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MORPHOLOGICAL CHARACTERISTICS AND SURFACE TRACES INDICATING THE USAGE OF TOOLS WITH ONE SPATULA-SHAPED WORKING END IN THE LA TÈNE PERIOD

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Fine rod-shaped instruments with two working ends – one flat and the other frequently olive-shaped – have been recovered from La Tène period oppida contexts in Central Europe. These tools are described as multifunctional or as cosmetic, medical, or surgical, however, there remains insufficient detailed understanding of the characteristics distinguishing their specific purposes. The goal of this paper is to demonstrate some of the characteristics of tools for treatment purposes, personal grooming, and make-up or substance application by examining manufacturing traces, subsequent modifications, and use-wear traces on the surface of selected tools with one spatula-shaped working part.

Keywords: La Tène period – traceology – bronze – sand mould – tool for treatment – make-up tools – spatula – spathomele

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Introduction

In the context of the La Tène period oppida of Central Europe, we encounter instruments with two working ends. While one end has usually form of a spatula, though flat with various modifications in shape, edge sharpness, bending, and thickness, the other varies in form including a differently shaped spatula, spoon, probe, and – most frequently – olive-shaped applicator. The La Tène period, spanning approximately from the 4th to 1st century BC, is characterized by distinct technological and material developments, particularly in metalworking, which facilitated the production of specialized tools. While associated with extensive trade networks and evolving societal structures, the complexity of these artefacts suggests diverse applications beyond simple craftsmanship.

These tools are often referred to as spatulas (technically, a spatula is just the flat working part) and are described as either multifunctional or cosmetic, medical, or surgical tools. However, tools with at least one spatula-shaped working part are specifically designed for different purposes and possess various characteristic morphological features. Consequently, traces of manufacture, surface modifications, and use may contribute to identifying their actual purposes. Determining the purpose of these tools is important since interpreting them as medical instruments or surgical tools implies the presence of a specialist in treating patients at a given site and influences the interpretation of other artefacts. In this context, it is important to note that referring to these tools as 'medical' may be misleading, as there is no evidence that treatment specialists in La Tène-era Central Europe adhered to the paradigms of medicine – assuming that medicine, as a structured practice, was established in ancient Greece around 5000 BC. Labelling difficult-to-interpret artefacts as tools for treatment complicates the understanding of the activities of treatment specialists in Central Europe during the La Tène period in phases LT B1 – D2.

Spatula in the Context of the Archaeology of Medicine

Research on artefacts with spatula-shaped tools extends into the "archaeology of medicine", a field that addresses health care questions that can be investigated by archaeological methods. The archaeology of medicine in Central Europe has a limited number of sources and relies mainly on metal artefacts, as organic materials are rarely preserved due to natural conditions. The separate development of medicine and surgery, as well as other fields such as eye and vision care, requires precise terminology. While modern medicine comprises a range of disciplines, including both surgical and internal fields, such an integrated framework did not exist between the 4th and 1st centuries BC. During this period, different areas of practice evolved independently, with distinct sets of instruments associated with specific fields, making it inappropriate to classify them under a unified medical category or collectively refer to them as 'medical tools'.

Medicine and surgery, along with many other branches that constitute modern healthcare, developed independently. In the Hippocratic texts (*Corpus Hippocraticum*, a collection of works by various authors of different periods originally attributed to Hippocrates), considered among the first paradigms of medicine, there is a clear demarcation between medicine and surgery, with texts prohibiting medical specialists from performing invasive surgical procedures. Medicine dealt with conditions, often with hidden and obscure causes, from which the sick suffered (according to *On Ancient Medicine*).[1] The principle of "not to use the knife" is enshrined in the Hippocratic Oath for physicians.[2] However, this prohibition may have been violated, as speculated in texts such as *On Fractures* and *On Head Injuries*. But, for example, Plato, in *Republic 407d*, states that both remedies and cutting were indeed practiced in the context of Asclepian practice (the healing traditions associated with the cult of Asclepius in the Greco-Roman world).[3]

The complexity increases when considering how many other areas, now part of holistic medicine, stood alone but addressed human difficulties in biological, psychological, social, and spiritual realms. For example, ophthalmic procedures were carried out outside the scope of medicine and surgery (based on texts from around the 6th century BC[4]) making it inappropriate to automatically include them in these fields. This separate development continued until the end of the 16th century when steps were taken to unite medicine and surgery. However, it was only from the 19th century onwards that a concerted effort

[1] Hynek Bartoš – Sylva Fischerová, *Hippokratés. Vybrané spisy*, Praha 2012, p. 366.
[2] H. Bartoš – S. Fischerová, *Hippokratés*, p. 152.
[3] H. Bartoš – S. Fischerová, *Hippokratés*, p. 172.
[4] Rafael J. Pérez-Cambrodí et al., *Hollow needle cataract aspiration in antiquity*, Acta ophthalmologica 93/8, 2015, p. 782.

emerged to integrate all disciplines and fields related to human health under the single field of medicine.[5]

Additionally, from the 4th century BC onwards, Central Europe shows no evidence of practices conforming to the paradigms of Greek medicine, which represent a complex system of principles and metaparadigms described in written sources. While diagnostic and therapeutic procedures were certainly practiced across various societies, these practices do not necessarily align with the structured framework of Greek medicine. Instead, they encompass a range of treatment procedures – activities related to diagnosis and treatment – that could have been carried out by specialists or non-specialists in different cultures and periods, and for which we find evidence in anthropological and archaeological material. Therefore, it is more accurate to refer to these as tools for treatment purposes rather than attributing them to a concept of 'medicine' as defined by Greek paradigms.

Nomenclature and Chronology

A spatula is the name of a flat working part of a double-sided tool, or the whole tool if one-sided, used in various forms across different fields. The exact definition states that a spatula is a broad, flat piece, a diminutive of spatha (broad/flat tool), from spáthē – σπάθη.[6] Although the etymology implies flatness as a basic characteristic of the tool, in archaeology, the word is also often used for olive-shaped applicators, spathomele – τῇ σπαθομήλῃ (a double-sided tool combining a spatula working end with an olive-shaped working end), and specillum (probe), often confused with various forms of spoons and other artefacts. Spatulas among archaeological finds have been interpreted and called tools for treatment, medical instruments, primary tools, secondary tools, and medical or cosmetic tools. Its classification as a secondary tool for treatment means it can be transferred between treatment procedures and cosmetic use.[7] The classification of tools into primary (associated with 'medical' activities) and secondary ('toiletries', i.e., for everyday use) categories was initiated due to difficulties in interpreting artefacts.[8] E. Riha[9] even created a third category for ambiguous material associated with treatment practices in Augst. However, this division can be misleading when determining the presence of any kind of specialist in the health care at an examined site.

Attempts to establish a chronology using the shapes of spatulas interpreted as tools for treatment have been unsuccessful in the past.[10] Spatulas are among the most common instruments for treatment purposes, taking on a spectrum of shapes, attributed to a variety of uses, and found in multiple contexts.

[5] Tatsuo Sakai, *Historical evolution of anatomical terminology from ancient to modern*, Anat-Sci-Int 82, 2007, pp. 65–81.
[6] Charlton T. Lewis – Charles Short, *A new Latin dictionary*, Oxford 1958, p. 1736.
[7] Kordula Gostenčnik, *Medizinische Instrumente aus Lauriacum in den Sammlungen der Oberösterreichischen Landesmuseen*, Römisches Österreich 36, 2013, p. 95.
[8] K. Gostenčnik, *Medizinische Instrumente aus Lauriacum*, p. 95.
[9] Emilie Riha, *Römisches Toilettgerät und medizinische Instrumente aus Augst und Kaiseraugst*, Forschungen in Augst 6, Augst 1986.
[10] Kordula Gostenčnik, *Medizinische Instrumente vom Magdalensberg in Kärntner*, Antichità altoadriatiche 51, 2002, p. 163.

Interpretation

Archaeological evidence suggests that the context in which an instrument is found is crucial for its interpretation, as the morphology of individual pieces alone may not provide sufficient information for determining their specific use without contextual data. However, at the turn of the 19th and 20th centuries, artefacts from important sites were often sorted and stored in groups of similar shapes rather than together with artefacts from the same spot and context (e.g., Píč[11]). The loss of contextual data makes the tools more difficult to interpret and the presence of a specialist in treatment is not proven by the spatula alone; other tools for treatment purposes need to be present.[12] Limited attention has been paid to a detailed investigation of the instrument's characteristics. Additionally, there is a general lack of studies investigating the functionality of shapes of tools for treatment typical of the Iron Age and their characteristic features.

This may be due to the apparent simplicity of the instrument's shape and its continuity to this day. A similar phenomenon may occur with spatulas as with small knives and razors, which were often interpreted as scalpels due to their unusual appearance and ornamentation.[13]

There are a significant number of generalizing assumptions about tools for treatment purposes (e.g., Bliquez[14]). So far, only casting into lost-wax moulds has been considered for manufacturing processes. Some scholars have directly linked the rich decoration to its use for treatment procedures. This assumption is based on written remarks that equipment for treatment was to be ornate and luxurious,[15] supposedly because those engaged in treatment were expected to come from financially stable backgrounds to afford the training and subsequent practice.

Questions and Methods of the Paper

This paper addresses the interpretation of the manufacturing methods, subsequent modifications, and the intended and actual uses of selected bronze tools from the La Tène period in Central Europe. The artefacts in question are double-sided tools, with one working end spatula-shaped and the other olive-shaped. Based on this configuration, the most appropriate name for the tool is spathomele. Our primary interest lies in artefacts with moulded ornamentation in the central part, typically with hook-like prominences situated about two-thirds of the length from the spatula end. Selected artefacts lack contextual data and have usually undergone drastic conservation.

[11] Josef Ladislav Píč, *Starožitnosti země České*, II, *Čechy na úsvitě dějin*, 2, *Hradiště u Stradonic jako historické Marobudum*, Praha 1903.

[12] K. Gostenčnik, *Medizinische Instrumente aus Lauriacum*, p. 95.

[13] Titus Kolník, *Das mitteldanubische Barbaricum-eine Brücke zwischen Zentrum und Peripherie am Beispiel der medizinischen Messerfunde*, Verlag der Österreichischen Akademie der Wissenschaften 2004, pp. 195–210.

[14] Lawrence J. Bliquez, *The tools of Asclepius: surgical instruments in Greek and Roman times*, Leiden 2014, p. 18.

[15] John Stewart Milne, *Surgical instruments in Greek and Roman times*, 1907, p. 54.

The research questions are:

What are the characteristics of a spathomele that point to its use in treatment procedures?

Could the spathomele with moulded ornamentation in the central part be used in the manner described in primary sources?

What uses of the tool can be detected through traces visible via microscopy analysis?

What manufacturing and subsequent modification practices can be identified through traces visible via microscopy analysis?

These questions will be answered through a survey of written and iconographic sources, a review of catalogues and previous analyses of similar tools from ancient environments and those found in Central Europe, traceology analysis, and experimentation.

Spatulas in Published Catalogues

The catalogues of leading scholars in the field of archaeology of medicine present numerous spatulas, spathomela, and probes from specific geographic areas; however, these catalogues do not comprehensively cover Central Europe.

Ancient Tools

The Scottish physician J. S. Milne, author of the first catalogue of ancient tools, analysed written sources, provided an overview of the artefacts, and expressed his conclusions about probes, spatulas, and spathomela recovered mainly from excavations of cities destroyed by the eruption of Vesuvius in 79.[16] Later, Ernst Künzl compiled another important catalogue.[17]

Archaeologist Lawrence J. Bliquez followed up on Milne's work,[18] expanding it to include grave finds from Colophon, Bingen, Asia Minor, Cyprus, and Italy, as well as artefacts from the surgeon's house at Rimini and the complex at Allianoi. The finds from the Domus del Chirurgo have been discussed in a new publication.[19] Emilie Riha prepared a summary of the toilet and medical tools from the Swiss sites of Augst and Kaiseraugst.[20] Kordula Gostenčnik[21] contributed to the understanding of the issue by analyzing tools from Magdalensberg. Another comprehensive work on ancient tools has been completed by L. J. Bliquez.[22]

16 J. S. Milne, *Surgical instruments*.

17 Ernst Künzl – Franz Josef Hassel – Susanna Künzl, *Medizinische Instrumente aus Sepulkralfunden der römischen Kaiserzeit*, Bonn 1983.

18 Lawrence J. Bliquez, *The Hippocratic surgical instrumentarium: A study in nomenclature*, Medicina nei secoli 15/3, 2003, pp. 403–439.

19 Jacopo Ortalli, *La domus del Chirurgo di Rimini: un eccezionale contesto archeologico*, 2023.

20 E. Riha, *Römisches Toilettgerät*.

21 Kordula Gostenčnik, *Medizinische Instrumente aus dem römischen Kärnten*, Carinthia 1, 2002, pp. 139–164.

22 L. J. Bliquez, *The tools of Asclepius*.

Patricia Baker's research focuses on ancient medicine,[23] healthcare in the Roman army, and tool finds in the UK.[24] Numerous individual artefacts relevant to this study can be recorded within publications of the sites of their discovery, though they have yet to be introduced into comprehensive catalogues.

Previous Analysis

The catalogues are notable for their inconsistent and disorganized recognition of the functional characteristics of these tools. This results in tools with working parts in the form of a spatula, probe, spoon, and often a phlebotome being grouped together as tools of the same type. Even re-examinations,[25] including analyses of the metal composition and production processes of selected spatulas,[26] have not led to a more precise determination of the purpose of specific specimens. Milne's synthesis of written sources is highly valuable. However, in the case of spatulas and the tools incorporating a spatula, some of his conclusions may be over-generalized, particularly regarding specific combinations of working parts. Tools that combine a spatula at one end and an olivary applicator at the other end are generally referred to as spathomele in written sources. This tool was used for the preparation and application of pharmaceutical products.[27] Milne[28] interpreted specilla as tools for probing wounds and holes, describing them as mostly made of bronze, with some coated in gold or silver, or made directly from gold or silver. He based these conclusions on observations of archaeological finds that he interpreted as specilla. However, written sources indicate that probes made of lead, tin, copper, wood, boar bristle, or garlic stems were also used to search body cavities, normal and abnormal holes, fistulas, and deeper wounds.[29]

Central Europe

K. Gostenčnik[30] concludes that the "Hellenistic" type of probes with a concave sunken spatula and some with small 'wings' (e.g., from Magdalensberg) are relatively common in the environment of the Late Iron Age oppida.[31] A very flat shank can be observed on artefacts from Late Iron Age settlements, such as those from Jüchsen, Thuringia, Germany,[32]

23 Patricia A. Baker, *Medicine*, in: Martin Millett – Louise Revell – Alison Moore (eds.), The Oxford Handbook of Roman Britain, Oxford 2016, pp. 555–572; Patricia A. Baker, *Tastes and Digestion: archaeology and medicine in Roman Italy*, in: K. Rudolph (ed.), Taste and the Ancient Senses, Abingdon 2017.

24 Patricia A. Baker, *Roman Military Medical Care in Britain*, Durham and Newcastle Archaeological Reports for 1997, pp. 46–50.

25 Ralph Jackson, *Lo Strumentario chirurgico della domus rimanese*, in: S. De Carolis (ed.), Ars Medica. I ferri del mestiere. La domus 'del chirurgo' di Rimini e la chirugia nell' antica Roma, Rimini 2009, p. 74; Antje Krug, *Römische Skalpelle, Herstellungstechnische Anmerkungen*, Medizinhistorisches Journal 28/1, 1993, pp. 93–100.

26 Katherine E. Jakielski – Michael R. Notis, *The metallurgy of Roman medical instruments*, Materials characterization 45/4–5, 2000, p. 387.

27 J. S. Milne, *Surgical instruments*, p. 59.

28 J. S. Milne, *Surgical instruments*, p. 54.

29 J. S. Milne, *Surgical instruments*, p. 56.

30 K. Gostenčnik, *Medizinische Instrumente aus Lauriacum*, p. 95.

31 K. Gostenčnik, *Medizinische Instrumente vom Magdalensberg*, p. 168, Abb. 3:4.

32 Thomas Grasselt, *Die Siedlungsfunde der vorrömischen Eisenzeit von der Widderstatt bei Jüchsen in Südthüringen*, Weimarer Monographien zur Ur- und Frühgeschichte 31, 1994; Ernst Künzl, *Medizin der*

and Basel-Gasfabrik in Switzerland.[33] Artefacts found at Oberleiserberg, Austria,[34] and Stradonice, Czech Republic,[35] also correspond to this description. The spatula with a smooth, rounded shaft differs from this form. Probes with a less decorated spatula-shaft transition, and also longer, are known, for example, from a set of tools found in the area of present-day Kapidaghi in Turkey, dating from the 1st to the early 2nd century AD.[36] Spatulas at Celtic oppida might have been imported.[37] The finds from Oberleiserberg and Stradonice are analogous to those from antiquity, with a slight difference in shape observed in the artefact from Stradonice.[38] Tools with a spatula-shaped working part from the Czech Republic are dated from LT C2 to LT D2.

Morphology and Use According to Written Sources

A spatula is the working part of a single-sided or double-sided tool characterized by its flatness. This flatness is the primary determinant for identifying the tool. Examining known finds from Central Europe, we observe specimens with a flat, elongated, or arched shape. These spatulas may vary in thickness, being thin or thick, concave, or featuring a central rib. They can also differ in dimensions, with transitions to the tool's central part being gradual, smooth, decorated, or circular in cross-section. The most common forms of spatulas and their typical combinations in tools with two working ends in the environment of central European oppida are illustrated in Fig. 1.

In the case of a double-sided tool, the opposite working part may be another spatula, a scalpel, or an olive-shaped applicator. Archaeological publications often name the entire tool after one of its working sides. Common combinations include spatula and spatula, spatula and piercer or phlebotome, spatula and scalpel, spathomele (a combination of spatula and probe in olivary or round shape associated with medicament preparation in written sources), spatula and tongue depressor. A specillum is a probe or small mirror.[39] The primary function of a probe is to explore a cavity tactilely without disturbing its base or surroundings. A highly polished instrument may also enable viewing of the cavity if a light source is available.

Bluntness of the Tool

A notable feature of the tool is the bluntness of all sides of the spatula. While macroscopic examination shows apparent sharpening along one edge of many spatulas, microscopic

Kelten. Ein archäologischer Forschungsbericht, in: R. Bedon – P. M. Martin (eds.), Mélanges Raymond Chevalier 2: Histoire & Archéologie, Caesarodunum XXIX, Tours 1995, Fig. 8.

33 E. Künzl, *Medizin der Kelten. Ein archäologischer Forschungsbericht*, Fig. 7.

34 A. Kern, *Spätlatènezeitliche Funde vom Oberleiserberg*, MG Ernstbrunn, N O, in: E. Jerem et al. (eds.), Die Kelten in den Alpen und an der Donau, Akten des Internationalen Symposions St. Polten 1992, Budapest – Wien 1996, Abb. 8.

35 J. L. Píč, *Starožitnosti země České*, II/2, *Hradiště u Stradonic*, Tab. XXIV: 10.

36 L. J. Bliquez, *The tools of Asclepius*, p. 433.

37 K. Gostenčnik, *Medizinische Instrumente vom Magdalensberg*, p. 168.

38 J. L. Píč, *Starožitnosti země České*, II/2, Tab. XXIV: 9–11.

39 Jan Kábrt – Jan Kábrt jr., *Lexicon medicum*, Praha 2015, p. 689.

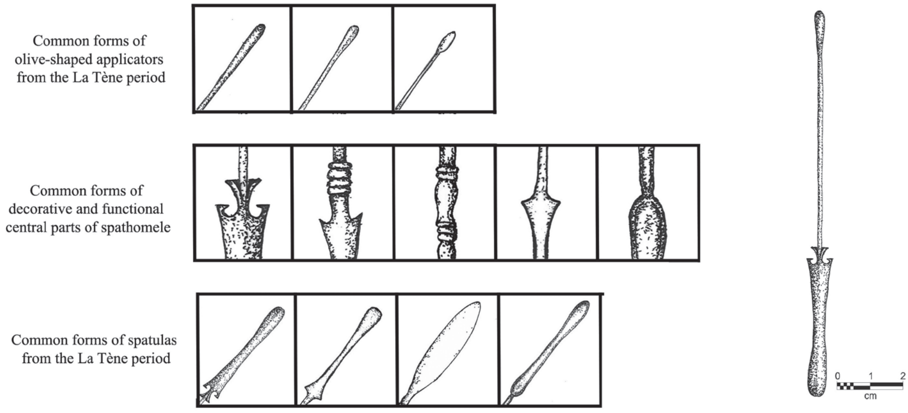


Fig. 1: The most common forms of olivary applicators, spatulas, and decorative and functional central parts of the spathomele. On the right is a drawing based on a spatula in the National Museum in Prague, inv. Nr. 81460

analysis reveals this to be irregular and one-sided wear, consistent with repeated contact with a flat abrasive surface at an angle. According to written sources, this sharpening would not be the result of processes associated with the preparation of medicaments.[40] Pharmaceutical use involves stirring medicaments with the olive-shaped end and spreading them on the affected area of body or on lint with the spatula end.[41]

The spatula is not equipped with a blade; however, some instruments may have a smoothed edge that approaches sharpness through use. This edge is not intentionally manufactured. Researchers sometimes refer to a sharp pointed tool with a relatively flat surface and often even a diamond-shaped cross-section, frequently combined with a scalpel on a double-sided tool, as a spatula. Morphologically, this tool is a phlebotome, intended for puncturing wounds, such as during bloodletting.

The Other End of the Tool

Olive-shaped applicators, as one-sided tools, are abundant among archaeological finds in Europe. The Turin Papyrus (ca. 1200 BC) often comes to mind, depicting a woman supposedly applying rouge with an olive-shaped applicator in the centre of the depiction. This shape is still used today to apply kohl or kajal to the eyes and surrounding areas. Pliny the Elder described a similar use, noting that although galena (a form of lead) is poisonous, when ground and applied as a liquid to the eyes, it protects against the sun during long periods of outdoor work. He also stated: "*It is, however, like scum of silver, a deadly poison*".[42]

40 J. S. Milne, *Surgical instruments*, p. 59.

41 Galen of Pergamum, *Claudii Galeni opera omnia*, ed. Carolus Gottlob Kühn, Lipsiae: C. Cnobloch (22 vols.), 1821–1833, xiii and 466 pp.

42 Pliny the Elder, *The Natural History*, translated by John Bostock and Henry Thomas Riley, London, 1855, LCL 394, 254–255.

The distinction between ear scoops and the various types of tools used in the preparation of medicaments and other activities is rather clear. Spatulas are flat and remain so even when bent along the midrib. Spoons, on the other hand, are bowl-shaped and are purposefully made (for example, cold forged after being cast in a mould) to have a spherical shape that retains liquid. A curette is a sharp spoon.[43] The overlap between spoons and spatulas lies in their use for applying medicaments. Spoons are used to apply liquid substances to the eye, for example, and the underside's bulging can be used to apply viscous substances.[44] We also find references to the *specillum vulnerarium*, described as a scoop-shaped tool adapted for removing stones and missiles from wounds.[45]

Use of Spatula, Spathomele and Probe

In primary sources, authors describe various uses of tools where at least one working part is a spatula. It is necessary to note that the written sources do not describe the La Tène period or the situation in Central Europe at that time. This makes it challenging to directly correlate the archaeological findings from this region and era with the documented uses and descriptions of similar tools from other periods and places.

Milne[46] points out that the spathomele is not a surgical tool, associating it with the production of pharmacs and pigments. Aetius[47] writes that medicaments were rubbed by the spathomele. Marcellus[48] frequently refers to its use for stirring liquids in a vessel. Soranus[49] notes that the spatula-shaped end of the spathomele was used as a cautery, for example, to close the cut end of the umbilical cord. He calls the exemplars of the spathomele, where the spatula has a central rib, a slight bend, and a structured central part the cyathiscomele (not quoting ancient authors in this) and associates them, for example, with the preparation of colours.[50]

Aetius[51] suggests examining the vaginal space with a probe followed by blunt dissection using the spatula part of the spathomele in cases of occluded vagina. Leonidas[52] used the spathomele as a tongue depressor. In their descriptions, the authors do not often refer to the middle part of the spathomele. However, the spathomele found in Central European oppida is typically a small instrument up to 17 cm long, with one end featuring a small spatula and the other an olive-shaped tip. The spatula end is often topped with a moulded ornament, usually with hook-like prominences. The sharp part is usually about two-thirds of the actual length from the end of the spatula, and occlusion of the vagina can occur at various depths, from 1 cm to about 8 cm. Thus, some of the procedures described directly point to the need to use the spathomele without the central part modification.

43 J. Kábrt – J. Kábrt jr., *Lexicon medicum*, p. 253.
44 J. S. Milne, *Surgical instruments*, p. 66.
45 Paulus Aegineta, *Chirurgie de Paul d'Égine*, translated by René Briau, Paris, 1855, VI. Lxxxviii.
46 J. S. Milne, *Surgical instruments*, p. 59.
47 Aetius of Amida, *Tetrabiblos*, translated by Janus Cornarius, Basel, 1533–1542, II. iv. 16.
48 Marcellus Empiricus, *De Medicamentis liber*, translated by Georgius Helmreich, Leipzig: Teubner, 1889, vii. 19.
49 Soranus of Ephesus, *Gynaecia ex Muscionis ex Graecis Sorani*, translated by Valentin Rose, Leipzig 1882, p. xxvii.
50 J. S. Milne, Surgical instruments, p. 62.
51 Aetius of Amida, *Tetrabiblos*, IV. iv. 96.
52 Aetius of Amida, *Tetrabiblos*, VI.

The olive-shaped end of the spathomele is generally larger than that of the probe and is not suitable for wound inspection. Galen[53] sought a suitable instrument for probing the torcular Herophili (the internal occipital protuberance of the occipital bone) to remove thrombi in head traumas. Though he did not rule the spathomele out, he found very small probes or tiny spoons more appropriate thanks to their size.

Manufacturing

There are no specific descriptions of the production processes for instruments used in treatment procedures. Thus, the identification of production methods relies on general knowledge of metalworking techniques and the traces left on the instruments.

For copper alloy objects, the metal was first heated and melted in clay crucibles placed in small clay furnaces, which are rarely preserved intact, and then poured into moulds. These moulds, rarely found intact, were made of either stone[54] or fired clay.[55] The use of single-use moulds (e.g., lost-wax moulds) or moulds that leave no observable traces cannot be ruled out. This work was typically done in workshops identified by finds of furnace fragments, miscast or unfinished artefacts, unused ingots, and broken copper alloy items for recasting. These workshops also often contain whole or fragmentary crucibles, sometimes with pieces of molten metal still present.[56] Examples of such workshops have been found at oppida such as Závist,[57] Hrazany,[58] Stradonice[59] and Třísov.[60]

Considering the suggestion by J. Kysela[61] that these artefacts might be imports, as evidenced by morphologically similar specimens in Roman finds assemblages, efforts are made to determine the elemental composition of the metal mixture used for the imported tools. K. E. Jakielski and M. R. Notis[62] found that Roman spatulas from the 1st–4th

53 Galen of Pergamum, *Claudii Galeni opera omnia*, ed. Carolus Gottlob Kühn, Lipsiae: C. Cnobloch (22 vols.), 1821–1833, ii. 712.

54 J. L. Píč, *Starožitnosti země České*, II/2, p. 97, tab. LVIII: 26–27, 29–33; Petr Drda – Alena Rybová, *Keltská oppida v centru Boiohaema*, Památky archeologické 88, 1997, Fig. 27.

55 Alžběta Danielisová – Jan Kysela – Martin Mihaljevič – Jiří Militký, *Metal working at the oppidum of Třísov, South Bohemia – a review*, in: Jan Kysela – Alžběta Danielisová – Jiří Militký (eds.), Stories that Made the Iron Age. Studies in Iron Age Archaeology dedicated to Natalie Venclová, Praha 2017, p. 86, Fig. 5; Libuše Jansová, *Hrazany. Das keltische Oppidum in Böhmen*, II, *Die Gehöfte in der mittleren Senkung*, Praha 1988, p. 305, Taf. 199: 17.

56 Petr Drda – Alena Rybová, *Prostorové rozložení specializovaného řemesla v zástavbě keltského oppida*, Archeologické rozhledy 47, 1995, pp. 608–610.

57 P. Drda – A. Rybová, *Prostorové rozložení specializovaného řemesla*, p. 596, Fig. 1–2.

58 P. Drda – A. Rybová, *Prostorové rozložení specializovaného řemesla*, pp. 605–607, Fig. 9.

59 P. Drda – A. Rybová, *Prostorové rozložení specializovaného řemesla*, pp. 602–605; Alena Rybová – Petr Drda, *Hradiště by Stradonice*. Rebirth of a Celtic Oppidum, Praha 1994, p. 120; J. L. PÍČ, *Starožitnosti země České*, II/2, p. 5, 8, 96.

60 A. Danielisová – J. Kysela – M. Mihaljevič – J. Militký, *Metal working at the oppidum of Třísov*, pp. 83–87; Jan Kysela, *L'oppidum de Třísov (CZ). L'atelier de bronzier (?) fouillé en 1981–1982 et l'artisanat sur les acropoles des oppida en Europe centrale*, in: S. Marion – S. Deffressigne – J. Kaurin – G. Bataille (eds.), Production et proto-industrialisation aux âges du Fer. Perspectives sociales et environnementales. Actes du 39e colloque international de l'AFEAF Nancy, 14–17 mai 2015. Collection Mémoires 47. Bordeaux 2017, pp. 467–474.

61 Jan Kysela, *Things and Thoughts*. Central Europe and the Mediterranean in the 4th–1st centuries BC, Univerzita Karlova, Filozofická fakulta 2021, pp. 175–176.

62 K. E. Jakielski – M. R. Notis, *The metallurgy of Roman medical instruments*, pp. 379–389.

centuries AD had an elemental composition consistent with La Tène bronze tools, typically an alloy of copper and tin in a 9:1 ratio with other elements. Specifically, they found 91.10% Cu, 8.33% Sn, and 0.31% Fe in a spatula, while an ear scoop contained 69.00% Cu, 0.38% Sn, 0.04% Pb, and 28.97% Zn. Valério et al.[63] reported elemental compositions of 90.3% Cu and 9.6% Sn in tweezers, and 89.2% Cu, 10.3% Sn, and 0.18% Pb in a needle. B. Molloy and M. Mödlinger[64] described yellow copper ("Type III") with a 5-12% Sn content. At 10% Sn, the polished alloy is distinctly golden, with good casting qualities, rapid hardness increase, manageable brittleness, and predictable behaviour.

However, small bronze artefacts from the La Tène period exhibit significant compositional variability. Research on similar artefacts in published sources reveals the following content ranges: 52.30-95.1% Cu, 3.52-34.40% Sn, 0.00-36.40% Pb, and 0.00-28.97% Zn (based on multiple analyses.[65] This disparity in composition is likely caused by the recycling and recasting of older copper alloy artefacts, as is known from oppida such as Manching[66] and Třísov.[67]

Traceology Analysis

Empirical knowledge, written and iconographic sources, and traditional production techniques preserved through time provide crucial insights into the likely manufacturing processes of artefacts.[68] Equally significant is the systematic study of use-wear traces, which

63 Pedro Valério – Rui J. C. Silva – António M. Monge Soares – Maria F. Araújo – Francisco M. Braz Fernandes – António C. Silva – Luis Berrocal-Rangel, *Technological continuity in Early Iron Age bronze metallurgy at the South-Western Iberian Peninsula – a sight from Castro dos Ratinhos*, Journal of Archaeological Science 37/8, 2010, pp. 1811–1819.

64 Barry Molloy – Marianne Mödlinger, *The organisation and practice of metal smithing in Later Bronze Age Europe*, Journal of World Prehistory 33/2, 2020, pp. 169–232.

65 Alžběta Danielisová – Ladislav Strnad – Martin Mihaljevič, *Circulation patterns of copper-based alloys in the Late Iron Age oppidum of Třísov in Central Europe*, Metalla 24, 2018, pp. 5–18; Lina Pacifico – Wayne Powell – H. Arthur Bankoff – Vojislav Filipović – Aleksandar Bulatović, *Iron Age and Roman metallurgical activities at the Spasovine placer tin deposit, West Serbia*, Journal of Archaeological Science: Reports 45, 2022, p. 103619; Daniel Penz, *Die chemische Analyse der Produktionsreste von Altenburg*, Fundberichte aus Baden-Württemberg 32/1, 2012, pp. 805–838; Roland Schwab, *Kupferlegierungen und Kupferverarbeitung im Oppidum auf dem Martberg*, Berichte zur Archäologie an Mittelrhein und Mosel 17, 2011, pp. 267–285; R. Schwab, *Resources and Recycling. Copper Alloys and Nonferrous Metalworking in the Oppidum of Manching (Germany)*, in: Ernst Pernicka – Roland Schwab (eds.), Under the Volcano. Proceedings of the International Symposium on the Metallurgy of the European Iron Age (SMEIA) held in Mannheim, Germany, 20–22 April 2010. Forschungen zur Archäometrie und Altertumswissenschaft, Bd 5, Rahden 2014, pp. 175–188; P. Valério – R. J. C. Silva – A. M. Monge Soares – M. F. Araújo – F. M. Braz Fernandes – A. C. Silva – L. Berrocal-Rangel, *Technological continuity in Early Iron Age bronze metallurgy*, pp. 1811–1819; Omid Oudbashi – Ata Hasanpour – Parviz Davami, *Investigation on corrosion stratigraphy and morphology in some Iron Age bronze alloys vessels by OM, XRD and SEM-EDS methods*, Applied Physics A 122, 2016, pp. 1–11; K. E. Jakielski – M. R. Notis, *The metallurgy of Roman medical instruments*, pp. 379–389; Elin Figueiredo – Maria Fátima D. Araújo – Rui J. C. Silva – Raquel Vilaça, *Characterisation of a Proto-historic bronze collection by micro-EDXRF*, Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms 296, 2013, pp. 26–31.

66 Matthias Leicht – Susanne Sievers, *Recycling im Oppidum von Manching?*, Das archäologische Jahr in Bayern 1998, pp. 60–62; R. Schwab, *Resources and Recycling*, pp. 175–188.

67 A. Danielisová – J. Kysela – M. Mihaljevič – J. Militký, *Metal working at the oppidum of Třísov*, pp. 92–93.

68 Pamela H. Smith, *The Material Culture of Empirical Knowledge*, West 86th: A Journal of Decorative Arts, Design History, and Material Culture, 25/1, 2018, pp. 1–17.

allows for a deeper understanding of the functional aspects of these tools.[69] The analysis of surface modifications, micro-abrasions, and wear patterns contributes to identifying the specific activities for which these artefacts were employed.[70]

For small, precise bronze tools from the La Tène period, particularly those featuring at least one spatula-shaped working end, a range of potential uses can be proposed, including diagnostic or therapeutic procedures, personal grooming, the application of protective eye salves, and makeup application. However, distinguishing between these functions requires a comparative approach. Experimental archaeology offers a controlled framework for replicating wear traces, facilitating direct comparisons between archaeological specimens and experimentally used replicas.[71]

A more refined traceological approach, incorporating microscopic analysis, could further enhance the accuracy of functional interpretations.[72] Tools used for treatment procedures can be differentiated from those used for personal grooming by comparing use-wear traces on artefacts with those produced on experimental tools through specific activities and contact with certain materials and substances. The authenticity of artefacts can be assessed by examining consistencies and deviations from normal production processes, degradation stages, and subsequent modifications.

Limitations

The observation and interpretation of traces on artefact surfaces depend heavily on the amount of baseline data. Traceology analysis of metal tools is still evolving and lacks a comprehensive database of traces, particularly for tools intended for treatment purposes. The physical characteristics of individual instruments, such as material, degree of corrosion, conservation methods, and handling, play significant roles in research. The availability and quality of hardware and software, research conditions, and factors related to the researchers' knowledge and experience, vision, attention, and working protocols also affect research outcomes.

Many changes and traces on archaeological artefacts result from post-depositional processes, detailed by Marreiros et al.[73] These processes can cause changes to the tool edge and/or surface, including edge damage, surface breaks, polishing, and striation. A coloured or shiny patina may develop from minerals in the surrounding soil, known as 'miscellaneous lustre', which produces a luminescent and shiny effect over the entire tool surface. Restoration interventions and artefact deposition often remove beneficial traces and create

[69] João Marreiros – Ivan Calandra – Walter Gneisinger – Eduardo Paixão – Antonella Pedergnana – Lisa Schunk, *Rethinking use-wear analysis and experimentation as applied to the study of past hominin tool use*, Journal of Paleolithic Archaeology, 3, 2020, pp. 475–502.

[70] W. James Stemp – Adam S. Watson – Adrian A. Evans, *Surface analysis of stone and bone tools*, Surface Topography: Metrology and Properties, 2015, 4.1: 013001.

[71] Valerio Gentile, *Reconstruct the unknown, replicate the uncontrollable. Current issues in the experimental archaeology of combat*, Journal of Archaeological Science: Reports, 2022, 46: 103709.

[72] Juan Luis Fernández-Marchena – Andreu Ollé, *Microscopic analysis of technical and functional traces as a method for the use-wear analysis of rock crystal tools*, Quaternary International, 2016, 424: 171–190.

[73] João Manuel Marreiros – Juan F. Gibaja Bao – Nuno Ferreira Bicho (eds.), *Use-wear and residue analysis in archaeology*, Springer 2015, 17–18.

new ones that can be mistaken for manufacturing alterations, most notably striation that simulates subsequent surface modifications.

Equipment and Techniques

We observe manufacturing traces, subsequent modification traces, and use-wear traces on selected artefacts using Dino Lite Edge microscopes with low and high magnification (20-220x, AM7515MZT, and 700-900x, AM7515MT8A). The equipment, funded by the researchers' own resources, was chosen for its portability and long-term usability in field and institutional settings, both domestically and abroad.

Comparative Databases

Interpreting artefacts based on microscope data requires a database of images with known traces. Conducting experiments to produce artefacts of the same type using suspected manufacturing methods creates these traces for comparison. Experiments are valid and beneficial for uncovering details about La Tène production processes. Implementing production in different variations, as seen in Nenakhov[74], according to assumptions based on previous research, enhances our understanding.

Although a comprehensive database of manufacturing traces, subsequent modification traces, and use-wear traces for artefacts used for treatment and diagnostic purposes is lacking, several studies present traces on artefacts of similar composition and origin but different uses. These studies aid in interpreting general traces, understanding material behaviour, and defining nomenclature. This study uses the nomenclature of C. G. Sáez and I. M. Lerma[75], preserving the original category breakdown while refining trace type divisions. We build trace databases throughout this study, separately monitoring traces on authentic artefacts and experimental tools. For authentic artefacts (clues for identifying forgeries are collected separately and are not relevant to this paper), we observe manufacturing traces, subsequent modification traces (Tab. 1), use-wear traces (Tab. 2), and post-depositional traces created after artefacts were removed from the ground (Tab. 3). For experimental tools, we track production traces, subsequent modification traces, and use-wear traces.

[74] Dmitriy A. NENAKHOV, *The Casting Molds for Celts of Type IV (Early Iron Age) According to M. P. Gryaznov's Classification: The Manufacturing Technology*, Vestnik NSU. Series: History and Philology 20/7, 2021, pp. 97–108.

[75] Carmen Gutiérrez SÁEZ – Ignacio Martín LERMA, *Traceology on metal. Use-wear marks on copper-based tools and weapons*, in: João Manuel Marreiros – Juan F. Gibaja Bao – Nuno Ferreira Bicho (eds.), Use-wear and residue analysis in archaeology, Springer 2015, pp. 171–188.

Tab. 1: Manufacturing traces on the spatula and spathomele. Based on and altered of C. G. Sáez and I. M. Lerma (2015)

Manufacturing and consequent modification	Description	Type of mark	Formation and origin
Plastic deformations	Depressions – widespread	Imprints	Widespread blow marks, displacing of material, hammer imprints made while shaping
			Hammer marks while finishing artefact, no displacing of material, imprints made while shaping
	Depressions – linear	Incisions	For forging, fitting, material cutting, grooving
		Striations	Sharpening with striate
		Fissure – singular	While casting, with connection to rapid cooling process
		Band of fissures	When cutting, bending
	Deep local hollowing	Misrun defect	Unfilled portion or space in the mould, presence of gas bubbles in process of casting
	Rounding	Dulling	For example, at the free end of the olivary applicator, a file, a hammer
	Edge deformation	Breakage	Cutting off sprues formed during casting
		Notch	Volute formed by chisel and hammer strikes
		Flattening	Hammering like traces along the edges
		Asymmetry	Casting cavities, hammering of spatula
	Profile deformation	Central folding	Hammering on the edge of the anvil
		Lateral folding	Hammering on the edge of the anvil or with the help of chisel
		Torsion	Clamp and pliers when creating a torsion on the neck of the tool
		Morphological asymmetry	Mismatch defect
		Ridge	Residual material at the junction of the mould parts
Physical and/or chemical changes	Alteration	Corrosion	Oxides produced by secondary heating
		Filing	Filing of surface
		Polishing	Area without polishing, polished with striate, polish with tenorite
			By leather with abrasives, stones, etc.
		Grinding	Grinding of surface and decoration
		Lustre bands	Fine sharpening fissures, polished
		Porosity	Mismatch defect and porosity
			Interdendritic shrinkage porosity
		Gas bubbles	Evidence of cast defects entrapped gas bubbles + cast defect after abrasive brushing
		Differential alterations	Stamps, inscription etc.
Added elements	Adhering materials	Wood, different metal parts, resin	Originating from handle or working part on the other end of the tool, tip of the wooden part

Tab. 2: Use-wear traces on the spatula and spathomele. Based on and altered of C. G. Sáez and I. M. Lerma (2015)

Use-wear traces	Description	Type of mark	Spatula and spathomele
Plastic deformation	Massive depression	Blow mark	Indentation, material loss
			Indentation with a displaced material
	Linear depression	Blow marks	Blowmark without displaced material
			Blowmark with displaced material
		Incision	Contact with other tools
		Striation	Superficial grooves, by contact with vessels and slabs from abrasive material
		Fissure	Deeper grooves, bending the tool
		Band of fissures	Bending the tool
	Rounding	Dulling	Contact with vessel or slab
	Edge deformation	Breakage	Thinning of the free end of the spatula by prolonged friction against the slab
			Edge damage
			Fractured holes
			Fractured tip
		Notch	Blow marks
		Flattening	Flattening by using with vessel or slab from abrasive material
			Flattening and reducing
		Torsion	Torsion and flattening
		Thickening	Buckling of the material on contact with the plate
		Edge asymmetry	Using always by one hand (right for example)
		Microfolding	The folding of the edges by using on the hard slab
	Profile deformation	Curving	Customization by user
		Folding	
		Bending	
		Torsion	
		Morphological asymmetry	Contact with hard surfaces
Physical and/ or chemical changes	Deformation	Hafting	The hafting process is associated with different types of wear traces: polish, striations, edge rounding, and micro striations.
		Corrosion	Acidity of mixtures applied by the tool
		Polishing	Contact with mixture from rather soft material
Added elements	Adhering material	Residues	Textile, leather, galena mixture residues, pigment mixture residues

Tab. 3: Post-depositional traces on the spatula and spathomele. Based on and altered of C. G. Sáez and I. M. Lerma (2015)

Post-depositional	Description	Type of mark	Spatula and spathomele
Plastic deformations	Depressions	Linear, widespread	During the excavation
	Depressions - linear	Striations	After cleaning by fibreglass
	Rounding	Dulling	Rounding and lustre band
		Dulling	Rounded teeth after cleaning
	Edge deformation	Breakage	Recent damages while storing
		Notch	Recent damages while storing
		Shaving of edge	Non-expert experimentation with an object
	Profile deformation	Folding	Flanges of handling
		Lateral folding	During the excavation
		Torsion	During the excavation
Physical and/or chemical changes	Chemical	Corrosion	Recent damages while storing
	Physical	Polishing	After cleaning
		Drilling	Metallography was performed
		Differential alterations	Marking and labelling artefacts
Added elements	Adhering materials	Textile hair	Pieces of textile gloves

Experiment

The experimental replication was conducted between April and May 2023 (Pl. 1:8) with the objective of production of a spathomele – a tool characterized by one spatula-shaped working end and the other shaped as an olive-shaped applicator – using traditional metal-working techniques. These instruments are relatively common in various archaeological contexts across Central Europe, yet they are frequently recovered without precise contextual data, complicating their functional interpretation.

The experimental process was designed to replicate the tool's hypothesized historical manufacturing techniques as closely as possible. The experiment consisted of several controlled stages: (1) crafting a wooden prototype to serve as a casting model, (2) constructing a moulding box, (3) preparing the mould using fine-grained oil-bonded foundry sand to achieve precise detailing, (4) melting and alloying metals to approximate the composition of period-specific materials, (5) casting the tool, (6) shaping and refining its morphology, (7) adding decorative elements where applicable, and (8) conducting surface finishing to replicate wear patterns observed in archaeological specimens.

This experimental approach was intended not only to reconstruct the manufacturing process but also to provide insight into potential use-related modifications, material constraints, and functional characteristics of the spathomele, thereby contributing to a more comprehensive interpretation of these artefacts within their broader archaeological and technological context.

Pl. 1: Experiment: small two-part wooden mould frame (1), wooden models (2), first (3), second (4) and fourth (5) casting attempt, sample of one of the crucibles (6), perfect product after surface modifications (7), images from the process of the experiment (8)

Original Artefacts

Forms of the original artefacts found at the Stradonice oppidum in the Beroun district were used as templates for the wooden models of the tools and the finished specimens. These artefacts are stored in the National Museum's depository under inventory numbers 81 459, 81 460, and 81 461. First, a model was made from ash hardwood using small carving tools, chosen for their reusability and properties suitable for this purpose.

Present-day carving tools corresponding in size and shape to those from the La Tène period were used, including a knife and a fine file, chisels were also utilized. No special carving tools were made according to traditional La Tène techniques, because we are not yet able to safely distinguish between the traces of a modern file, knife or chisel and those of period tools if the dimensions and file grooves are the same. The creation of a database of file and chisel marks will hopefully lead to such distinctions in the future.

Due to findings on real artefacts, the lost-wax mould casting method was not used in the experiment. Although the lost-wax mould is mentioned in the literature as a likely method for producing small precision products (e.g., Bliquez[76]), artefacts examined showed traces of casting into a two-part mould, with imprints of round casting sand grains and occasional embedded grains on the surface. Practically, the sand mould is also more economically viable, especially for this common shape frequently found at various archaeological sites.

Experimental Tool

Three models were made. The models (Pl. 1:2) used for casting were precisely carved and ground to shape, without decorative and functional small details. A small two-part

[76] L. J. Bliquez, *The tools of Asclepius*, p. 18.

wooden mould frame (Pl. 1:1) was made using the usual carving tools, consisting of two hollowed-out pieces of fresh hard wood fitted with funnel, pouring, and venting channels. The frame was filled with fine sand to simulate the documented fine-grained silica sand with round grains. Two models were positioned in a lateral alignment to achieve higher level of efficiency (Pl. 1:2). Subsequent to the removal of the models, casting and venting channels were formed, and the two halves were firmly joined and secured with wooden pins. The metal mixture was melted in a wood-burning furnace made of clay. The crucible for melting the metals (Pl. 1:6) was made traditionally from heat-resistant clay with an admixture of sand and crushed older crucible as a sharpener, and hay and tallow as lightening agents. The crucible was thoroughly dried before use and embedded with a mixture of metals, as presented in Tab. 4. Zinc and part of the copper content were added in the form of brass pieces.

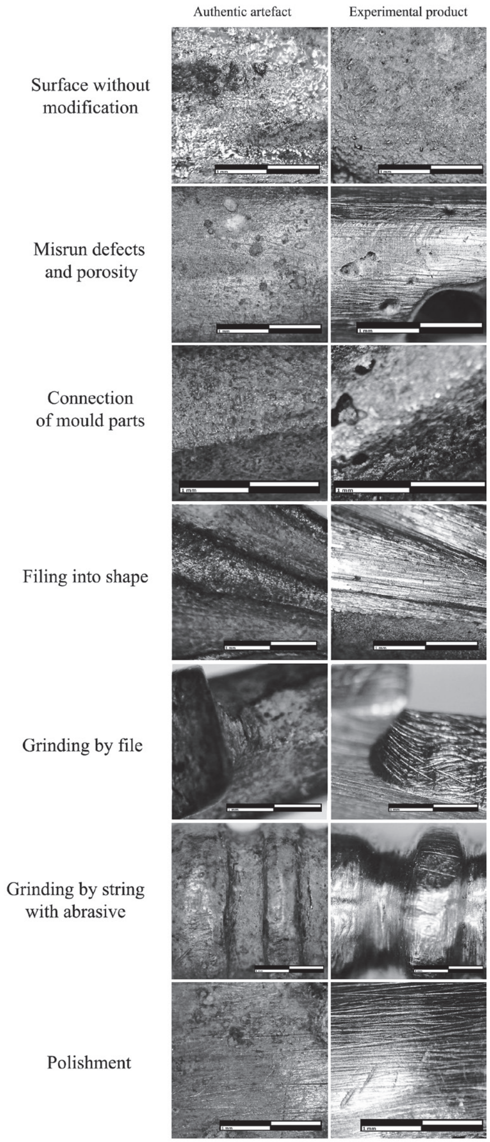
Tab. 4: Experiment – elemental composition of the material used

Sample	1		2		3		4	
Material	wt (g)	wt (%)	wt (g)	wt (%)	wt (g)	wt (%)	wt (g)	wt (%)
Cu	56,45	91,299	50,00	88,794	32,00	91,664	47,83	85,871
Sn	3,09	4,998	4,46	7,920	1,60	4,583	4,55	8,169
Pb	1,79	2,895	1,85	3,285	0,81	2,320	2,73	4,901
Zn	0,5	0,809	0,00	0,000	0,50	1,432	0,59	1,059
Results	One perfect tool (Fig. 2:3)		Parts of the tools (Fig. 2:4)		The material burned		Part of one tool (Fig. 2:5)	

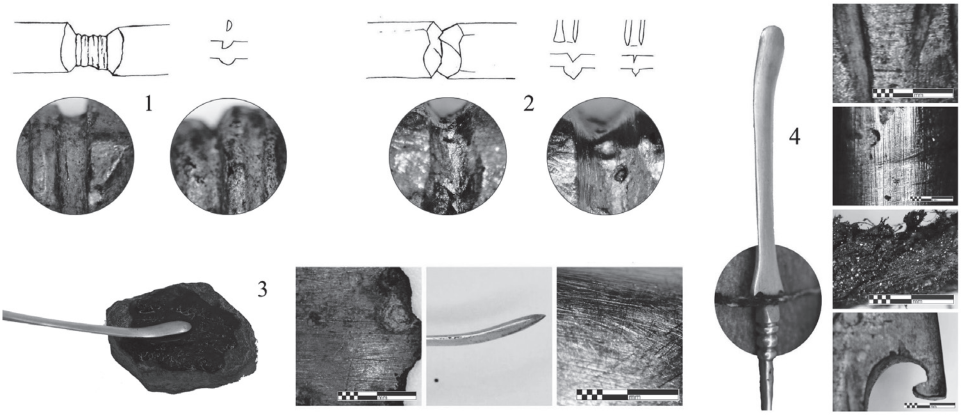
The desired temperature was achieved using bellows. The optimum alloy consistency was ascertained through observation of the surface, and the mixture was subsequently poured into the mould. Four casting trials were conducted, yielding only one perfect product. After removing each casting from the mould, the two tools were disassembled, and sprues were removed using a chisel and hammer. Subsequent to this, the tool in this rough form was ground. Decorative and functional elements in the central part of the tool were shaped with a file, and decorative rings were created using string dipped in a mixture of abrasive sand and oil. The entire object (Pl. 1:7) was then polished using leather with abrasive material and oil. As an abrasive material a modern carborundum was used for its ability to emulate the properties of Naxos stone. Failed attempts (incomplete or damaged products) were repurposed to emulate other methods of surface treatment or to create decorative and functional elements. This approach served to augment the existing database of traceological findings on experimental products.

Traceology Analysis and Comparison with Experimental Data

The examined artefacts exhibited manufacturing traces, traces of subsequent modifications (Pl. 2; Pl. 3:1, 2), use-wear traces (Pl. 3: 3, 4), and traces of post-depositional processes. Notably, the traces of the joints of the casting mould parts were critical for determining the production processes. These ridges located around the entire circumference of the artefacts were particularly visible where minimal subsequent modification through grinding and filing was present. This observation strongly supported the use of a sand-casting mould, as such joints would not be present when using a lost-wax mould. Other surface features included mould marks, residues of parting lines, and areas with imperfect mould fits, as well as grooves formed during casting and later filed and polished (creating lustre bands). Porosity and 'misrun defects' due to air bubbles were also noted. A misrun defect occurs when the liquid metal does not completely fill the mould during casting due to an obstruction, usually an air bubble, resulting in holes larger than typical porosity.



Pl. 2: Selection of significant manufacturing traces on artefacts. The research of artefacts from Stradonice, Beroun district, inv. Nr. 81460, 81461, 81462 was allowed by National Museum (NM), Prague, where the artefacts are stored. The research of artefact from Brigetio, inv. Nr. 16849 was allowed by Naturhistorisches Museum Wien (NHM) where the artefact is stored. Surface without modification: NHM, inv. Nr. 16849; misrun defects and porosity: NM, inv. Nr. 81460; connection of moulds parts: NM, inv. Nr. 81 462; filing into shape: NM, inv. Nr. 81460; grinding by file: NM, inv. Nr. 81460; grinding by string with abrasive: NM, inv. Nr. 81461; polishing: NM, inv. Nr. 81461



Pl. 3: Decorative rings made with a string dipped in an abrasive mixture (1), decorative rings made with a chisel and hammer (2), microscopic and macroscopic changes after use (3), traces of the presumed hanging of the tool on the vessel with a string (4)

Subsequent Modifications

There is substantial evidence of surface modification and subsequent surface treatment on the artefacts. Traces of rough grinding, filing, shaping, and the creation of decorative and functional features using a file and polishing are present. Various methods were employed to create the decorative and functional elements, each leaving distinct traces visible under the microscope. Although the grooves of different shapes show signs of being created by a file, the situation is more complex for the decorative rings in the central part of the tools. When these rings are created using a string dipped in a mixture of abrasives and oil, a very regular and precise groove is produced. While the grooves made with a chisel and hammer may appear regular to the naked eye, especially if subsequently smoothed, under a microscope the irregularities of the individual cuts become evident.

Bending and Folding

Although some spatulas are bent during use, folding can also occur during the manufacturing process. This involves folding the spatula longitudinally to form a central rib. It should be noted that this does not create a spoon; it remains a flat tool. At the olive-shaped end of the artefacts, the surface of the individual tools examined is usually relatively smooth, and it is often possible to observe traces of the casting mould, impressions of rounded grains of sand, and almost no surface modifications, except where the ridge formed by the mould joint has been removed by filing. Surface modifications at the flat end of the tool are often altered and covered with use-wear marks, and it is also on this surface of the tool that traces of rough treatment as part of the restoration of the artefacts are usually most evident. With regard to the evident signs of utilization observed on the spatula end, particular consideration should be directed towards the specific bends that have been formed during its operation. These bends are presumed to have been caused by the spatula's contact (friction) with a coarse surface, presumably a stone slab or ceramic plate.

Friction against a rough surface is also associated with the sharpening of the end of the spatula, usually at a certain angle and segment. The folding of the same edge on each side of the flat part of the tool and the sharpening of the opposite edge usually indicates how the spatula was used and how prolonged rubbing of the material and scooping and application led to the deformation of the original shape. The olive-shaped applicator on the tools examined is generally relatively smooth, first with no traces of rough processing after casting, and second with almost no traces of friction in the highly abrasive material.

Olive-shaped End

The olive-shaped applicator can take several shapes, and in all the artefacts examined, the olive transitions very smoothly into the neck. This design is suitable for applying mixtures to the eye and has continued in this form for applying kohl/kajal to the eye until the present day. A very small spatula with a free end abraded from a stone or ceramic slab and curved for more precise application of the mixture to the face is suited and adapted for the application of makeup.

Central Part of the Tool

The central part of the tool, with decorative and functional elements often in the form of hooks, is practical for scooping substances or pigment from the container and for storing the tool. Examination under the microscope revealed that this part, which has so far been regarded as ornamental, can also serve a number of purposes (Pl. 3:4). The hooks present on many specimens serve very well to hang the instrument on a string tied around the vessel. They also serve as a barrier to prevent the instrument from falling into a relatively deeper or wider container. However, these sharp hooks are a considerable hindrance to the intended purpose of examining the base of the wound. Even in a not very deep wound, they can cause further damage to the wound or to the surrounding tissue. Therefore, the olivary end on the richly decorated spathomele should not be considered a probe.

Use of the Tool

Examination of the artefacts in this study and comparison of the traces on the artefacts with those obtained from the experimental tools showed several changes associated with use. The working part, in the form of the spatula, is considerably ground down on most tools and is often bent only in use, at a point approximately 1 cm from its free end (Pl. 3:3). From this bend, significant grinding is often observed, leading to a sharp edge at the end of the tool.

Wider spatulas exhibit more pronounced sharpening along one edge, a pattern likely attributed to consistent hand use during work. This sharpening consistently appears on one specific side, regardless of the tool’s orientation. When viewed from above, the sharpening might be on the left edge. If the tool is flipped, the sharpening remains on the left edge. This indicates that the tool was always held in the same hand, resulting in uniform sharpening on one side due to the repeated grinding motion against a stone slab. Microscopic examination reveals that only the top surface on one side displays this distinctive wear pattern.

Simple spatulas and spatulas with a central rib, which are slightly curved, usually have a more significant microfold along one edge due to scraping against a hard surface. Very fine surface smoothing was present on the surface of the olivary applicator in some specimens, while in others, the surface appears as if the applicator had hardly been affected at all by use. Traces of the impression of the casting mould are often strongly present, almost untreated further. In the case of the use of an olivary applicator, it is considered that it may have been used to apply the galena mixture to the eye. As the galena is soft (hardness about 2.6), it did not cause significant marks on the surface of the tool even in experimental use. This was not the case when the galenite was intentionally or unintentionally applied to the string for hanging the tool, and it rubbed against the surface of the tool, leaving fine grooves.

Technique Distinction

Examination of artefacts under a microscope proved highly effective in revealing traces of both manufacturing and subsequent modification. Even at magnifications ranging from 20 to 50 times, it was possible to discern the details such as how the decorative rings in the central part of the artefacts were created. Though the rings appear perfectly regular to the naked eye, under a microscope, it is possible to determine whether they were made with a string dipped in an abrasive mixture (Pl. 3:1) or with a chisel and hammer, and then polished (Pl. 3:2). The string with abrasive produces a very regular circle of levelled depth. The result of using the chisel and hammer appears regular, but under a microscope, the individual cuts become distinguishable. These cuts lead to the very sharp lowest point of the ornamental ring, which cannot be polished to this depth by any technique considered in connection with contemporary tool making and therefore remains sharp.

Summary

This paper, through detailed traceology analysis and experimental work, demonstrated the capacity to distinguish the purposes of tools – specifically those combining spatula features – based on traces of manufacture, modification, and use. It also confirmed, at least for the artefacts analysed, the use of two-piece moulds rather than lost-wax moulds, a method previously considered. We anticipate that this approach will generate extensive data for other tools presumed to be used in treatment procedures.

Characteristics of the Spathomele for Treatment Procedures:

The spathomele is characterized by a distinctive combination of functional features and decorative elements. The flat spatula end, often ground down through use, and the olive-shaped applicator are suited for precise application of mixtures. Evidence suggests that the tool was adapted for applying kohl or similar substances to the eye, indicated by the smooth surface of the olivary end and the specific wear patterns observed. Microscopic analysis reveals that this specific spathomele's form and surface modifications align with its intended use in cosmetic applications.

Use in the Manner Described in Primary Sources:

The central part of the spathomele, featuring intricate moulded ornamentation, served probably not only decorative but rather functional purposes. The hooks and decorative rings could be used for hanging the tool on the container of the applied substance. While primarily suspected to be only ornamental, these features could indeed be consistent with descriptions found in primary sources, indicating the tool's use for applying cosmetic mixtures.

Uses Detected Through Microscopy Analysis:

Microscopy analysis reveals significant use-related modifications, including grinding patterns, bending, and sharpening on specific edges. The distinct wear patterns suggest the spathomele was used for scraping or applying substances, with clear evidence of deformation and wear consistent with practical use.

Manufacturing and Modification Practices Identified:

The study identified several key manufacturing practices through microscopy. The use of two-piece moulds is evident from the joint ridges on the artefacts, contrasting with lost-wax methods. Surface modifications, such as filing and polishing, were used to refine the tool's functionality and appearance. Distinct traces of grinding and polishing reveal the steps taken to adapt the tool for specific uses, while post-depositional modifications further complicate the interpretation of these traces.

The spathomele exemplars under examination, while complex in design, are tools precisely adapted for their intended functions. These specific pieces are not suited for general treatment procedures but are tailored for creating suspensions by smoothing solid matter into a liquid with the spatula and applying mixtures to the eye with the olive-shaped applicator. Tools incorporating spatulas have a lineage extending to the present day, with significant variations across different fields and disciplines. This variability was also evident during the La Tène period. The integration of decorative and functional elements, examined through detailed traceology analysis, provides valuable insights into their historical use and production techniques.

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Morfologické charakteristiky a povrchové stopy ukazující na používání nástrojů s jedním lopatkovitým pracovním koncem v období La Tène

RESUMÉ

Průzkum artefaktů pomocí traseologické analýzy a metod experimentu v archeologii ukázal, že je možné rozlišit účel nástrojů, jejichž součástí je spatula neboli špachtle, na základě stop po výrobě, následných úpravách a používání nástroje. Bylo doloženo, že zkoumané artefakty byly vyrobeny pomocí dvoudílných forem, nikoli metodou ztraceného vosku. Metody jsou vhodné k odhalování charakteristik i dalších nástrojů používaných při léčebných procedurách v době laténské. Spathomele představuje nástroj značně komplexního designu, jehož

jednotlivé části jsou přizpůsobeny specifickým funkcím. U zkoumaných exemplářů je na základě nalezených stop možné předpokládat používání při přípravě substancí a jejich aplikaci na kůži či do očí. Stopy neodpovídají použití při léčebných výkonech a morfologie daných exemplářů, kvůli řešení střední části, kde spatula přestupuje do olivkovitého aplikátoru, přímo znemožňuje provádění některých úkonů popsaných antickými autory pro nástroje kombinující pracovní části v podobě spatuly a sondy. Traseologická analýza odhaluje výrobní praktiky a přispívá k porozumění použití konkrétních nástrojů, čímž umožňuje odstup od dřívějších teorií o multifunkčnosti nástrojů a jejich přenosu mezi účely během jejich životního cyklu.

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