The perception of gloss: a comparison of three methods for studying intentionally polished bone tools

Justin Bradfield (justinb@uj.ac.za), Palaeo-Research Institute, University of Johannesburg, P.O. Box 524, Auckland Park, 2006, Johannesburg, South Africa

Abstract

Polished bone and stone tools are well known from many archaeological contexts. In use-wear studies, polish is usually characterised by the degree of surface roughness, or more subjectively by its visual appearance. Visual appearances, however, may be deceptive, and the scale of analysis of traditional surface roughness studies is often too fine to consider the overall visual effect of a polished surface. Here I consider three techniques for characterising modified bone surfaces and assess the correlation between surface roughness and gloss. My results show that softer contact materials generally produce higher gloss values than harder materials, but within these two broad categories results are more complex. Based on these experimental results a trial assessment is presented of archaeological bone tools from assorted Holocene sites. The ability to perceive and appreciate polished surfaces is linked to developments in the superior temporal sulcus region of the human brain, which is the same region in which our ability to perceive shapes and colour originated. Deliberately polished bone tools from Pleistocene contexts therefore have the potential to provide insights in to cognitive developments in our species. The specular reflectance or gloss of a polished surface provides a quantifiable and repeatable measure, more suitable than surface roughness analysis, for characterising deliberate polish, although a combined approach is advocated.

Keywords: Glossmeter; polished bone; atomic force microscopy; surface roughness; visual perception; superior temporal sulcus

Introduction

Polished bone and stone tools are known from many archaeological contexts around the world. Since the publication of the English translation of Sergi Semenov's (1964) book, scholars have recognised that the characterisation of polishes and micro-striations that develop on a tool's surface can provide information about the contact material and the type of activity in which a tool was involved, which in turn can tell us about subsistence practices, economic activities and possible ritual behaviour in the past (e.g., Stemp et al., 2016). In most cases this micro-wear is the result of use, but sometimes it is deliberately applied. Deliberate polishing may form part of the production and finishing process of the tool (e.g., Soressi et al., 2013). Some bone tools, however, were polished far beyond the extent necessary to impart a smooth surface. For example, a bone point (SAM-AA-8947) recovered from 75-77 ka levels at Blombos Cave on the south coast of South Africa, is so highly polished over its entire surface that it is thought to have been deliberately applied to "add value" to the tool (Henshilwood et al., 2001: 668). Polished bone tools, like other decorative ornaments, may have been used for social and other symbolic signalling in the past (Gamble, 1980; Bird & Smith, 2005; Majkić et al., 2017). Bone tools may be intentionally polished for symbolic purposes, or to prolong the life of the tool, as polished surfaces are more resilient to the effects of weathering (Moore, 2013).

Polish is usually the result of abrasive smoothing of an object's surface, although certain accretive substances, such as silica deposits, may also impart polish (Fullagar, 1991; d'Errico et al., 1995). Although we tend to characterise polishes based on surface roughness properties (e.g., Keeley, 1974; Griffitts & Bonsall, 2001; Gonzales-Urquijo & Ibanez-Estevez, 2003; Fullagar, 2006; Van Gijn, 2007; Bradfield, 2015a; MacDonald et al., 2018; Martisius et al., 2018), it is unlikely that people in the past viewed their polished tools in these terms. It seems self-event that people would have assessed the polish on their tools based on its aesthetic visual and tactile appeal. A polished tool may be deemed attractive owing to its gloss or lustre. Gloss is a visual quality of a surface related to the manner in which specular light is reflected, and is measured in gloss units (Gu). Gloss indexes have been used in the paint and textile sectors for many years (Ingersoll, 1921; Quynn et al., 1950; Vashisht & Radhakrishnan, 1974), yet have not found a widely accepted archaeological application. Whereas archaeologists have tended to focus on various surface roughness measurements (e.g., Ra, Rq and Rz values; but see Martisius et al., 2018 for a different set of roughness parameters), gloss may be a more appropriate measurement for intentionally polished surfaces as it is more closely related to our ability to perceive and appreciate the visual qualities of objects than surface roughness.

Here I present an experiment and case study to assess the relevance of gloss measurements for analysing deliberately polished bone tools. The intentionality of polish application to the archaeological bone tools is inferred based on extent and degree (i.e., well-developed polish occurring over the entire surface of the bone tool; see Shipman & Rose, 1988; d'Errico et al., 1995; Griffitts, 2006), as well as the absence of markers to indicate taphonomic or other natural causes (e.g., Olsen, 1984; Nami & Scheinsohn, 1993; Fisher, 1995; Andrews, 1997; Thompson et al., 2011; Rabet & Piper, 2012; Zhang et al., 2018). I compare and contrast traditional tracaeological descriptions obtained with a reflected light microscope, surface roughness measurements obtained with Atomic Force Microscopy (AFM) and gloss measurements obtained with a glossmeter. The reflective index of a surface is quickly and effortlessly measured with a glossmeter. The relevance and potential application of gloss measurements to the overall traceological repertoire is assessed.

Background to the study of polished bone and stone tools

The archaeological application of traceology has a long and complex history, owing to the perceived subjectivity of observations and descriptive discrepancies between different analysts (cf. Keeley, 1974, 1980; Newcomer et al., 1986, 1988; Gonzales-Urquijo & Ibanez-Estevez, 2003; Evans et al., 2014; Van Gijn, 2014; Stemp et al., 2016). Although reflected light microscopy is still used to evaluate use-wear (e.g., Fullagar, 2006, Bradfield, 2015a; Falci et al., 2018), there has been growing reliance on profilometric techniques, including AFM, capable of quantifying surface roughness features, including polish (e.g., Evans & Donahue, 2008; d'Errico & Backwell, 2009; Guisca et al., 2012; Stemp, 2013; Martisius et al., 2018; Ibanez et al., 2019; Stemp et al., 2019). In microwear studies, polish is used, in a general sense, to discriminate between hard and soft contact materials, and may be described qualitatively by its extent, distribution, texture (matt, dull, smooth etc.) and brightness (high, bright, weak etc.), or by its surface roughness values (e.g., Ra, Rq and Rz) (Lemoine, 1994; d'Errico et al., 1995; Kimball et al., 1995; Gonzales-Urquijo & Ibanez-Estevez, 2003; Griffitts, 2006; Stone, 2013). Kimball et al. (1995) and Watson & Gleason (2016) found strong congruence between qualitative descriptions and quantitative surface roughness measurements. One of the limitations of many quantitative surface roughness techniques, however, is that their scale of analysis is very small. Most of these studies rely on characterising relatively small areas of a tool's surface, typically in the region of 20-100 μm^2 (but see d'Errico & Backwell, 2009 and Martisius et al, 2018 for examples of scan lengths of 300-700 μm^2). This can create a problem of not recognising the forest from the trees (see Calandra et al., 2019), and provides no consideration of the specular qualities (or gloss) of the polished surface (i.e., the degree to which it reflects light), which is only discernible at a larger scale of analysis.

Gloss may be defined as the specular reflectance of a surface. Polished surfaces tend to reflect light, whereas rough surfaces scatter light (Quynn et al., 1950; Vashisht & Radhakrishnan, 1974). The smoother the surface, the acuter the angle of light reflectance, the higher the gloss value. Specular reflectance is measured in gloss units (Gu). While there is no linear relationship between the various surface roughness parameters and Gu units, gloss values tend to increase as Ra values decrease (Vashisht & Radhakrishnan, 1974). Gloss measurements are subject to some limitations, however. The shape, texture and colour of an object can all adversely affect the specular reflectance of a surface, as indeed can any film or residue adhering to the surface (Quynn et al., 1950; Vashisht & Radhakrishnan, 1974; Chadwick & Kentridge, 2015). For these reasons Quynn and colleagues (1950: 508) described Gu values as “convenient but not necessarily empirically valid ratings”.

Specular reflectance, or gloss, has been a standard measurement in the paint and fabric industries for many decades (Anderson & Reamer, 1940; Quynn et al., 1950), and its application in other sectors, such as dermatology, is growing (Asamoah & Peiponen, 2018). Keeley (1980) made the first attempt to quantify the brightness of use-wear polish using a light intensity metre. His results, however, were criticised for incorporating areas containing polished and unpolished surfaces in his readings (see Vaughn, 1985). Since then, except for notable exceptions (e.g., Pelter & Plisson, 1986; Fullagar, 1991; O’Connor et al., 2014), gloss is seldom considered in assessments of use-wear polish.

The aesthetic properties of gloss and how gloss is perceived by the human brain are important considerations when discussing deliberately polished bone tools. Indeed, the consumers’ psychological experience of glossy surfaces and the appeal that gloss gives to a product is an acknowledged factor in the marketing strategies of many retail companies (e.g., BAMR, 2019). If we allow that bone tools were deliberately polished as a symbolic gesture to beautify the tool (e.g., Gorman, 2000; Henshilwood et al., 2001; Luik, 2011), then some understanding of how the human brain perceives polish and gloss is important.

The perception of gloss is processed in the superior temporal sulcus region of the brain (Kentridge et al., 2012; Okazawa et al., 2012; Wada et al., 2014), the development of which is linked to early cognitive developments in primates (Nisho et al., 2012). The superior temporal sulcus is responsible for numerous aspects of social cognition, including empathy, perspective-taking, high levels of prosocial behaviour and theory of mind (Sturm et al., 2016). In both humans and lower primates, the superior temporal sulcus is involved in reading facial expressions and audio-visual cue processing (Kropotov, 2009; Albohn & Adams, 2016). How people perceive gloss is just as important from a psychological perspective as how people perceive colour and texture. Individuals may perceive gloss differently, just as colour may be perceived differently, depending on a host of factors, including activation zones in the brain (Chadwick & Kentridge, 2015). Correlating the physical properties of polished surfaces or gloss measurements with how these are perceived psychologically, however, is not straight forward (Quynn et al., 1950; Chadwick & Kentridge, 2015). The physical properties of gloss ought to take into account a large enough surface area to be meaningful (Vashisht & Radhakrishnan, 1974). In other words, variables measured over a sub-millimetre area are unlikely to provide suitable information about the overall effect of the gloss/polish on the human brain and how this is perceived. Mainstream surface roughness studies then may be of little value for understanding this aspect of polished tools.

Finely made and deliberately polished bone tools are known from many sites in addition to the well-known bone point from Blombos Cave. In more recent periods, bone arrowheads were "polished" by rubbing against a flat whetstone in order to impart a "white lustre" to the surface (Goodwin, 1945: 438). Although it is not mentioned what type of stone was used, nor exactly what is meant here by 'polish', other instances are recorded of stones used to polish bone tools from Neolithic contexts in Europe (Olsen, 1984). A fine sediment applied to a leather cloth is also thought to have been used as an aid to polish bone tools from Later Stone Age contexts in Africa (Barham, 2002) and Uluzzian and Châtelperronian contexts in Europe (d'Errico et al., 2003, 2011). Bone sewing needles from early Holocene contexts in China were highly polished as a final stage in their manufacture, although the material used to polish them is not mentioned (d'Errico et al., 2018). Experimental studies have shown polish to develop on bone surfaces as a result of prolonged fricative contact with a wide range of both hard and soft materials (e.g., LeMoine, 1994; Buc, 2011; Bradfield, 2015a; Martisius et al., 2018).

Methods

I conducted two sets of analyses to better understand the suitability of Gu measurements, their relationship to traditional surface roughness values derived from AFM, and the qualitative visual descriptions of worked bone tool surfaces based on reflected light micrographs. In the first instance, a set of seven experimental bone tools, which had been used to work different contact materials for 30 minutes was analysed. The surface use-wear descriptions obtained via reflected light microscopy have been published previously (see Bradfield, 2015a). Briefly, prepared bone blanks were rubbed by hand for 30 minutes, each on a different contact surface, and the resulting surface deformation recorded.

These specimens were prepared for the present study by cleaning their surfaces of incidental oils and particulates, which may have accrued during the intervening period, following standard protocol (MacDonald & Evans, 2014). Two surface roughness parameters (Ra and Rz) were obtained using a Veeco Di3100 AFM set to tapping mode. Ra is the averaged roughness of all points on a plane, whereas Rz represents the averaged values of the five highest peaks and 5 lowest valleys. Standard protocol with AFM use-wear studies differs only in respect to the size of the scan area, with scan lengths ranging from 15 µm (e.g., Kimball et al., 1995) to 700 µm (e.g., Martisius et al., 2018). I used a scan length of 50 µm for an effective scan area of 2470 μm^2. Although a larger scan area would have been preferred, this is the limit of the Veeco Di3100 machine.

Gloss unit (Gu) values were measured using a Graigar WG60 portable glossmeter, with 60° light source, 8 mm x 4 mm light aperture, and 0-200 Gu capability. Gloss measurements were taken of those areas that visually appeared to be the shiniest. Ten readings were taken of each area and averaged. All my readings were obtained in a light-controlled environment to help limit incidental light contamination. Glossmeters measure the specular reflectance of a surface by projecting a light at a 60° angle onto a surface and measuring the reflected light (Wen, 2016). The acuter the angle that light is reflected, the higher the gloss unit value will be (Fig. 1). Gu measurements are automatically calculated relative to a black glass standard. Glossmeter readings have a natural advantage over AFM, as they are obtained without direct contact with the artefact's surface. Vashisht and Radhakrishnan (1974) found no appreciable differences in Gu readings obtained with apertures greater than 1.6 mm.

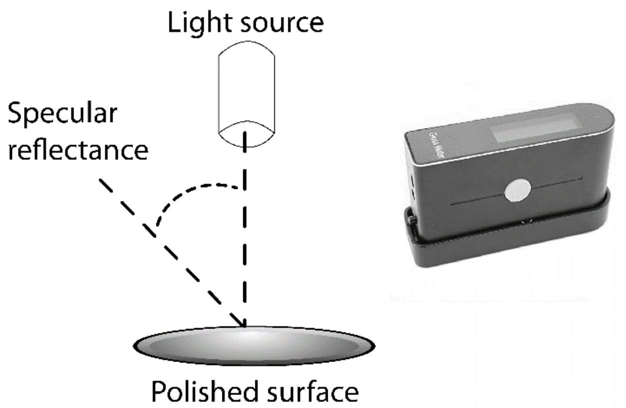


Figure 1. Schematic representation showing the principles of specular reflectance. The glossmeter on the right works by projecting a beam of light onto a polished surface. The angle at which the light is reflected is measured and a gloss unit value assigned. Polished surfaces tend to reflect light at close to 90°, whereas rougher surfaces scatter light away from the source.

Background to the archaeological samples

The archaeological specimens chosen for this study come from several collections dispersed across the country. The specimens were selected for inclusion in this study based on their polished appearance and texture. There is no other rationale for selecting specimens from these particular sites other than that they were conveniently accessible.

The examples of polished bone tools included in this study come from Holocene deposits at several sites in South Africa (Fig. 2), dating to between 6540 BP and 1100 BP. There is very little commonality between all of these sites, except that they have yielded bone tools. In the case of the south coast sites, Byneskranskop, Die Kelders and Nelson Bay Cave, they were occupied in the winter months, during which marine and terrestrial fauna were consumed (Klein, 1972; Schweitzer & Wilson, 1978, 1982; Schweitzer, 1979; Klein & Crus-Uribe, 2000). A wide range of bone tool types are present at these sites, with putative arrow components being the most common. The range of formal bone tools contrasts with the relatively informal nature of the lithic assemblages during this time period, at least at Die Kelders and Nelson Bay Cave (Schweitzer, 1979; Schweitzer & Wilson, 1982; Deacon, 1984). Several bone tools from these sites are very highly polished – an attribute none of the authors mention. Polish seems restricted to points and awls.

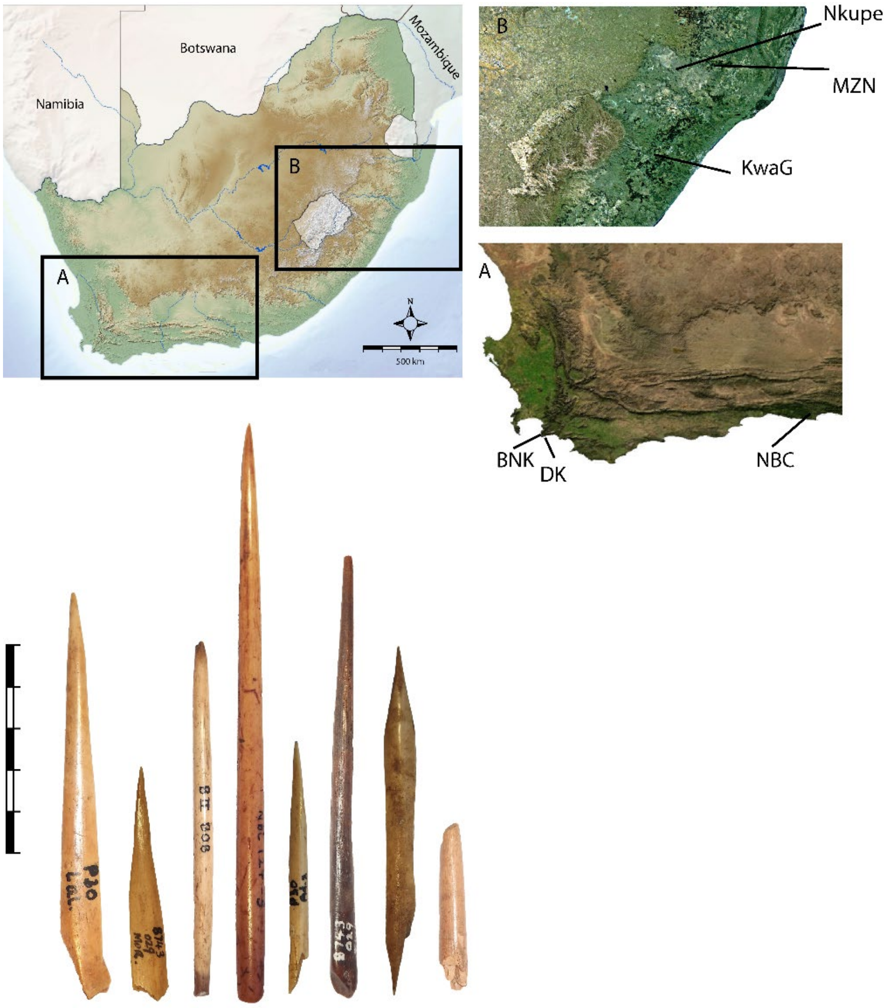


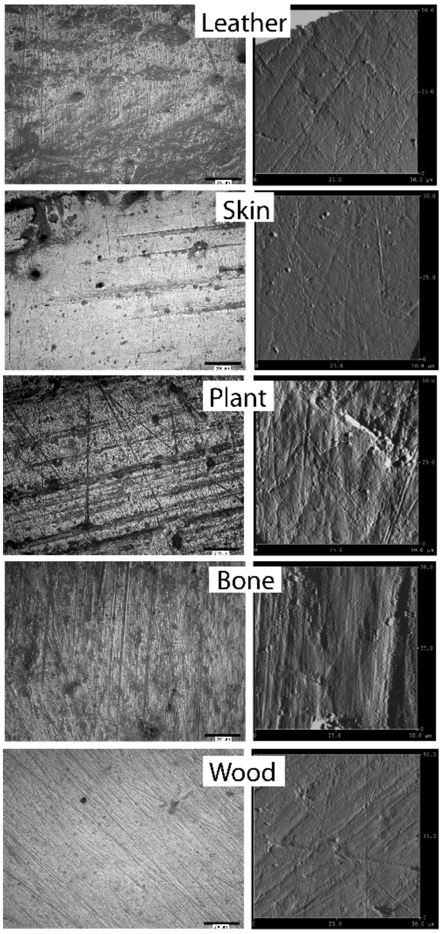
Figure 2. Map showing the location of sites in two regions of South Africa. A) Byneskranskop (BNK), Die Kelders (DK), and Nelson Bay Cave (NBC) in the Western Cape. B) KwaGandaganda (KwaG), Mzinyashana (MZN), and Nkupe in KwaZulu-Natal. Below are eight of the polished bone artefacts examined in this paper.

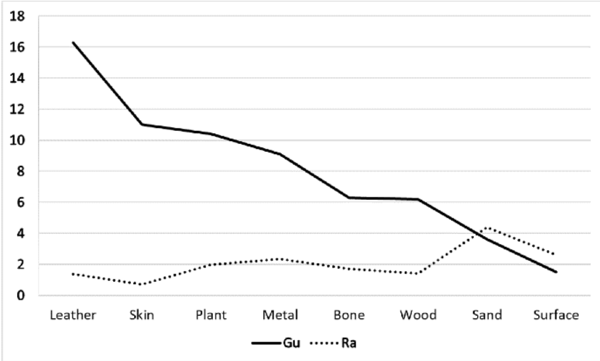
The three sites in KwaZulu-Natal, Mzinyashana, Nkupe and Kagandaganda, are mostly younger in age than the three coastal sites, and, except for Nkupe, the polished bone examples come from first millennium AD levels. Mzinyashana and Nkupe have large bone tool assemblages comprising many different tool types and were hunter-gatherer sites during this period, occupied during the spring and early winter months in the case of Mzinyashana (Mazel, 1997; Plug, 2002), and summer to autumn in the case of Nkupe (Mazel, 1988). KwaGandaganda, on the other hand, was an Iron Age agriculturalist village, with few bone tools (Whitelaw, 1994). Bone points, akin to arrow components, are the most frequent worked bone type at Mzinyashana and Kwagandagada, whereas Nkupe is dominated by awls and spatulae. The large number of pointed bone tools from Kwagandaganda is unusual in that bone points are never frequent at Iron Age sites in southern Africa, although they do occur. Polish seems restricted to points and awls, although the fish hooks at Mzinyashana and Nkupe are all finely polished similar to fish hooks from other nearby sites (e.g., Maggs & Ward, 1980; Mazel, 1989). Polish occurring over the entire surface of the bone tools is rarer, with only two examples out of 406 pieces of worked bone from Nkupe (Bradfield, 2014, 2015b), and a solitary example from Mzinyashana.

Results

The results of the experimental bone sample are presented in Figure 3. Congruent with the findings of Vashisht & Radhakrishnan (1974), gloss values *tend* to decline as roughness values increase, but no direct correlation exists. It is apparent that the softer contact materials (leather, skin and soft plant tissue) produce a higher gloss than the harder contact materials (metal, bone and wood). But, if we look at just the two broad categories of hard vs soft contact materials then the results seem reversed, with the harder type of material in each category producing higher average gloss values than the softer type. For example, in the category of hard contact materials the hardest of these (metal) produces a higher average gloss value than the softest (wood). Likewise, in the category of soft materials, leather produces a higher average gloss value than plant tissue.

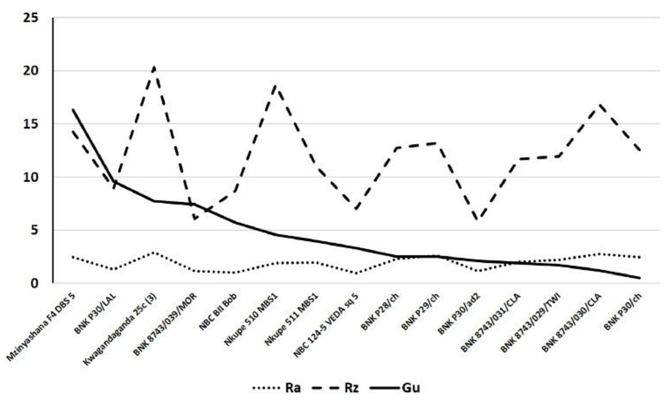
The natural, unaltered bone surface produced the lowest average gloss value and the second highest average roughness value. Unsurprisingly, the bone surface that underwent coarse-grained sediment abrasion had the highest roughness values, yet its average gloss value was higher than the natural bone surface. This may be because tiny quartz particles in the sediment impart a smooth shiny quality to the striation ridges (see Bradfield 2015a: table 2). This shiny quality lends credence to the notion that people sometimes used sand or ochre powder wrapped in a leather cloth to polish their bone tools (sensu Barham, 2002).





	Gu	Rz	Ra
Leather	16.3	8.68	1.36
Skin	11	19.74	0.7
Plant	10.4	9.2	1.98
Metal	9.1	9.51	2.34
Bone	6.3	8.18	1.7
Wood	6.2	2.96	1.42
Sand	3.6	18.05	4.4
Surface	1.5	15.51	2.6

Figure 3. Results of the experimental bone scans. The images on the left come from Bradfield (2015a) and show the surfaces of bone used to work various materials as seen under a reflected light microscope. Micrographs are taken at 100x magnification. The scale bars represent 500 µm. The images on the right show the surfaces of the same specimens obtained during AFM scanning. Scan areas are 50 μm^2. The graph shows comparative Ra and Gu values for each specimen. Note that, although there is no direct correlation, Gu values decline as Ra values increase.



	Ra	Rz	Gu
Mzinyashana F4 DBS 5	2.45	14.26	16.32
BNK P30/LAL	1.31	8.91	9.6
Kwagandaganda 25c (3)	2.92	20.33	7.72
BNK 8743/039/MOR	1.13	6.08	7.4
NBC BII Bob	1.01	8.68	5.7
Nkupe 510 MBS1	1.9	18.68	4.56
Nkupe 511 MBS1	1.95	10.99	3.94
NBC 124-5 VEDA sq 5	0.94	7.03	3.3
BNK P28/ch	2.33	12.74	2.5
BNK P29/ch	2.62	13.18	2.5
BNK P30/ad2	1.13	5.83	2.1
BNK 8743/031/CLA	2.02	11.69	1.9
BNK 8743/029/TWI	2.2	11.94	1.7
BNK 8743/030/CLA	2.78	16.8	1.2
BNK P30/ch	2.46	12.53	0.5

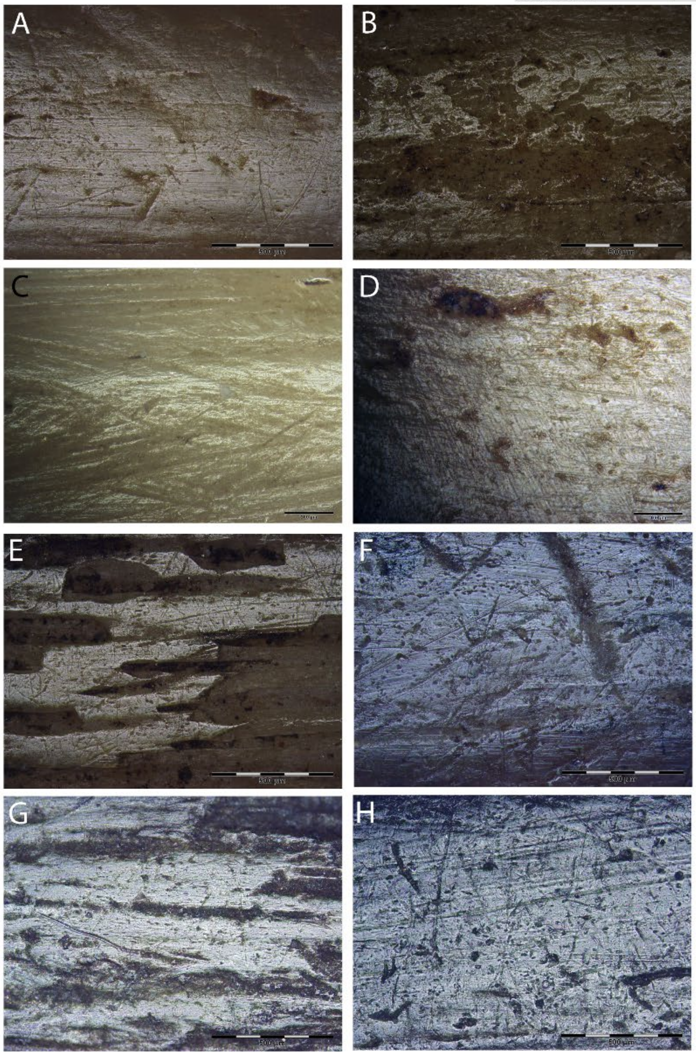


Figure 4. Results of the archaeological polished bone tools. The graph reflects the same trend seen in the experimental sample where gloss values decline as surface roughness values increase. Importantly, however, there is no direct correlation between Gu and Ra values of individual specimens. This is highlighted in the Rz spectrum. Below are reflected light micrographs obtained of the polished surfaces of some of the artefacts: A) BNK P30/LAL; B) BNK 8743/039/MOR; C) NBC Bii Bob; D) NBC 124-5 VEDA; E) BNK P25; F) BNK P30; G) BNK 8743/029/TWI; H) BNK 8743.030/CLA. Micrographs are taken at 100x magnification. The scale bars represent 500 µm.

The results of the 15 archaeological bone tools analysed is presented in Figure 4 and shows a similar pattern. There is little correlation between surface roughness and gloss. However, if we compare my use-wear analysis (see Fig. 4 micrographs of selected specimens) with the gloss readings it is clear that softer contact materials produced the highest Gu readings. Based on the visual appearance of the bone surface deformation, micro-striations and pitting, I interpret the contact materials as follows: soft malleable contact material is indicated on BNK P30/LAL; BNK 8743/039/MOR; NBC Bii Bob; BNK 8743/029/TWI (Fig. 4A-C, G). A hard, contact material, possibly wood is indicated on NBC 124-5 VEDA; BNK P25 (Fig. 4D, E), while a very hard contact material, similar to bone, is indicated on BNK P30; BNK 8743.030/CLA (Fig. 4F, H). The only exception to the pattern just described is BNK 8743/029/TWI (Fig. 4G), which, from a traceological perspective, appears to have contacted a soft skin-like material, yet produced a relatively low gloss value. I discuss some of the possible reasons for this anomalous result below.

Discussion

While traditional traceological analyses, including surface roughness, have proved reliable for discerning between different contact materials, it is clear that these values do not correlate well to the specular reflectance of an object's surface. Gloss is typically measured over a much larger area than surface roughness, which is appropriate for a number of reasons. By considering larger surface areas, the prejudicial impact of post-depositional factors like sediment abrasion is lessened (sensu Keeley 1980; Vashisht & Radhakrishnan, 1974). Larger surface areas also allow us to consider the overall macro-scale effect of polishes and how these may have been perceived by their makers. The perception of polish or gloss, together with the tactile properties of a polished surface, are important aspects to consider. As archaeologists, we need to attempt to understand polished tools from the point of view of their makers.

Gloss perception developed in the superior temporal sulcus region of the brain. The superior temporal sulcus plays a key role in the evolution of many human social abilities, including our ability to understand and respond to sensory stimuli, such as speech, gestures and facial expressions (Kropotov, 2009; Albohn & Adams, 2016; Sturm et al., 2016; Patel et al., 2019). The growth of this region of the brain is intimately linked to the development of language and therefore our ability to produce technology (Stout & Chaminade, 2012). The superior temporal sulcus is located close to the praecuneus, another region of the brain that is increasingly being linked to the evolution of various cognitive specialisations in humans (e.g., Bruner et al., 2018a, 2018b). Deliberately polished bone tools therefore have the potential to tell us, not merely about the beautification of an object, but about the cognitive abilities of people, particularly where these artefacts occur in Middle Stone Age contexts.

Before undertaking this study, my prediction was that the highest gloss values would come from bone polished with a hard material. This prediction was based on my own visual perception of experimentally polished bone tools, which appeared, to my mind, shinier and smoother when polished against a hard material. From a mechanical perspective, friction against a hard material would create a flatter surface, eliminating most of the natural high point surface topography. This study has clearly shown that this is not the case. My subjective experience may, however, account for why, in some instances, people chose hard material like stone or wood to polish their bone tools (Goodwin, 1945; Sparrman, 1975; Olsen, 1984; d'Errico et al., 2011). What may appear to the naked eye as shiny or glossy may in fact not reflect light optimally. My results agree with the recent findings of Martisius and colleagues (2018) who showed that soft skin abrades and deforms bone surfaces faster and more definitively than some other materials. I am not aware of any study from the southern African context that has looked at the dominant bone polishing technique on bone tools from an archaeological site; this would be a worthwhile avenue of exploration.

Another factor to be aware of is that well-developed polish over the entirety of a tool's surface, which is the criterion I used to select for intentionality of polish application, may result from prolonged use life or extensive handling, particularly on body ornaments (Falci et al 2018; d'Errico et al., 2020), and would therefore not have been intentionally applied. At the six archaeological sites considered in this study polish was restricted to purported bone awls and points/arrowheads. It is conceivable that awls, particularly those used to work skin garments, would have accrued use-wear over their entire surface resembling intentional polish. This is possibly the case with the three awls shown in Figure 1 and corresponding to Figure 4A, B and G, all of which show evidence of contact with a soft, skin-like material. However, on the specimens which have contacted a hard material over their entire surface, particularly the arrowheads (see Figure 1 and Figure 4C-F and H), the polish almost certainly would not have resulted from use, but must have been deliberately applied.

The reasons for applying polish, specifically polish imparted by a hard material, could be manifold and one could speculate *ad nauseum*. Polish is a decorative element and could have served a symbolic role, but it may also serve to 'preserve' the bone and may be applied to deliberately extend the working life of the tool (Moore, 2013). Unfortunately, the sample of archaeological specimens included in this study is too small and comes from too geographically dispersed contexts to be able to ascertain whether people were specifically selecting certain materials to polish certain functional categories of tools. The use of ochre powder wrapped in a leather cloth reported at some sites may have less to do with imparting a polish to the bone tool than with imparting a specific colour. In at least one archaeological example looked at in this study (BNK P30/LAL; Fig. 4A) it appears that fine-grained sediment was used as a 'lubricant' with which to polish the bone in a soft skin or leather cloth. However, caution is required when inferring this technological strategy, as post-depositional sediment abrasion can mimic these traces.

Accurate assessment of gloss is hampered by several factors. The shape of the tool or curvature of the surface can affect the accurate measurement of specular reflectance. But there are glossmeters on the market suitable for non-planar surfaces (Asamoah & Peiponen, 2018). Extreme colour differences may also affect gloss readings (Chadwick & Kentridge, 2015). It is probable that this factor accounts for the low gloss value obtained on BNK 8743/029/TWI, which a microscopic assessment suggests contacted a soft material. Despite some of these limitations Gu readings may be obtained quickly, easily and at a fraction of the cost of a traditional AFM or light microscope.

In this paper I have tried to show that gloss measurements of the specular reflectance of the surface of a polished bone tool can indicate the type of material used to polish the bone. Although softer materials impart a higher gloss value and are more reflective, people sometimes chose harder materials with which to polish their tools. This may be because of the subjective visual perception of individuals, or it may indicate a more ingrained cultural choice. Gloss readings obtained with a glossmeterare quantitative measures that may be used in conjunction with traditional light microscopy and have the potential to provide a better understanding of deliberately polished bone tools, particularly as they relate to the subjective experiences of their makers.

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