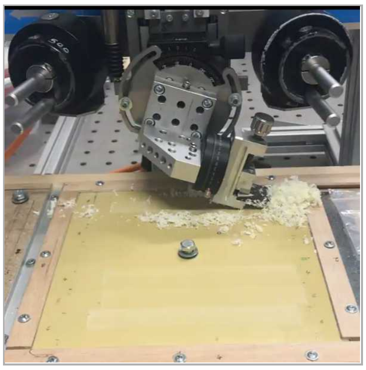

JUL 12, 2023

Past human stone tool performance: experiments to test the influence of raw material variability and edge angle design on tool function

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TraCErMonreposLEIZA

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DOI: dx.doi.org/10.17504/protocols.io.3byl4kr6ovo5/v1

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Protocol status: Working

Created: Apr 23, 2021

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PROTOCOL integer ID: 49365

ABSTRACT

The goal of this sequential experiment was to test tool performance of Late Middle Palaeolithic *Keilmesser* by examining two relevant characteristics concerning their edge design: the raw material and the edge angle.
To do so, a controlled, mechanical setup was used. The samples and the contact material were standardised to limit the number of confounding factors. As tasks, unidirectional cutting and carving movements were performed. The edge angle values for the experimental standard samples were chosen to reflect the calculated edge angles from the analysed *Keilmesser*.

Keywords: Controlled experiments, Keilmesser, tool durability, tool efficiency, edge angle, Middle Palaeolithic, Neanderthal technology

Documentation of the archaeological tools

1 The research question behind this here presented experiment is based on archaeological artefacts, so-called *Keilmesser* from the Late Middle Palaeoltihic. The artefacts are from the sites of Balver Höhle, the Upper site of Buhlen (both Germany) and Grotte de Ramioul (Belgium). For more information about the sites see the following (exemplary) references:

CITATION

K. Günther (1964). Die altsteinzeitlichen Funde der Balver Höhle, Münster.

CITATION

O. Jöris (2001). Der spätmittelpaläolithische Fundplatz Buhlen (Grabungen 1966-69): Stratigraphie, Steinartefakte und Fauna des oberen Fundplatzes. Universitätsforschungen zur prähistorischen Archäologie 73, Bonn.

CITATION

M. Ulrix-Closset (1979). Le paleolithique moyen dans le bassin mosan en Belgique, Liege.

1.1 3D scanning

In total 175 N *Keilmesser* were analysed and scanned with an AICON smartScan-HE R8 from the manufacturer Hexagon (software version OptoCat 2018R1). The S-150 FOV (field of view) used has a point-to-point distance of 33 µm.

Equipment

smartScan-HE R8 NAME

3D structured light scanner TYPE

AICON BRAND

- SKU

https://www.hexagonmi.com/products/structured-light-scanners/aicon-smartscan LINK

S-150 FOV, resolution of 33 µm SPECIFICATIONS

Software

OptoCat NAME

Hexagon Manufacturing Intelligence Software DEVELOPER

The scanning settings are identical to the following protocol, and details can be found there:

Protocol

NAME

Enhancing lithic analysis: Introducing 3D-EdgeAngle as a semi-automated 3D digital method to systematically quantify stone tool edge angle and design

CREATED BY

Lisa Schunk

PREVIEW

The editing steps to create a closed 3D model are also the same as in the protocol mentioned above and were executed with GOM inspect, a free software for 3D measurement data.

Software

GOM Inspect NAME

Hotfix 2, Rev. 111729, build 2018-08-22 OS

GOM DEVELOPER

1.2 Edge angle calculation

The edge angle measurements on the 3D models of the *Keilmesser* were taken with *3D-EdgeAngle*. For details about the method see (publication of the forthcoming paper):

Protocol

NAME

Enhancing lithic analysis: Introducing 3D-EdgeAngle as a semi-automated 3D digital method to systematically quantify stone tool edge angle and design

CREATED BY

Lisa Schunk

PREVIEW

For calculating the edge angles, the following parameters were applied:

- "2-lines" measuring procedure
- the length of the line was defined with 2 mm
- 10 mm as distance to the intersection
- only sections two to eight were used

Mean values were calculated in R, a free software and programming language for statistical computing and graphics.

Software

R Studio Desktop NAME

The R Studio, Inc. DEVELOPER

See "analysis_EA_Keilmesser" within the following repository on GitHub:
https://github.com/lschunk/PastHuman_StoneToolPerformance.git

Or in open access on Zenodo:
https://doi.org/10.5281/zenodo.7564605

Sample preparation

2 Standardised tools

24 experimental standard samples were produced for the experiment:

6 x 35 ° Baltic flint sample
6 x 35 ° silicified schist sample
6 x 45 ° Baltic flint sample
6 x 45 ° silicified schist sample

2.1 Raw material

Baltic flint:
Southern Sweden (secondary deposit):
55.945852 N, 12.767851 E

Silicified schist:
Balver Höhle
51.339167 N, 7.871944 E
Buhlen

[51.191022 N, 9.086585 E](#)

Note

In this experimental context, silicified schist is termed **lydite**. The experimental samples are labeled **LYDIT**x-x (lydite in German = Lydit). Experimental flint samples are labeled **FLT**x-x. The first number identifies the nodule and the second number identifies the blade cut from the nodule.

2.2 Blanks

Raw material nodules/ blocks (step #2.1) were first cut into rectangular cuboids (blanks) of the following dimensions:

10 mm thickness

25 mm width

60 mm minimum length

Equipment

Goliath 450	NAME
Lapidary rock saw	TYPE
Steinschleifmaschinen & Lapidary tools Ltd.	BRAND
-	SKU
https://www.steinschleifmaschinen.at/index.php?main_page=product_info&cPath=1_17&products_id=184	LINK
-	SPECIFICATIONS

a) cut 10 mm slices

Cutting slice (here: flint).

Cutting slice, with safety cover lifted for photo (here: flint).

Cut to provide level surface, photo with safety cover lifted (here: flint).

Slice, side view (here: flint).

Slice, top view (here: flint).

b) cut slices into blanks

Blank, top view (here: flint).

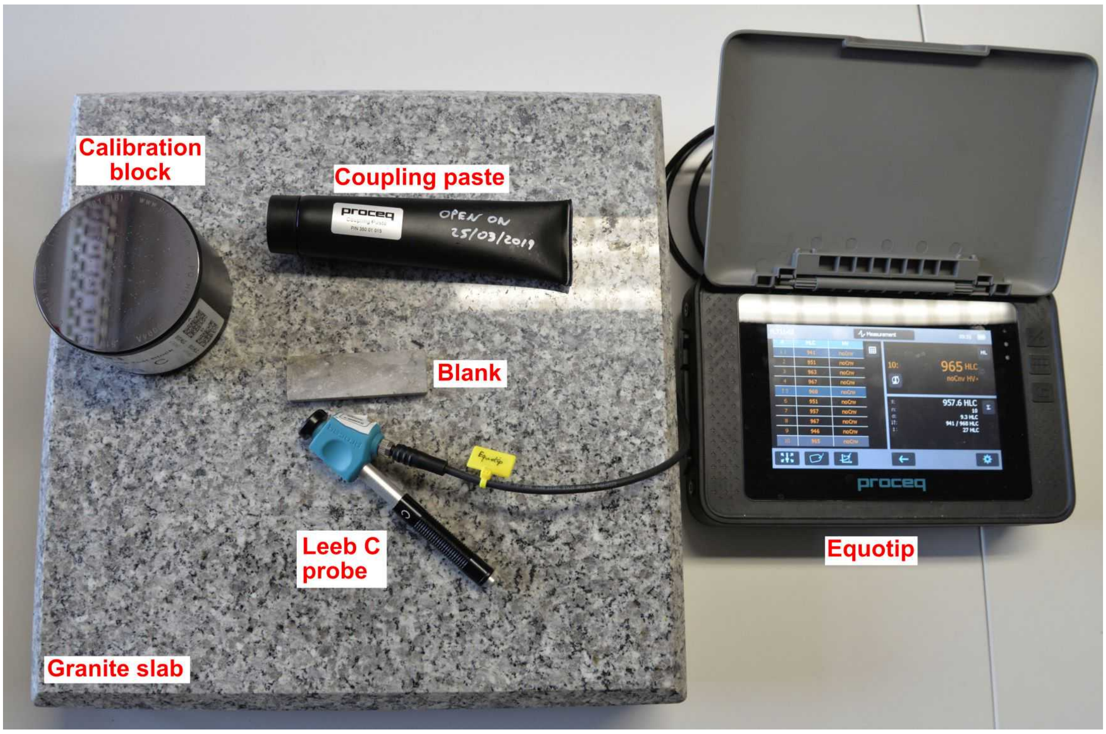
Blank, lateral view (here: flint).

2.3 Hardness measurement

The hardness of the blanks (step #2.2) was measured with a Leeb rebound hardness tester.

Equipment	
Equotip 550	NAME
Portable hardness tester	TYPE
Proceq	BRAND
-	SKU
https://www.proceq.com/products/list/Category/equotip-portable-hardness-testing/	LINK
Leeb C probe	SPECIFICATIONS

The blanks were placed on a stable base of sufficient mass (here a polished granite slab of about 20 kg). Since the samples did not fulfill the requirements for minimum sample size and weight, coupling paste was used between the sample and the base. Each blank was measured ten times to insure and test intra-blank variability.



Setup for measuring Leeb rebound hardness with the devices/components labeled.

Measuring Leeb rebound hardness.

2.4 Edge angle

One end of the blanks (step #2.2) was cut to produce samples with a 35 ° / 45 ° edge angle , with the following dimensions:

10 mm thickness
25 mm width
30 mm minimum length

Equipment	
310 CP	NAME
Diamond band saw	TYPE
Exact	BRAND
-	SKU
https://www.exakt.de/en/products/thin-section/industry.html	LINK

Cutting the edge angle.

Positioning blank, close-up (here: flint).

Cutting the edge angle, close-up (here: flint).

Experimental standard sample without chamfered edge, view of side A (corresponding to the "dorsal" side of bifacial lithic artefact; here: flint).

Experimental standard sample without chamfered edge, view of side D (corresponding to the "lateral" side of bifacial lithic artefact; here: flint).

2.5 Chamfered edge

To avoid catastrophic breakage of the edge during experiments, the leading edge of the experimental standard samples (step #2.4) was chamfered to a 45 ° angle (see #2.6 for photos).

Equipment

310 CP	NAME
Diamond band saw	TYPE
Exact	BRAND
-	SKU
https://www.exakt.de/en/products/thin-section/industry.html	LINK

Cutting chamfered edge (here: flint).

The cut with the band saw left a small burr between the two adjacent surfaces at the edge of the chamfered surface and the lateral side D. This burr was manually removed with a diamond drill bit in a mini drill.

2.6 Coordinate system

Three ceramic beads were adhered onto each side of the cutting edge to provide a coordinate system on each side.

Final experimental standard sample with beads, view of side A (corresponding to the "dorsal" side of bifacial lithic artefact; here: flint).

Final experimental standard sample with beads, view of side C (corresponding to the "ventral" side of bifacial lithic artefact; here: flint).

For details, see:

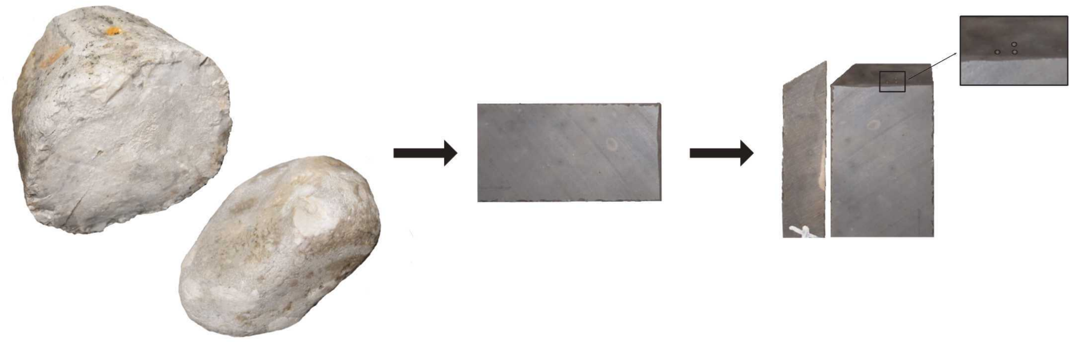
CITATION

Calandra I, Schunk L, Rodriguez A, Gneisinger W, Pedergnana A, Paixao E, Pereira T, Iovita R & Marreiros J. (2019). Back to the edge: relative coordinate system for use-wear analysis. Archaeological and Anthropological Sciences.

LINK

https://doi.org/10.1007/s12520-019-00801-y

2.7 **Summary of the standard sample production**



Standard sample production. The rock nodules (left; here Baltic flint) are cut into blanks (middle; step #2.2) with a Lapidary rock saw. A diamond band saw was used to cut the blank to create a typical standard sample with a defined edge angle (step #2.4) and a 45° chamfered edge (right, step #2.5). Highlighted are the three beads used as coordinate system (step #2.6).

2.8 Cleaning

5m

100 mL Cleaning solution

1 Mass / % volume

Plurafac LF 901 **BTC Europe GmbH, Rheinpromenade 1, D-40789 Monheim Catalog #-**

Equipment

Sonorex Digitec DT255H	NAME
Heated ultrasonic bath	TYPE
Bandelin	BRAND
-	SKU
https://ultraschall-welt.de/ultraschallreiniger/serien/bandelin-geraete/269/bandelin-sonorex-digitec-dt-255-h-5-5?c=0	LINK
4.5 L	SPECIFICATIONS

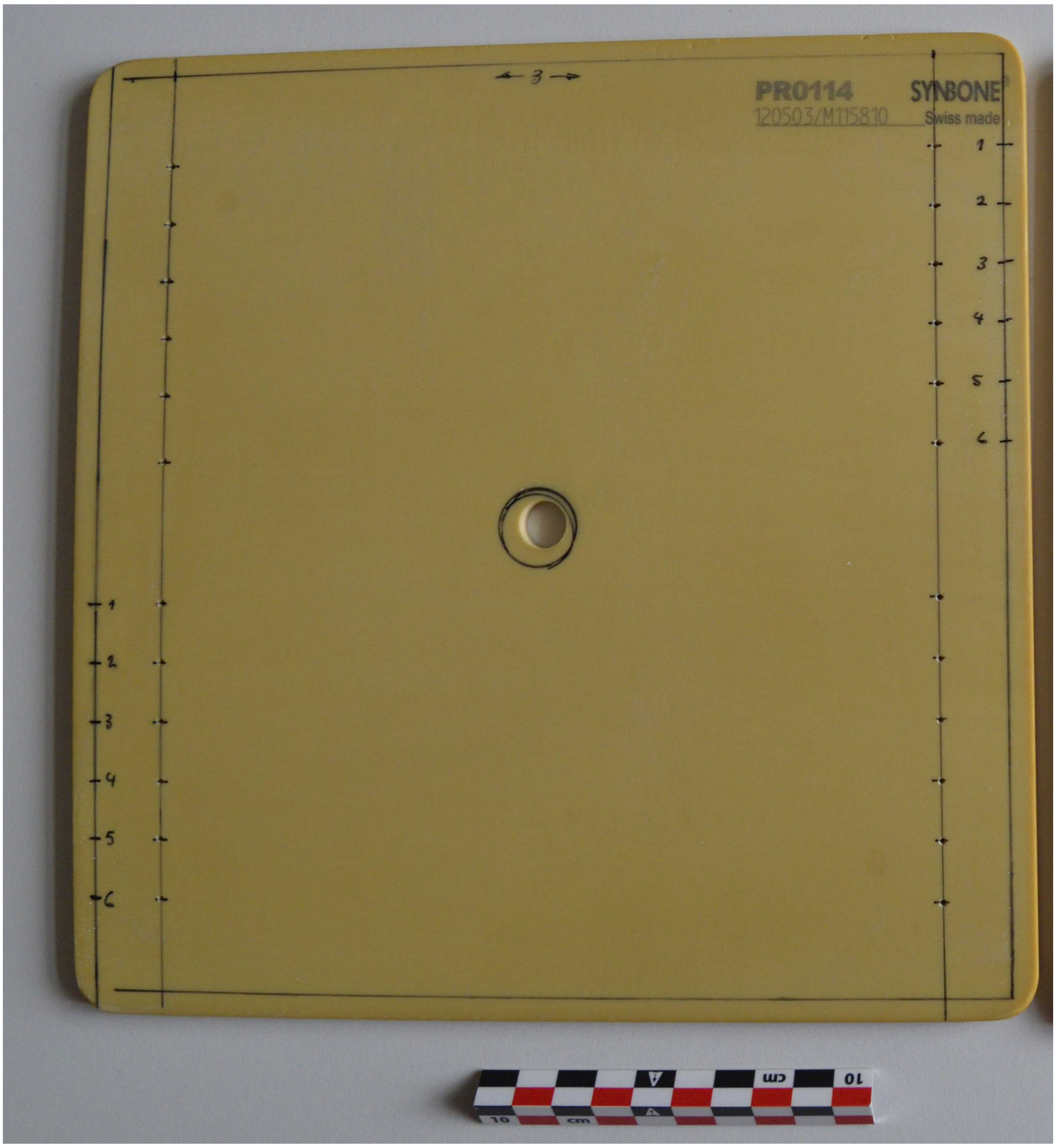
40 °C
00:05:00

Contact material

3 **Standardised contact material**

Three synthetic bone plates Modified bone-like polyurethane **SYNBONE® Catalog #PR0114** with the following dimensions were used as contact material:

250 mm length
250 mm width
6 mm thickness
75 % Shore hardness D (+/- 5)



Artificial bone plate.

Mechanical device

4 General settings

Linear unidirectional movements (cutting & carving): 2000 strokes split in 4 cycles .

The cycles are defined by the following number of strokes:

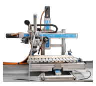
1 strokes to 50 strokes

51 strokes to 250 strokes
251 strokes to 1000 strokes
1001 strokes to 2000 strokes

5 Experimental setup

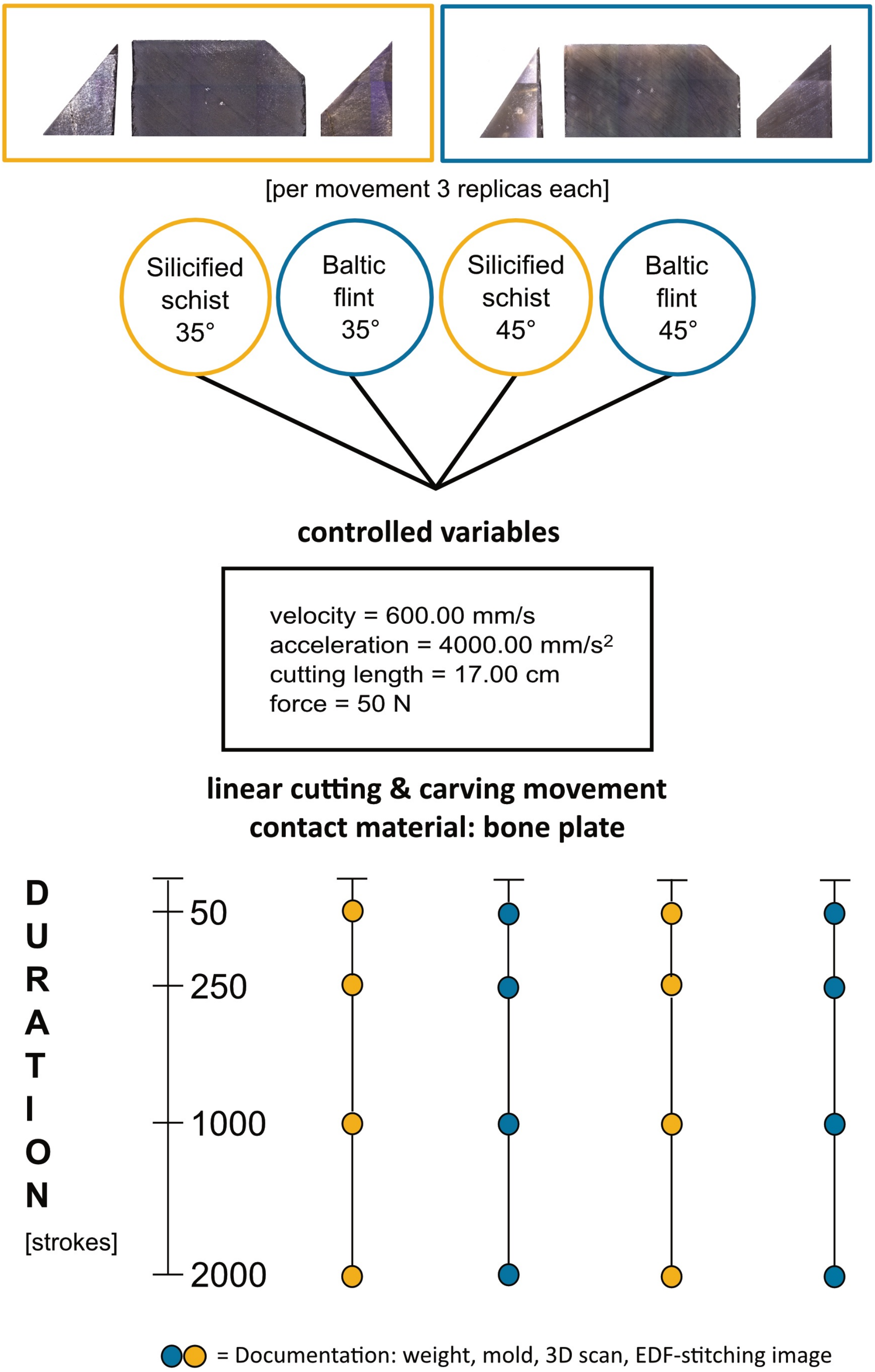
Equipment

SMARTTESTER	NAME
Modular material tester	TYPE
Inotec AP	BRAND
-	SKU
https://www.smarttester.info/	LINK
recorded values with the time stamps: - for each drive: position, speed, acceleration (+ deceleration) - penetration depth with distance sensor - apllied force with force sensor 1 (strain gauge sensor) - friction with force sensor 2 (strain gauge sensor)	SPECIFICATIONS



Linear movement from start point to end point:

5 kg dead weights (= ~ 50 N)
170 mm movement length
600 mm/s movement speed
4000 mm/s2 movement acceleration
10 Hz reading frequency (for each channel)

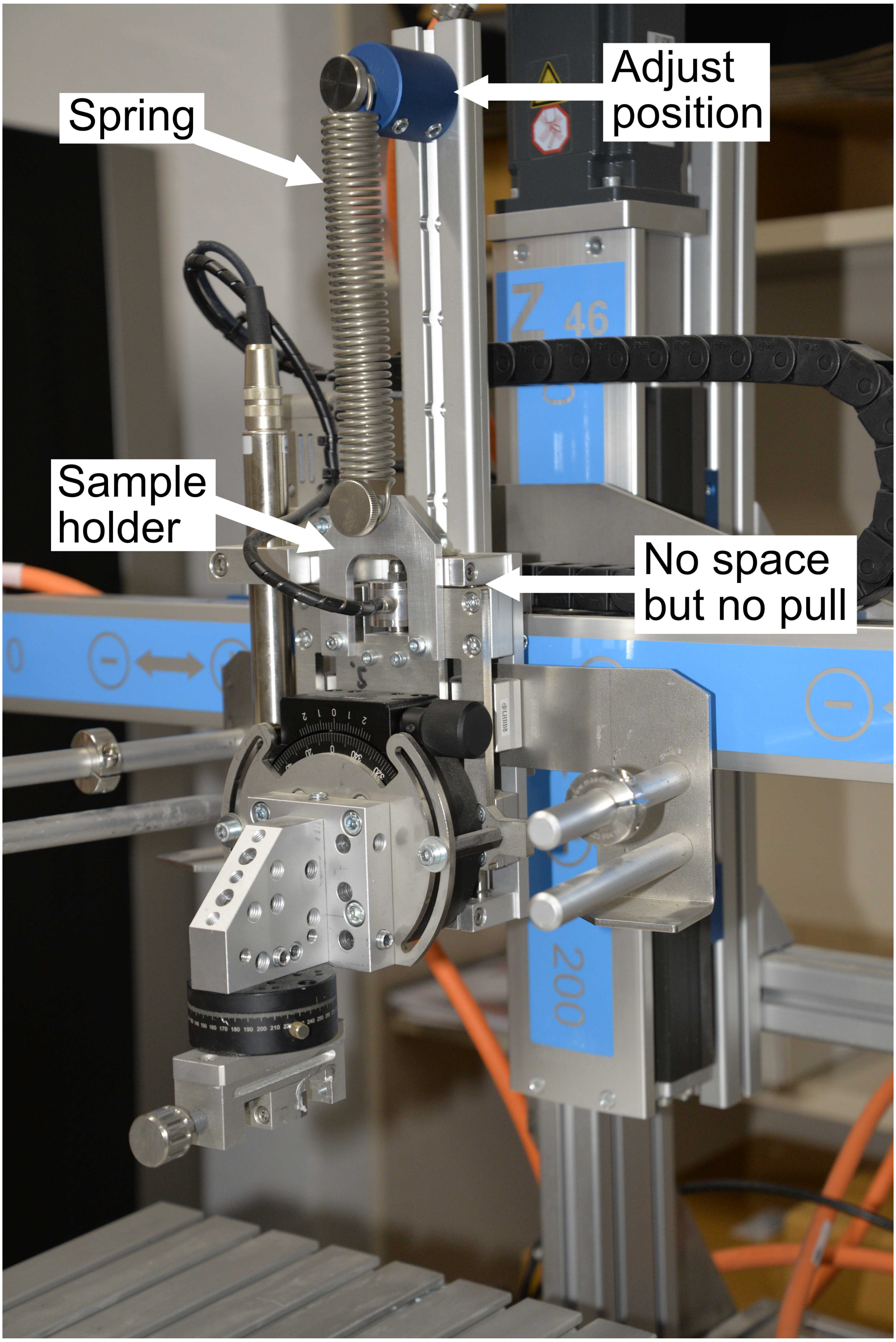


Experimental design.

5.1 Setup sample holder

The length of the spring of the sample holder was adjusted to compensate for the weight of the sample holder (without dead weights and sample).

Adjust the position of the upper end of the spring on the rail, so that:
1. the sample holder almost touches the frame, and
2. at the same time, there should be no pull from the spring onto the sample holder.



Zeroing sample holder.

5.2 Setup sample

The experimental standard sample (step #2) was clamped in the sample holder (SMARTTESTER) and manually oriented in all directions.

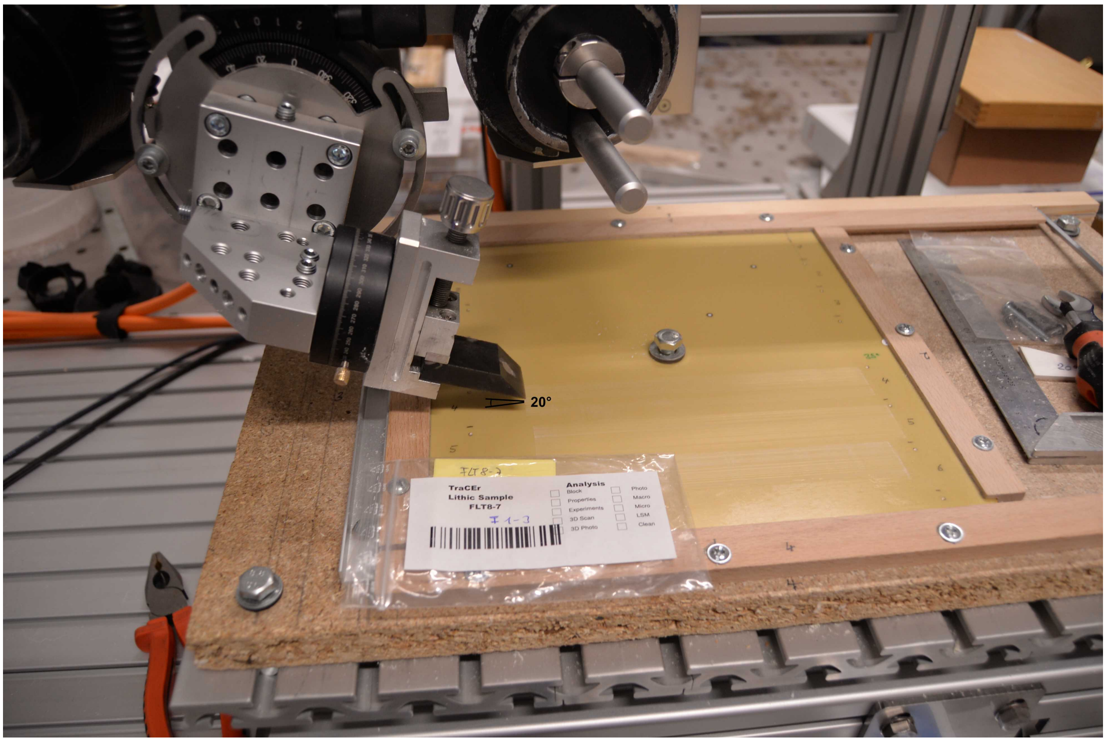
a) cutting movement

the active edge was parallel to the contact material and the blade is mounted perpendicular to it
(90 ° angle)

Sample FLT8-2 set up above bone plate, ready for the cutting experiment.

b) carving movement

the active edge was orientated in a flat angle towards the contact material (20 ° angle)



Sample LYDIT5-13 set up above bone plate, ready for the carving experiment.

5.3 Setup contact material

The bone plates (step #3) were clamped in a custom-made sample holder and fixed with a screw in the middle of the bone plate (see photos in step #5.2).
The plate was aligned with the X-axis.

5.4 Program cutting and carving movement

The program is identical for cutting and carving. For each sample, a new template was created (named with the sample ID and the stroke number).

a) Move down in Z-direction to start position
The z-value of the starting point was defined as follows: the sample holder on the z-drive was moved down slowly until the edge of the sample was in contact with the bone plate. 5 mm were added to the position of the z-drive in order to give the sample the possibility to penetrate into the bone plate without cutting through the 6mm-thick bone plate.
b) Move forward in X-direction 170 mm (linear movement)
c) Move up in Z-direction approx. 20 mm (above bone plate; no contact between contact material and sample)
d) Move backwards in X-direction to starting point
e) Loop 50 times over steps #5.4a-5.4d and export data to CSV
f) Loop 200 times over steps #5.4a-5.4d and export data to CSV
g) Loop 750 times over steps #5.4a-5.4d and export data to CSV

h) Loop 1000 times over steps #5.4a-5.4d and export data to CSV

The experiment was planned as a sequential experiment. The 2000 strokes were therefore split into four sequences (steps #5.4e-h). The experimental standard samples were documented after each sequence (step #6).

For each sequence, five CSV files were exported, one for each recorded channel:

- Penetration depth as measured by the distance sensor in the sample holder.
- Force applied (Z-direction) as measured by the force sensor in the sample holder.
- Friction as measured by the force sensor on the stage for the contact material.
- Position of the X-drive (travel range).
- Velocity of the X-drive.

Program as seen in the GUI. Blue = sensors, red = actuators (drives) and green = control flow elements.

Program for sample FLT8-1 as example:

FLT8-1_cutting_template.Smart

5.5 Run program

7h

Each sample was used for a duration of ~ 07:00:00 (= running time SMARTTESTER)

The following samples were used for the experiment:

Cutting 35° edge angle:

FLT8-4
FLT8-5
FLT8-6
LYDIT5-5
LYDIT5-6
LYDIT5-7

Cutting 45° edge angle:

FLT8-1
FLT8-2
FLT8-3
LYDIT5-2
LYDIT5-3
LYDIT5-4

Carving 35° edge angle:

FLT8-7
FLT8-8
FLT8-9
LYDIT5-11
LYDIT5-12
LYDIT5-13

Carving 45° edge angle:

FLT8-10
FLT8-11
FLT8-12
LYDIT5-8

LYDIT5-9
LYDIT5-10

Documentation

6 Sample documentation

Before the experiment as well as after each cycle all 24 samples were documented in an identical way following these steps:

- cleaning with tap water and commercial washing up liquid
- weight measurement (threefold repetition)

Equipment

Kern PCB 3500.2	NAME
weighing scale	TYPE
Kern	BRAND
-	SKU
https://www.kern-sohn.com/	LINK
accuracy of 0.1g	SPECIFICATIONS

- 3D scanning of all samples (identical settings for all scans; step #1.1)
- based on the 3D models, the volume of each sample could be calculated

Equipment

smartScan-HE R8	NAME
3D structured light scanner	TYPE
AICON	BRAND
-	SKU
https://www.hexagonmi.com/products/structured-light-scanners/aicon-smartscan	LINK
S-150 FOV, resolution of 33 µm	SPECIFICATIONS

- 3D scanning of the contact material (only before and after 2000 strokes)

Equipment

smartScan-HE R8	NAME
3D structured light scanner	TYPE
AICON	BRAND
-	SKU
https://hexagon.com/products/smartscan	LINK
M-450 FOV, resolution of 108 µm	SPECIFICATIONS

- optical documentation of three of the four surfaces per sample (one lateral and the two main surfaces)

Equipment

Smartzoom 5	NAME
digital microscope	TYPE
Zeiss	BRAND
-	SKU
https://www.zeiss.de/mikroskopie/produkte/imaging-systems/smartzoom-5.html	LINK
PlanApo D 1.6x/0.10 objective; EDF-stitched images	SPECIFICATIONS

JPG

- cleaning the area of interest with a cotton bud with Isopropanol 70% **Carl Roth Catalog #CN09.4**
- cleaning the area of interest with a cotton bud with Acetone ≥99.5 % **Carl Roth Catalog #5025.6**
- moulding of the two main sample surfaces with

Technovit Provil Light regular **Kulzer GmbH Catalog #66009333**

Moulding of one of the two surfaces (here: flint).

Data acquisition

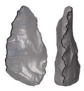
7 After conducting the experiment and the final documentation of all experimental standard samples, further data was acquired:

- the edge angles of the samples
- the depth and width of the cuts and scratches on the artificial bone plate

7.1 **Edge angle of the experimental standard samples**

The 3D models (samples + contact material) were imported as STL files into GOM Inspect and existing mesh holes were closed. 3D models were edited as described in the previously mentioned protocol:

Protocol



NAME

Enhancing lithic analysis: Introducing 3D-EdgeAngle as a semi-automated 3D digital method to systematically quantify stone tool edge angle and design

CREATED BY

Lisa Schunk

PREVIEW

Software

GOM Inspect NAME

Hotfix 1, Rev. 111729, build 2018-08-22 OS

GOM DEVELOPER

Based on the closed models, the volume could be calculated.
Additionally, the edge angles of the samples after each cycle were calculated by means of GOM Inspect. To calculate the edge angle, *3D-EdgeAngle* was applied again as for the archaeological artefacts (see step #1.2). Note that the parameters changed slightly ('3-points" instead of "2-lines" measuring procedure), since the "3-points" measuring procedure seems to be more suitable for simple morphologies as represented by the standard samples.

The following parameters were applied:

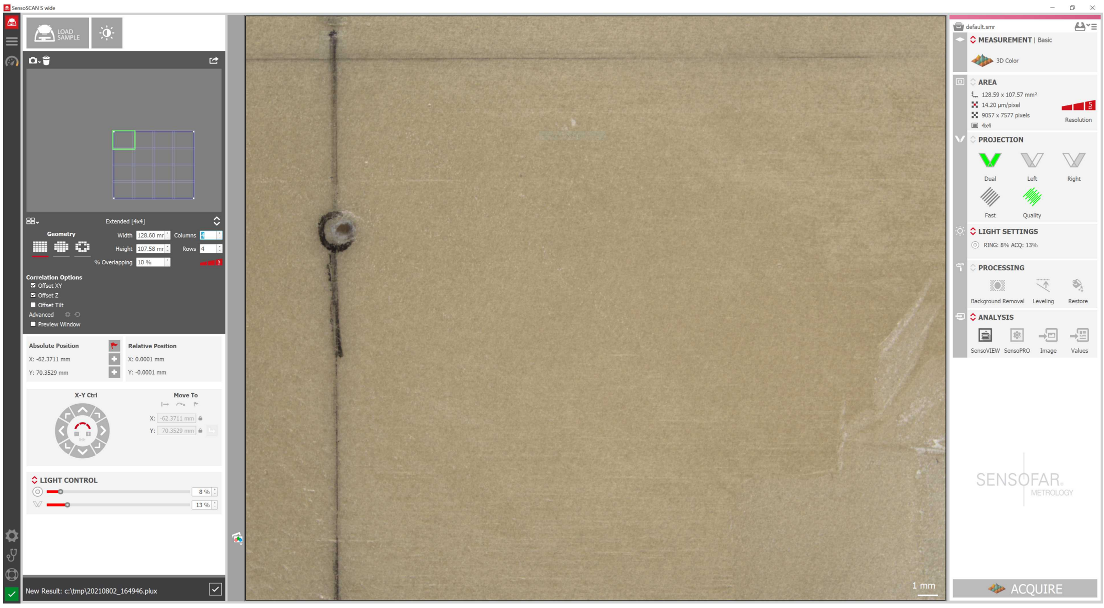
- "3-points" measuring procedure
- length of the line was defined with 2 mm
- as distance to the intersection the mean for distance three to six was calculated
- only sections two to eight were used

7.2 Penetration depth / dimensions of the grooves on the contact material

In addition, the contact material was documented with a Sensofar S-wide (Sensofar Metrology, Spain), a 3D optical metrology system. This way, the cuts and the scratches on the bone plate could be quantified.

Equipment	
S wide	NAME
3D optical metrology system	TYPE
Sensofar	BRAND
-	SKU
https://www.sensofar.com/metrology/	LINK

- each bone plate was documented in four quadrants due to the limited travel range of the stage



Acquisition settings used with the Sensfar S-wide.

The data was processed in ConfoMap (a derivative of MountainsMap Imaging Topography developed by Digital Surf, Besançon, France; version ST 8.1.9286).

Software

ConfoMap (MountainsMap Imaging Tophography) NAME

Digital Surf, Besançon, France DEVELOPER

In total, two templates were used:

a) "Patch surfaces of the bone plates acquired with the Sensofar S-wide"
An initial template was needed to patch the single quadrants together, so that the grooves are complete again. This involves levelling and aligning. Afterwards, each groove can be exported individually.

BP-I-TFE_S-wide_cutting_2000strokes_20210803_A-B.pdf

b) "Processing on single grooves"
This template extracts the topography layer of the grooves and calculates a mean profile of a series of 30 profiles. After levelling the mean profiles, the height and the width of each groove can be calculated.

BP-I-TFE_S-wide_cutting_2000strokes_20210803_FLT8-1_45deg.pdf

The ConfoMap templates for each surface in MNT and PDF formats are available in open access on Zenodo (https://doi.org/10.5281/zenodo.7565158). This also includes all original and processed surfaces.

Data analysis

8 Data analysis

The data acquired within the experiment was analysed in R.

Software

R Studio Desktop NAME

The R Studio, Inc. DEVELOPER

The different datasets were split in separate analyses:

a) "analysis_HLC"
This R script imports and plots the Leeb rebound hardness data acquired on the experimental standard samples (see step #2.3).

b) "analysis_EA"
This R script deals with the calculated edge angles from the experimental standard samples (see step #7.1).

c) "analysis_ST.all_sensors"
These R scripts contain the analysis of the data acquired with the five sensors connected to the SMARTTESTER (see step #5.4). However, plots concern only the data from the penetration depth.

d) "analysis_S.wide"
These R scripts deal with the penetration depth of the experimental standard samples into the contact material. The penetration depth is already part of "analysis_ST.all_sensors", but was additionally calculated with a Sensofar S-wide (see step #7.2).

e) "analysis_VW"
This R script contains the volume and the weight measurements for all experimental standard samples from before and after the experiment (see step #6).

The entire repository with all R analyses can be found on GitHub:
https://github.com/lschunk/PastHuman_StoneToolPerformance.git

and on Zenodo:
https://doi.org/10.5281/zenodo.7564605

8.1 Results

Available in open access on Zenodo:
https://doi.org/10.5281/zenodo.7564605