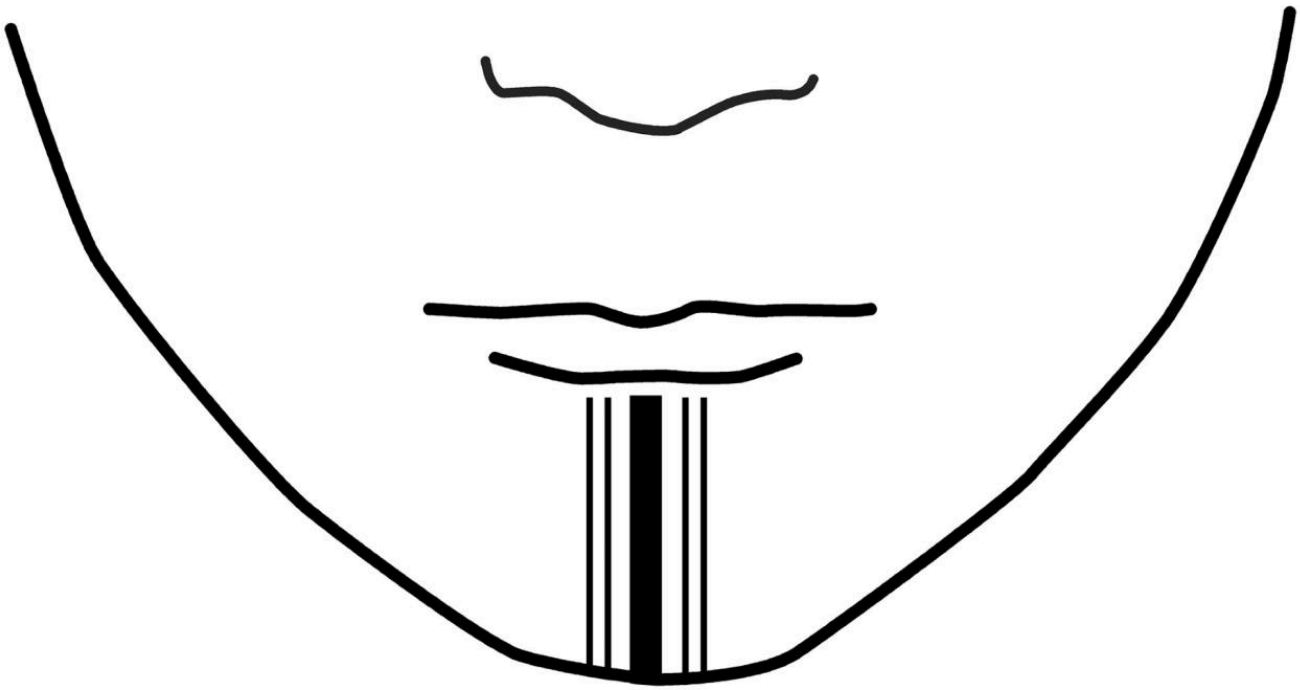

FIG 16. EXAMPLE OF INUPIAQ CHIN TATTOOING SHOWING VARIATIONS IN LINE WIDTH. DRAWING BY AARON DETER-WOLF