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RESEARCH

Exploring the "Microburin Blow": An Insight into the Variability of the Microburin Blow Method for the Production of Sauveterrian Geometrics in the Site of Mondeval de Sora (N-E, Italy)

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Abstract

This paper examines the microburin blow method and its impact on geometric microliths production during the Early Mesolithic. Through experimentation, a novel analytical framework was developed, combining a high- and a low-magnification analysis of a large sample of microburins. This approach enabled both the identification and description of combinations of micro-, meso-, and macroscopic features diagnostic of diverse microburin blow techniques and provided valuable insight into the variability of production modalities of Sauveterrian geometrics, *i.e.* the number of microliths and microburins obtainable from a single blank. Furthermore, this research extends beyond the experimental realm, examining an assemblage of microburins from SU 8 of Mondeval de Sora (San Vito, N-E Italy), for which two new radiocarbon dates are reported here, providing a more precise chrono-cultural attribution of its occupation. Such an analysis revealed the application of one specific microburin blow technique applied by the Sauveterrian inhabitants of the site. At the same time, a meticulous technological study of a representative sample of geometrics was performed, enhancing our understanding of the *chaîne opératoire* involving their production. The results of this study represent a major advance for the interpretation of the microburin blow method and its role in Mesolithic armatures production, contributing to a richer characterisation of the Sauveterrian technical traditions.

Keywords Microburin blow method · Experimentation · Geometrics · Sauveterrian · Mondeval de Sora · N-E Italy

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Introduction

The study of lithic technology is instrumental in deciphering the complexities of prehistoric societies, providing crucial glimpses into their cognitive abilities, adaptive strategies, and cultural practices. Among the production modalities employed by ancient human groups, the microburin blow method is known for its essential role in some of the *chaîne opératoires* involving microliths production. Its introduction during prehistory brought significant technical advantages: it allowed (1) the normalisation of microlith morphology and size starting from a high array of blanks; (2) the shaping of a sharp trihedral extremity, known as *piquant trièdre*, that cannot be obtained by simple retouching; and (3) the potential production of more than one microlith from each blank (Neeley & Barton, 1994; Tixier, 1963). At a European scale, the microburin blow method sporadically appears in the second half of the Upper Palaeolithic, especially during the Gravettian, the Solutrean, the Magdalenian (Langlais, 2008), and the Epigravettian (Bisi *et al.*, 1983; Duches & Peresani, 2010; Duches *et al.*, 2014; Fasser *et al.*, 2024a), becoming a common technical expedient at the end of the latter techno-complex (*i.e.* Terminal Epigravettian, *sensu* Binder, 1980; Tomasso *et al.*, 2020). However, it reached its maximum diffusion at the onset of the Mesolithic (Peresani & Miolo, 2012; Visentin, 2018). The discussion concerning when this blank segmentation method transformed from an unintentional breakage into a deliberate practice (Krukowski microburin vs. ordinary microburin), and whether in Europe it was a Mesolithic invention or rather the result of a gradual development during the Late Upper Palaeolithic, is still open (De Wilde & De Bie, 2011). Recently, evidence from the Late Epigravettian layer of Riparo Biarzo (UD, Italy) points to certain intentionality and predetermination also of some Krukowski microburins, suggesting a gradual development of the microburin blow method, from accidental to intentional, during the Italian Upper Palaeolithic (Fasser *et al.*, 2024a).

Microburins were identified by G. Chierici (1875), who first understood their technical connotation. Later, several scholars analysed and discussed this production waste, such as L. Siret (1893) and H. Breuil (1921)—who introduced the term "microburin" due to a misinterpretation—St. Krukowski (1914), E. Vignard (1923, 1934), E. Octobon (1926), F. Bordes (1957), and M.N. Brézillon (1968). Nonetheless, it was J. Tixier and colleagues who explained in detail the technical process involved in this fracturing method for the first time (Tixier, 1963; Tixier *et al.*, 1980). According to these authors, the procedure requires the use of a blank (flake, blade, bladelet, or microbladelet), which must be positioned on the edge of an anvil (*e.g.* a stone, a piece of wood or antler, a flint core, and the ridge of a thick blank) with its ventral face facing up. Then, a deep notch must be produced by applying an abrupt and direct retouch until the fracture occurs. The breakage orientation follows that of the anvil edge. This operation produces two pieces: one piece that remains on the anvil, showing part of the notch and the *piquant-trièdre* (negative component of a cone initiation fracture with a *languette* development and a hinged termination, Fig. 1a), and the other, called microburin,

Fig. 1 **a** *Piquant trièdre* (negative component) on the left and microburin fracture (positive component) on the right; **b** stone percussion; **c**, **d** pressure by an organic tool; **c** "A" holding modality; **d** "B" holding modality

presenting the residual portion of the notch and the opposite fracture surface of the *piquant-trièdre* (positive component, Fig. 1a). The microburin is the production waste, while the blank portion displaying the *piquant-trièdre* was usually transformed into a microlith either by using the obtained morphology or by retouching it. According to K. Kompatscher (2011), the fracture of the microburin can be divided into three main steps: (1) a traction force starting the fracture due to the action of the retoucher on the ventral face of the blank, (2) an opposite compression force on the dorsal face, and (3) a rotation movement caused by these two forces that guide the fracture development.

While archaeologists have always referred to the microburin blow as a production technique (*i.e*. the "microburin blow technique"), according to the definitions of "technique" and "method" proposed by the main references for lithic technology (Arzarello *et al*., 2011; Boëda, 1986, 1994; Inizan *et al*., 1999; Tixier *et al*., 1980), the microburin blow should be interpreted as a production method. The literature, in fact, proposed and described different techniques for applying the microburin blow (Albarello, 1987; Finlay, 2000; Kompatscher, 2011; Miolo & Peresani, 2005; Tixier *et al*., 1980): percussion by a stone retoucher and pressure by an organic tool. While several observations regarding the efficacy of these two techniques and their technical procedures have already been published in the aforementioned papers, the criteria useful for differentiating them have rarely been discussed (Albarello, 1987). For this reason, an experimental program has been conducted to identify and describe micro-, meso-, and macroscopic criteria useful for identifying different microburin blow techniques. Furthermore, the variability of applying the microburin blow method to produce Early Mesolithic geometrics has been experimentally explored. The aim was to answer two main questions concerning the manufacture of geometrics during the Italian Sauveterrian: how many microburins were detached for each geometric? How many geometrics were obtained from a single blank? The results of this experiment were then applied to a Sauveterrian assemblage of microburins from the site of Mondeval de Sora (BL, Italy) (Fontana *et al*., 2009, 2012). To reconstruct all steps of the *chaîne opératoire* of geometrics production, from blank selection to its transformation, a sample of triangles and crescents has also been analysed.

Material and Methods

The Experimental Program

The Microburin Blow

Raw materials selected for the experiment are nodules belonging to the Maiolica Formation from the Lessini Mountains (VR, Italy), Scaglia Rossa and Scaglia Variegata from the Non Valley (TN), and a single block of radiolarite from the Cariadeghe plateau (BS, Italy). The workflow was divided into two different phases: firstly, we selected a random sample of 60 blanks, from small microbladelets (length ≥ 20 mm) to longer bladelets (length ≤ 59 mm) with a thickness varying from 1 to 6 mm. These blanks were split at either one or both extremities by a microburin blow to understand the correct blank position and the gesture needed to reach a *piquant-trièdre* fracture with different techniques, blank morphology, and size. In the second phase, the blank selection was more parameterised and done in function of the production of a series of geometrics (triangles and crescents) comparable with those attested in the Early Mesolithic SU 8 of the site of Mondeval de Sora (BL, Italy). Therefore, only microbladelets smaller than 35 mm with a thickness lower than 3 mm were selected ($n = 49$). Longer bladelets were rarely exploited ($n = 6$).

Two force application modes for producing the notch and obtaining the *piquant-trièdre* fracture have been experimented with: percussion (Fig. 1b) and pressure (Fig. 1c, d). Percussion was applied using a little flat sandstone pebble, whereas pressure was applied with a bone antler or lithic compressor. The former was shaped from a cow tibia and hafted on a wooden handle; the latter was collected from a red deer antler tine, and the third was an elongated and flat pebble with a tempered extremity. Several types of anvils were used: a boxwood log, a flat cobble, and a flint core. Two blank holding modalities were used, depending on which blank side (left or right) and portion (distal or proximal) the notch was located. For a right-handed knapper (such as the first author), the most convenient way to retouch a right notch on the proximal portion and a left notch on the distal portion is the "A" modality (Fig. 1c), while for applying a left proximal notch or a right distal notch, the "B" modality (Fig. 1d) is the most appropriate. For a left-handed knapper, the opposite would be true.

According to our experiment, the procedure for obtaining a *piquant-trièdre* changes according to the force application mode: using a percussion technique, the blank was positioned on the edge of the anvil with its ventral face facing up, its longitudinal axis diagonally oriented compared to the edge (around 45°) and slightly inclined (around 10°–20°) towards the retoucher and its transverse axis inclined with respect to the anvil surface (around 10°–20°). A direct retouch generates the notch, and once the latter reaches the maximum transversal thickness of the blank (*e.g*. the main dorsal ridge for triangular cross-section blanks), a spontaneous fracture occurs. Otherwise, the pressure technique involved a different strategy. The notch was retouched while the blank was blocked on the anvil surface, not on the edge. Once the maximum transverse thickness of the blank was reached, the blank was positioned on the anvil edge with its longitudinal axis diagonally oriented (around 45°) and its ventral face more or less parallel to the anvil surface. The fracture occurs by a perpendicular pushing applied with the lithic or organic (antler or bone) compressor in the mid part of the notch. The same technique was used to produce the notch and reach the fracture. Table 1 shows the number of microburin blows obtained through our experimental tests for each technique used.

In the final phase of our experiments, a total of 42 microliths were shaped, divided among the four major types attested during the Italian Sauveterrian according to Laplace's typology (1964) (T): crescent (Gm1), trapezoidal crescent (Gm2), scalene triangle (Gm3), and isosceles triangle (Gm4). Several production modalities were tested according to the number of microburin blows applied to each blank (Fig. 2) (Table 2):

Modality 1—A single geometric from each blank by a distal or proximal microburin blow.
Modality 2—A single geometric from each blank by both a distal and a proximal microburin blow.
Modality 3—Two geometrics from each blank by two microburin blows.
Modality 4—Two geometrics from each blank by three microburin blows. This modality required two microburin fractures to shape the first geometric; then, a third microburin was removed from the distal portion of the previous distal microburin, resulting in a piece characterised by a microburin fracture opposed to a *piquant-trièdre*. This element was turned into the second geometric by retouching. In this case, a blank of at least 30 mm in length is needed.

Table 1 Number of microburin blows attempted according to fracturing technique

	Successful and unsuccessful microburins produced
Pressure by an organic compressor	45
Pressure by a lithic compressor	8
Stone percussion	54
Total	107

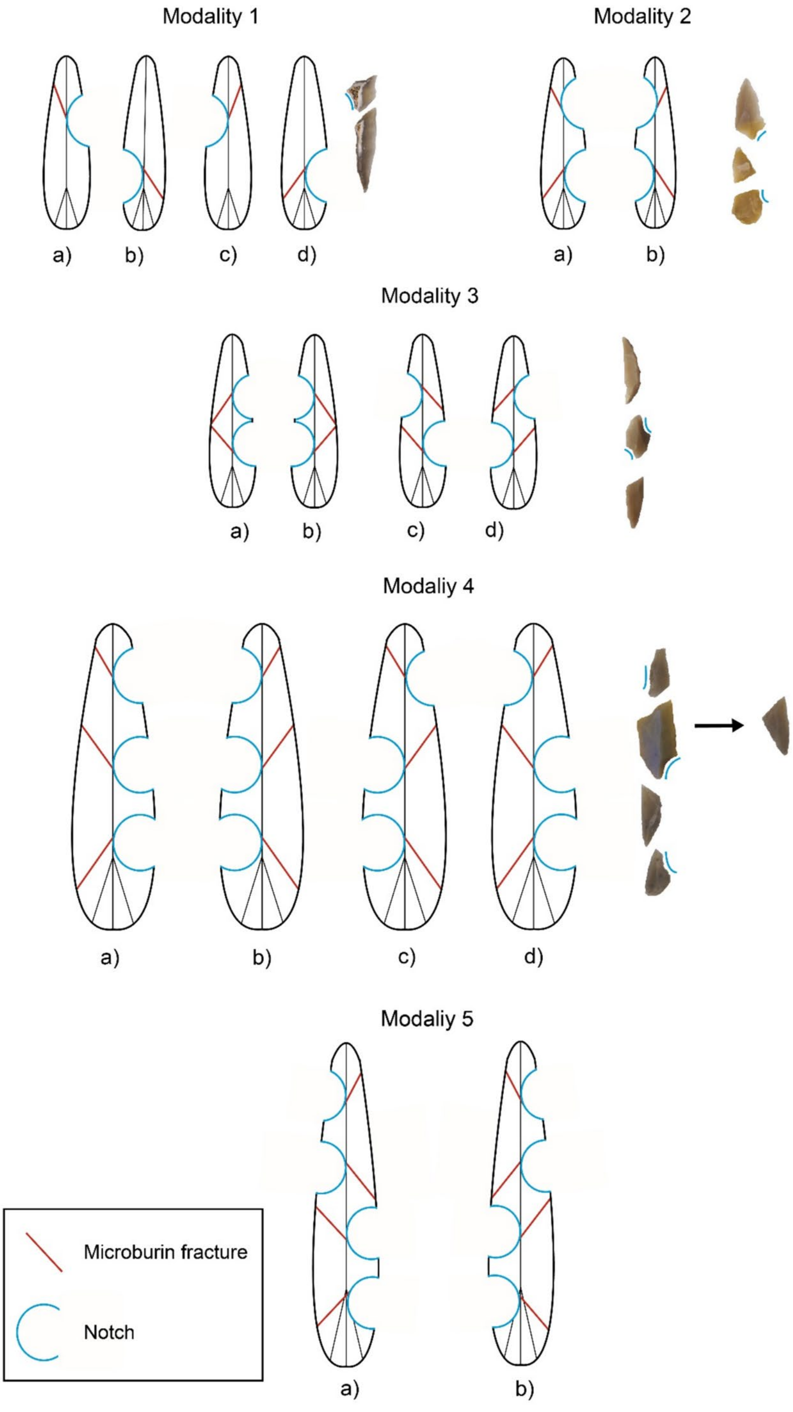

Fig. 2 Different production modalities according to the number of microburin blows applied and geometrics obtained for each blank

Table 2 Types of geometrics produced according to Laplace's typology (1964)

Type	n
Gm1	8
Gm2	1
Gm3	28
Gm4	4
Gm1/Gm4	1
Total	42

A sequence involving four microburin blows and the production of two geometrics and three microburins (one proximal, one distal, and a double mesial) is also possible. However, the blanks length selected for this experiment did not allow such a modality (Fig. 2, modality 5).

After the blank fragmentation, to shape the geometric microliths, the same backing techniques tested in Fasser *et al*. (2019, 2024b) have been used:

SSPA: soft stone percussion on anvil ($n=4$)
PSS: pressure by soft stone ($n=12$)
POT: pressure by an organic tool ($n=23$)
Ab: abrasion ($n=3$)

Analysis of the Experimental Trials

The low magnification analysis was carried out using a stereomicroscope (Optika SZN-T; magnification range 6.3×–30×), and it was applied exclusively on successful microburins ($n=64$). In order to characterise different microburin blow

Table 3 Features considered for microburin blow techniques recognition

Features	Variables
Contact point	Large (> 2 mm); small (≤ 2 mm); elongated; linear; isolated; multiple; absent
Bulb	Compact, pronounced, diffuse, absent
Languette development	Highly developed; slightly developed; no *languette*
Inclination of the transverse fracture	Low (< 45°); semi-abrupt (between 45° and 70°); abrupt (> 70°)
Distribution of removals on the notch	Regular; irregular
Notch edge morphology	Rounded; fresh
Longitudinal profile of the notch	Denticulate; linear
Morphology of removal scars	Fan-shaped; elongated
Initiation of removal scars	Large; punctiform
Retouch inclination	Abrupt; semi-abrupt; obtuse
Presence and position of incipient cones	Attached to the notch edge; far from the edge

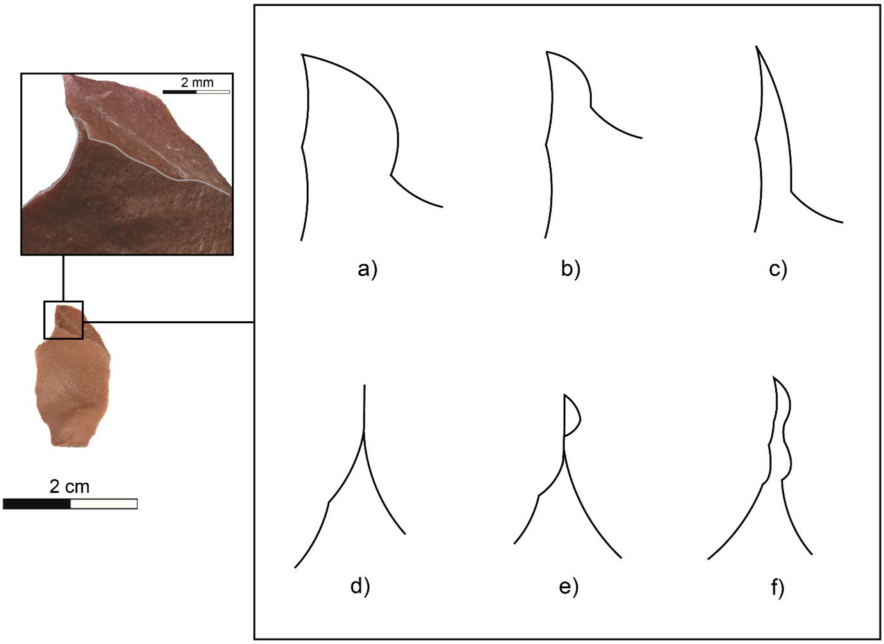

Fig. 3 Contact point morphology: **a** large, **b** small, **c** elongated, **d** linear, **e** isolated, **f** multiple

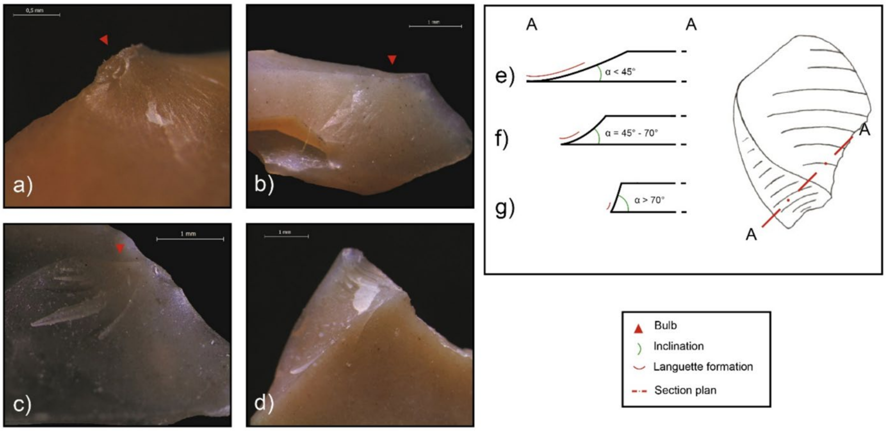

Fig. 4 Bulb morphology: **a** compact, **b** pronounced, **c** diffuse, **d** absent. In this latter case, the contact point is also absent. Inclination of the transverse fracture: **e** low, **f** semi-abrupt, **g** abrupt. Profile delineation of the transverse fracture (*i.e. languette* development): **e** highly developed, **f** slightly developed, **g** no *languette*

techniques, we considered parameters related to both the fractures and the notch. Their variability is presented in Table 3 and illustrated in Figs. 3 and 4. As a notch is formed by abrupt retouches, most of the parameters considered for the recognition of backing techniques correspond to those presented in Fasser *et al.* (2019).Based on the interesting results obtained through a high-power approach for the recognition of backing techniques used to produce backed armatures (Fasser *et al.*, 2024b), we decided to evaluate the efficacy of this method to distinguish different microburin blow techniques. This analysis was conducted using an Optika metallographic microscope with incident light with a magnification range between 50× and 500×. Pictures were taken with a Moticam 2500 (5.0M Pixel USB2.0). The experimental microburins were cleaned with neutral soap, water, and an ultrasonic bath for 3 min. The sample selected for the high magnification analysis counts 43 microburins: 14 were obtained by stone percussion, 23 by pressure with an organic tool, and 6 by pressure with a stone retoucher. The description of polishes and striations follows the parameters listed in Fasser *et al.* (2024b).

The validity of the parameters presented in Table 3 was verified through a blind test aimed at better clarifying their relevance and variability, as well as testing the significance of gestures and interpersonal differences. The blind test consists of determining, through both a high and low power approach, the microburin blow technique applied for a random series of experimental artefacts ($n = 31$) produced by a knapper (AP) unfamiliar with this experimentation. AP applied two techniques: pressure by an organic tool and stone percussion. In both techniques, a stone anvil was used.

The Archaeological Sample

Site VF1 of Mondeval de Sora (San Vito di Cadore, BL) is located beneath the overhang of a large erratic boulder in the middle of the wide Mondeval basin, at an elevation of 2150 m a.s.l. The excavation was carried out by the University of Ferrara between 1986 and 2000, revealing evidence of intensive human occupations, particularly on the southwestern (sector I) and northeastern (sector III) sides of the boulder. Sector I covered a surface of about 60 m^2, whereas sector III was explored over an area of 30 m^2. Both yielded a stratigraphic sequence approximately 50 cm thick, with layers dated to the Early Mesolithic (Sauveterrian) at the bottom (Fontana *et al.*, 2009, 2012).

Focusing on sector I, the Sauveterrian evidence includes several structures, such as a paved area made of local tufa slabs (SU 14), an arrangement of blocks of dolomite stones (SU 33), and a sub-circular hearth (SU 32). Above them, two main anthropic layers were recorded in the inner (SU 8) and external parts of the shelter (SU 31). Stratigraphic Unit 8, from which the geometric armatures and microburins analysed in this paper come, represents a palimpsest of several frequentations. A previous radiocarbon date located these occupations between 11,111 and 9694 cal BP (9185 ± 240 BP, Fontana & Vullo, 2000). Two new dates were recently undertaken on charcoal samples from the two sub-levels (8I and 8II) in which part of the SU was arbitrarily divided. The results obtained, so far unpublished, are as follows:

10,582–10,407 cal BP (9300 ± 30 BP; Lab. code: Beta – 543677) for SU8I and 10,716–10,556 cal BP (9400 ± 30 BP; Lab. code: Beta – 543678) for SU8II.

A random sample of 421 microburins from SU 8 of sector I of Mondeval de Sora (BL, Italy) has been the object of a technological analysis. A few attributes were recorded for each of them: size, blank portion from which they come (proximal, distal, or mesial) and notch lateralisation (right or left). Among them, 100 microburins have been observed at low magnification to reconstruct which techniques were used to apply the microburin blow using the criteria listed in Table 3. In order to achieve a higher degree of reliability on the raw material of the used retoucher, among the 100 examined microburins, 43 were also analysed through a metallographic microscope. The experimental results showed that micro-traces formed primarily on microburins with a thickness of at least 2 mm; thus, items were selected following this specific criterion.

A sample of complete geometric armatures belonging to SU 8 was also analysed. It is composed of scalene triangles, isosceles triangles, and crescents for a total of 103 items. These items were analysed using a technological approach to reconstruct the whole *chaîne opératoire*, from blank selection to retouch methods and techniques. To characterise manufacturing methods of the selected armatures, several attributes related to blank morphology and the transformation process were recorded by the naked eye and through a stereomicroscope (see Fasser, 2022; Fasser *et al.*, 2022, 2024a for a detailed list of criteria recorded). To reconstruct backing techniques, we based our work on previous experimental studies (Fasser *et al.*, 2019) and a wide reference collection developed during the Ph.D. of one of the authors (Fasser, 2022). Furthermore, geometrics were divided into several morpho-typological categories following the G.E.E.M. list (G.E.E.M., 1969).

Results

Experimental Data

Efficacy of the Different Microburin Blow and Backing Techniques

As already claimed by several authors (Finlay, 2000; Miolo & Peresani, 2005; Tixier, 1976; Tixier *et al.*, 1980), both percussion and pressure prove to be effective to obtain a *piquant-trièdre* fracture. However, the former turns out to have a higher error index, being less precise (Table 4). A blow targeted too far from the

Table 4 Success rate according to the microburin blow technique applied considering only artefacts produced by NF

	Success	Failed	Success rate
Pressure by organic compressor	32	13	71.11%
Pressure by lithic compressor	6	2	75%
Stone percussion	26	28	48.15%
Total	64	43	100%

notch edge or an inappropriate position of the blank can easily determine the formation of a fracture without a *piquant-trièdre* (mainly a snap terminating bending fracture or a snap terminating cone fracture) and a transverse orientation. This low degree of precision and the larger active surface required by a lithic retoucher compared to an organic one involves the formation of wide notches, often resulting in a production waste more comparable to a Krukowski microburin than an ordinary one. Adapting the stone retoucher dimension and weight to the blank thickness is always important. Moreover, the more tapered the retoucher extremity is, the more precise the blow. The main advantage of a percussion microburin blow technique is its good flexibility: it can be easily applied with both the "A" or "B" holding modality.

The low unintentional fracture index makes pressure the most reliable technique (Table 4). Another important advantage concerns the possibility of better controlling the fracture location on the blank and determining the moment in which the fracture occurs. Regarding the compressor raw material, an organic one allows managing both thin (from 1 to 3 mm) and thick blanks (more than 4 mm). This latter requires a higher force, which can be obtained by lengthening the handle of the compressor. A lithic retoucher also proved suitable for obtaining a *piquant-trièdre* by pressure, even though it presents some constraints: firstly, the lower elasticity of the stone compared to hard animal tissue material makes reaching the fracture more complicated with thick blanks (> 2 mm). Furthermore, it tends to create much larger notches. A pressure microburin blow technique can be effortlessly applied, holding the blank by the "A" modality. The study has proven the "B" modality can cause some troubles at the beginning and needs a bit of practice.

The anvil raw material can also play a significant role due to the different capacities to absorb the force released during retouching. A lithic anvil (a flat pebble, a core, or the main dorsal ridge of a thick blank) increases the risk of unintentional breakage during the notch production because of the low control of the recoil. On the contrary, due to its superior capacity to absorb the force, an organic anvil allows easier control of the fracture process.

The small size of Sauveterrian geometrics from N-E Italy does not allow great freedom in the choice of the retouching technique to be applied after the microburin blow. SSPA and Ab prove to be poorly suitable. The former because of the reduced workspace and the high fracture index; the latter for the impossibility of holding the artefact in one hand while rubbing the edge with a stone cobble. Conversely, the two pressure techniques (POT and PSS) are extremely appropriate thanks to their high precision and elevated capacity to control the force and the retouch angle applied. With both pressure techniques, the blank is laid on a boxwood log while retouching. In addition, removing unnecessary blank portions by applying the microburin blow greatly reduces the time of the retouching process, making the major disadvantage of POT, namely the low operating speed, completely irrelevant. The same applies to pressure by soft stone: the difficulty in modifying thick blanks (> 4 mm) recorded by Fasser *et al.* (2019) does not occur during geometrics production due to the reduced thickness of the blanks selected.

Morphological Variability of Microburins

The analysis of experimental microburins through a low-power approach allowed the description of the morphological variability of five main parameters (contact point, bulb morphology, fracture inclination, *languette* development, notch morphology), according to the microburin blow technique applied. The data presented in the following paragraphs consider both microburins produced by NF and those produced by AP for the blind test.

Contact Point Looking at the contact point (*i.e.* the area of contact between the retoucher and the ventral face of the blank when the fracture occurs) according to the microburin blow technique employed, interesting results were recorded (Table 5). A microburin fracture reached by percussion almost systematically yields a contact point (92%). The most frequent morphology is the small one (35% Fig. 3b), followed by multiple (20% Fig. 3f) and large (10% Fig. 3a). Sometimes, a clear ring crack that propagates into a Hertzian cone is visible. The isolated type (Fig. 3e) and the elongated (Fig. 3c) one reach a percentage of 7.50% and 5%, respectively. A linear impact point (Fig. 3d) is lacking, while occasionally, the percussion shock causes the removal of the contact point and cannot be determined (15%). On the contrary, the pressure technique frequently does not develop any contact points (32.73%, Fig. 4d). This is related to the fact that the fracture is reached by resting the tip of the compressor exactly on the notch edge and not in the inner part of the ventral face. When a contact point is visible, it tends to be small (20% Fig. 3b), large (12.73% Fig. 3a), or linear (9.09% Fig. 3d). Multiple impact points are poorly recorded (3.64% Fig. 3f).

Bulb Morphology Also the bulb morphology strongly changes according to the microburin blow technique used (Table 6). A percussion blow systematically provokes a cone fracture with a bulb. The latter can be compact (40%, Fig. 4a), pronounced (25%, Fig. 4b), or—less frequently—diffused (17.5%). Otherwise, the

Table 5 Contact point morphology according to microburin technique

	Percussion		Pressure	
	n	%	*n*	%
Small	14	35.00	11	20.00
Large	4	10.00	7	12.73
Elongated	2	5.00	3	5.45
Multiple	8	20.00	2	3.64
Isolated	3	7.50	3	5.45
Linear	-	-	5	9.09
Absent	3	7.50	18	32.73
N.D. (broken)	6	15.00	6	10.91
Total	40	100	55	100

Table 6 Bulb morphology according to microburin technique

	Percussion		Pressure	
	n	%	*n*	%
Absent	2	5.00	23	41.82
Diffuse	7	17.50	21	38.18
Pronounced	10	25.00	3	5.45
Compact	16	40.00	4	7.27
N.D. (broken)	5	12.50	4	7.27
Total	40	100	55	100

Table 7 Inclination of the transverse fracture according to microburin technique

	Percussion		Pressure	
	n	%	*n*	%
Low	7	17.50	24	43.64
Semi-abrupt	24	60.00	30	54.55
Semi-abrupt/abrupt	1	2.50	-	-
Abrupt	7	17.50	1	1.82
N.D. (broken)	1	2.50	-	-
Total	40	100	55	100

pressure technique more commonly produces a bending initiation fracture with no visible bulb (41.82%, Fig. 4d). When a cone fracture develops, the bulb tends to be diffused (38.18%, Fig. 4c).

Inclination of the Transverse Fracture Looking at Table 7, it is evident that fracture inclination tends to be between 45° and 70° with both pressure and percussion technique. Fractures with a low angle ($<45°$) are more frequently attested with the pressure technique, while an open angle ($>70°$) is mainly related to percussion. However, the transverse inclination should not be considered as strictly related to the force application mode, but to the blank position (inclination of the transverse axis of the blank) with respect to the anvil surface and, therefore, to the retouch angle. The more the ventral face is inclined, the more open the fracture angle is and vice versa (Fig. 5a 1, Fig. 5b 1). Thus, this association between pressure and lower angles and percussion and open angles is related to the knapper's different ways of positioning the blank according to the technique used. The only exception is represented by blanks with a triangular cross-section and a width-thickness ratio close to 1:1. In this case, the blank turns spontaneously in an inclined position, producing fractures with an open transverse inclination also when a pressure technique is applied.

***Languette* Formation** A *languette* development is related to two main factors: (1) the distance between the contact point of the retoucher on the ventral face and the contact point of the dorsal face of the blank on the anvil edge during the fracturing and (2) the inclination of the longitudinal axis of the blank with respect to the

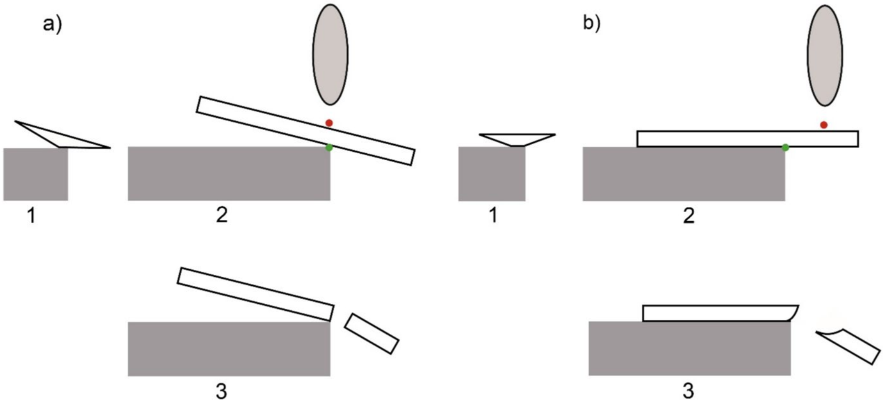

Fig. 5 Fracture inclination and *languette* development related to blank position: **a** blank positioned with its transverse axis inclined with respect to the anvil surface (1) and its longitudinal axis inclined towards the retoucher (2). This position tends to produced microburin with an abrupt fracture inclination and no *languette* development (3); **b** blank positioned with both the transverse (1) and longitudinal (2) axis parallel to the anvil surface. This position tends to produce a microburin with a lower fracture inclination and a *languette* development (3). Red dot is the contact point between the ventral face of the blank and the retoucher during the microburin blow. Green dot is the contact point between the dorsal face of the blank and the anvil edge during the microburin blow

anvil surface (Fig. 5). When these two contact points are on the same vertical axis and the longitudinal axis of the blank is inclined (Fig. 5a 2), the *languette* does not develop (Fig. 5a 3). By contrast, when the contact point between the ventral face and the retoucher is beyond the edge of the anvil and the longitudinal axis of the blank is parallel to the anvil surface (Fig. 5b 2), a *languette* formation occurs (Fig. 5b 3). Thus, the author's way of holding the blank resulted in a higher percentage of *languette* formation when using a pressure technique (Table 8).

Notch Morphology The description of diagnostic criteria useful for distinguishing backing techniques published in Fasser *et al.* (2019) fits with those observed on the microburin's notches. SSPA produces a large notch, as already observed by Miolo and Peresani (2005), with an irregular sequence of removals characterised by a denticulated longitudinal profile due to residual protrusions connected to removals starting at variable depths. The edge is rounded with hammered portions, and

Table 8 *Languette* formation according to microburin technique

	Percussion		Pressure	
	n	%	*n*	%
Well developed	9	22.50	21	38.18
Slightly developed	10	25.00	26	47.27
No *languette*	21	52.50	8	14.55
Total	40	100	55	100

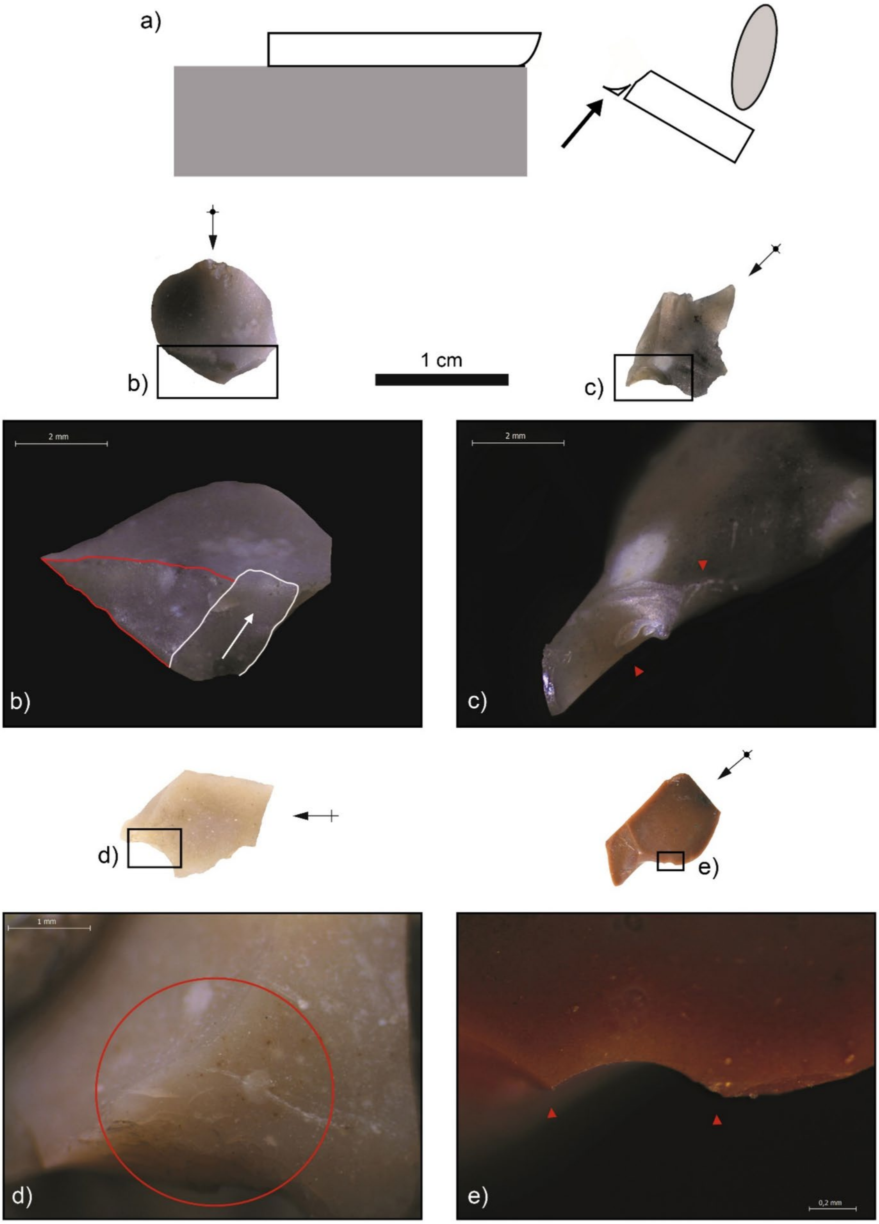

Fig. 6 **a** mechanical dynamics of the recoil effect on the microburin; **b** a little flake detached from the dorsal face, removing completely the contact point diagnostic of a stone anvil. The red line delimits the surface of the microburin fracture, while the white line delimits the negative of the small flake detached by the recoil effect; **c** a notch characterised by a bipolar retouch diagnostic of a stone anvil; **d** deep incipient cones located far from the notch edge (ventral face), diagnostic of a stone percussion technique; **e** residual indentations visible on the notch edge (ventral face), diagnostic of a pressure technique applied by an organic tool

the retouch inclination is abrupt or sometimes even obtuse. The morphology of the scars frequently results in a fan-shaped outline and sometimes presents an oblique or orthogonal development. The initiation of the scars is punctiform with a deep bulb negative. Occasionally, single or grouped incipient cones far from the notch edge are visible on the ventral face (Fig. 6d). PSS also produces large notches, but these are characterised by a more regular sequence of removals composed of elongated, flat, and sub-parallel negatives associated with small unintentional removals along the edge. The edge is strongly rounded, and the longitudinal profile is linear. The initiation of the scars tends to be punctiform with a diffused bulb negative. POT creates smaller notches with a fresh edge characterised by sharp residual indentations visible from the ventral face (Fig. 6e); these are associated with negatives characterised by a large cone initiation and a diffuse bulb negative, sometimes even bending. The edge can be rounded in the case of thick (> 2 mm) blanks. Removals are more frequently elongated, flat, and sub-parallel, producing a more linear longitudinal profile. Sometimes, invasive removals on the dorsal surface (micro-overshots) are attested. Both pressure techniques can produce marginal incipient cones on the ventral face.

Recoil Traces The use of a lithic anvil easily produces features related to the recoil effect visible on microburins: (1) the presence of little flakes detached from the dorsal face removing completely or partially the contact point (Fig. 6a, b), (2) a notch characterised by a bipolar retouch (Fig. 6c). By using the percussion technique, the first feature occasionally appears also with an organic anvil (Table. 9).

Micro-traces

Micro-traces observed on the microburins are comparable with those produced by the backing process (Fasser *et al.*, 2024b). They are located in correspondence with the contact point (Fig. 7a) or adjacent to the notch edge (Fig. 7b). The most diagnostic trace produced by a stone retoucher is a well-developed wide or linear polish characterised by a smooth texture, a flat topography, and a compact or tight linkage (polish linkage refers to the portion of surface microtopography affected by polishing). The directionality of the gesture applied is highlighted by several short,

Table 9 Presence or absence of recoil retouch according to microburin technique and type of anvil

Technique	Type of anvil	Recoil effects	*n*	%
Percussion	Organic	Yes	3	16.67
		No	15	83.33
	Stone	Yes	6	27.27
		No	16	72.73
Pressure	Organic	Yes	-	-
		No	38	100
	Stone	Yes	8	47.06
		No	9	52.94

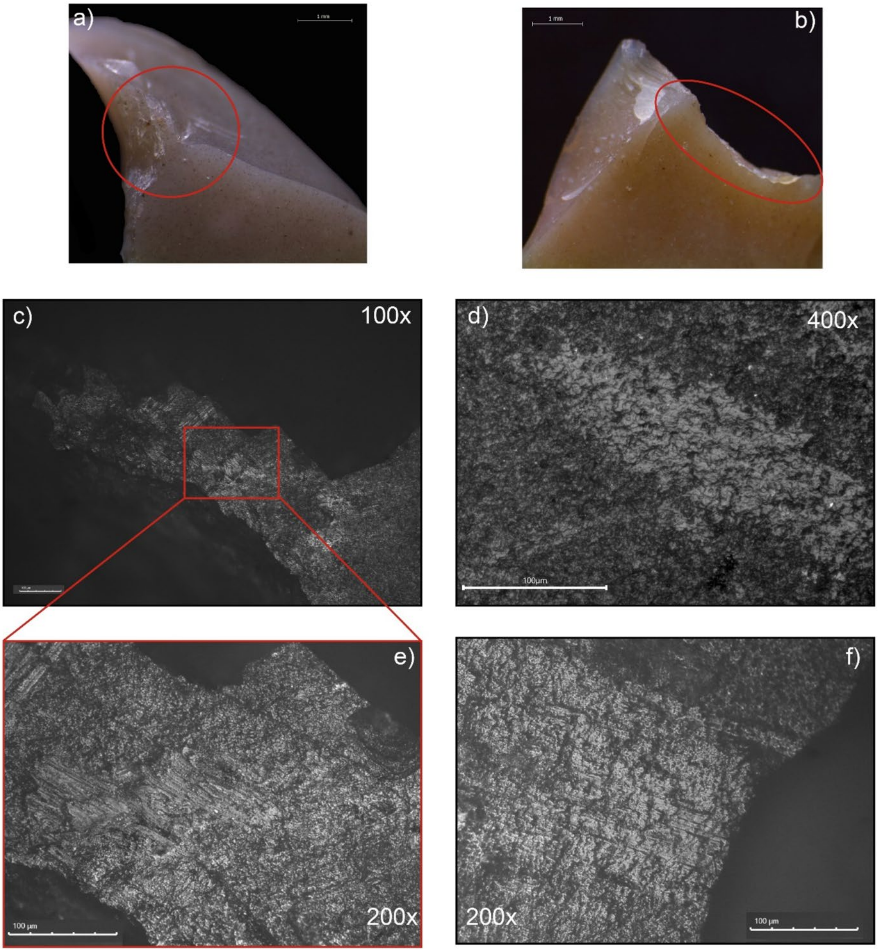

Fig. 7 Micro-traces recorded on experimental microburins: **a** and **b** micro-traces position, **a** contact point, **b** notch edge; **c** and **e** micro-traces produced by a lithic retoucher at the contact point; **d** micro-trace produced by an antler compressor near the notch edge; **f** micro-trace produced by a bone compressor in contact with the notch edge

matt, narrow striations with a transverse or oblique orientation with respect to the retouched edge. Sometimes, striations' orientation can be parallel or even crossed (Fig. 7c, e), likely due to a change in blank position during notch production.

By using organic retouchers, a well-developed micro-trace appeared only in two cases. An antler tip produced a large and linear polish with a transverse or oblique orientation resulting from the punctual contact between the tool and the notch edge (Fig. 7d). It has a smooth texture, a domed topography, and a compact linkage. By contrast, a bone tip yielded a polished area with a smooth texture, a domed topography, and a compact linkage crossed by several narrow, short, and matt striations with a transverse orientation with respect to the notch (Fig. 7f).

Matt striations in association with a polished area were not formed using an organic retoucher in previous experiments (Fasser *et al.*, 2024b). For detailed analyses and descriptions of experimental micro-traces related to retouching, see Fasser *et al.* (2024).

Blind Test Result

To further test the validity of the identified parameters, the 31 microburins, produced by AP, were analysed by one of the authors (NF). When a low magnification analysis was not enough to determine the microburin blow technique, a high-power approach was also adopted. Although 80% of microburins were positively identified, by dividing the sample between the two techniques employed, well-distinct success rates appear (Table 10): 93% for percussion and 71% for pressure. Thus, mistakes were mostly unidirectional. This result must be ascribed to the occasional formation of features more frequently reported for percussion on microburins experimentally obtained by pressure, such as follows:

- Abrupt transverse angle and no *languette* development ($n=3$)
- Multiple contact point ($n=2$)
- A polished area crossed by narrow, matt and short striations ($n=1$, Fig. 7f)

The first point was also detected on a few microburins previously produced by NF. As previously discussed, an abrupt inclination of the transverse fracture primarily depends on the blank position while retouching rather than the retoucher raw material (organic vs. mineral) and the force application mode (percussion vs. pressure). On the contrary, the other two features were absent in the author's experimental collection produced by pressure using an organic tool. For example, the formation of a multiple contact point might depend on a different strategy used by AP for applying pressure technique. AP places the blank directly on the anvil edge (like the author did for percussion technique), and he immediately tries to reach the fracture while creating the notch before achieving the thickest transverse point of the blank. This modality requires a higher force during notch production, provoking more frequent rates of marginal incipient cones, which—once the microburin is removed—turn into a multiple contact point. Furthermore, it is likely that greater force caused the polish illustrated in Fig. 7f.

Table 10 Blind test results carried out on the experimental microburins produced by AP

	Percussion	Pressure
Microburins recognised	13	12
Microburins not recognised	1	5
Total microburins per technique	14	17
Success rate per technique	92.86%	70.59%

Notch Lateralisation: Definition and Significance

Based on the assumption that the "A" holding modality (Fig. 1c) is the most convenient for applying a microburin blow, a right-handed knapper would locate a right notch on the proximal portion and a left notch on the distal portion. In contrast, a left-handed knapper would do the opposite. However, this condition is not systematically true in practice. The blank morphology could require locating the notch on the opposite side, switching to the "B" holding modality (Fig. 1d). Using this latter modality, a right-handed knapper can locate a left notch on the proximal portion and a right notch on the distal portion and vice versa for a left-handed knapper. Besides blank morphology, another element that can strongly affect notch lateralisation is the modality adopted for manufacturing geometrics (Fig. 2). Using Modality 1, notch lateralisation of proximal and distal microburins simply depends on the knapper's handedness and blank morphology, which can require the use of the "B" holding modality instead of the "A". On the contrary, by applying modality 2, the notch lateralisation is not only influenced by the knapper's handedness and the blank morphology but also depends on which portion (proximal or distal) is removed first. For instance, if the manufacturing process starts by removing a distal microburin with a left notch, the proximal microburin will also have a left notch. The same applies to modality 4 (Fig. 2) and, in general, to all modalities that involve more than one microburin blow on the same blank. Consequently, many factors can influence the notch lateralisation: the knapper's handedness (right-handed vs. left-handed), the portion of the blank removed first (proximal or distal), the holding modality (A or B), the blank's morphology, and, finally, the modality adopted for manufacturing geometric armatures. The latter point is particularly interesting as there are modalities that discard proximal and distal microburins with opposite notch lateralisation and modalities that discard proximal and distal microburins with equal notch lateralisation. The first group includes modality 1 (if applied using the same holding modality), modality 4 (*c* and *d* variant), and modality 5 (Fig. 2). The latter would also produce a significant number of double mesial microburins. On the other hand, the second group comprises modality 1 (if applied using different holding modalities), modality 2, and modality 4 (*a* and *b* variant) (Fig. 2). Modality 3 generates exclusively double mesial microburins. Thus, a detailed analysis of notch lateralisation in an archaeological assemblage can provide important information about the number of microburins and geometric armatures potentially obtained from a single blank and, in a larger sense, about the existence of common and normalised technical procedures among specific human groups or techno-complexes.

Archaeological Results: The Production of Geometrics from the Site of Mondeval de Sora

Blank Selection

The original morphology of the blank selected for geometric microlith production is difficult to reconstruct due to the significant reduction in width and length during the manufacturing process. Nevertheless, a significant exploitation of full debitage elongated blanks with a triangular cross-section and a rectilinear profile can be inferred by observing both microburins and geometrics. Furthermore, comparing the thickness interquartile range of geometrics and microburins (from 1 to 2 mm) and length variability of full debitage lamino/lamellar blanks with the same thickness values, an exploitation of microbladelets shorter than 30 mm can be supported. The occasional selection of longer blanks must also be taken into account. Microburins in which the original blank width were measurable (only proximal and mesial microburins were considered) attest values ranging from 5 to 18 mm (interquartile range: 5.5–10.5 mm).

Microburin Blow Technique

Microburins analysed were removed equally from the proximal (50.36%) and the distal portion (46.32%). Only 1.9% were double mesial microburins. Microburins length attests to an amount of blank removed by the microburin blow varying between 3 and 18 mm (interquartile range: 7–11.5 mm). Any significant differences concerning length values were detected between proximal and distal microburins. An important lateralisation was observed looking at the notch position according to the blank portion removed (proximal or distal). Proximal microburins mostly have a right notch (75.9%), whereas distal microburins have a left one (72.17%). The experimental activity revealed that this notch lateralisation may result from three distinct production modalities (Fig. 2):

- Modality 1, alternating the *c* and *d* variant
- Modality 4, *d* variant
- Modality 5

Nevertheless, modality 4 would require a blank of at least 30 mm, as seen during experimentation, while modality 5, in addition to needing an even longer blank, would yield an important amount of double microburins. Since the blanks exploited in our sample seem to be shorter than 30 mm and double mesial microburins are extremely rare, Modality 1 might be the most used. Also, the comparison between the length values of microburins (mean values: 9.4 mm), geometric microliths (mean values: 9.7 mm), and unmodified elongated lamino-lamellar blanks (<30 mm) suggests the production of one microlith for each blank by removing only one microburin.

Conversely, the lower number of distal microburins with a right notch and proximal microburins with a left notch might result from the occasional use of different production modalities:

- Modality 1 applied by a left-handed knapper using the "A" holding modality
- Modality 1 applied by a right-handed knapper using the "B" holding modality
- Modality 2 (in fact, 13 geometrics out of 100 analysed show a double *piquant-trièdre*)

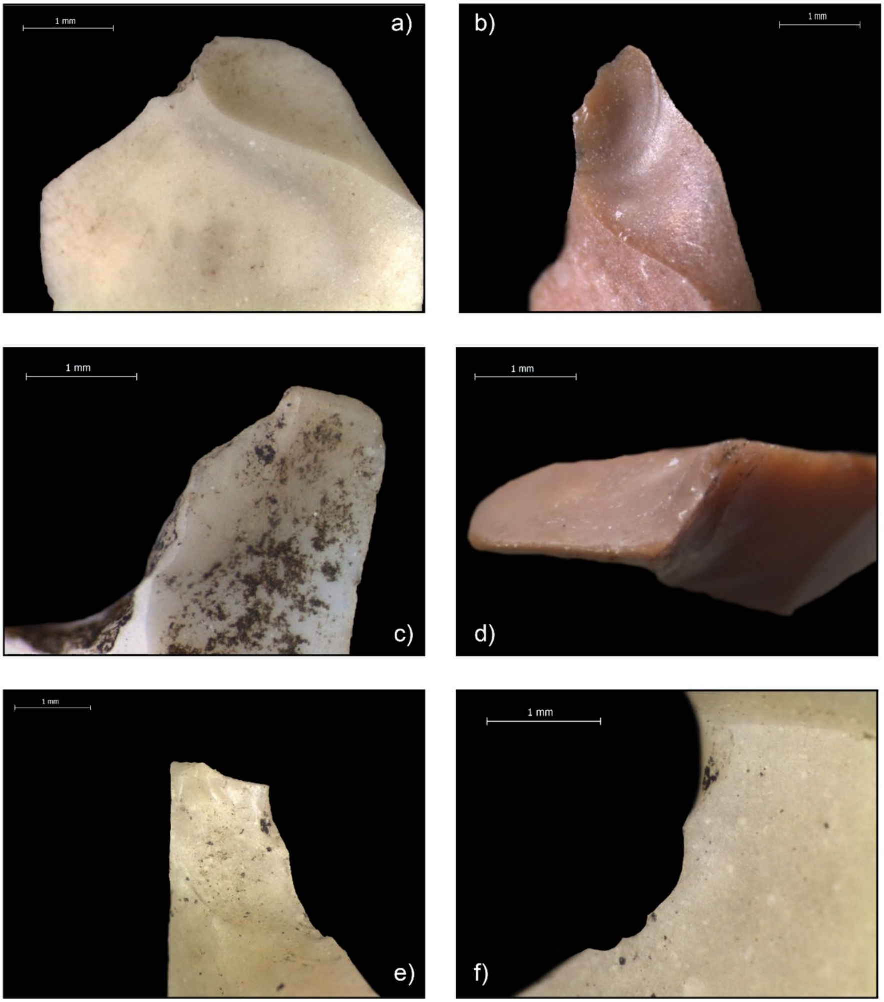

Fig. 8 Archaeological microburins from SU 8 of Mondeval de Sora (VF1—sector I) showing diagnostic criteria of a pressure technique applied by an organic tool: **a** no contact point and bulb; **b** linear contact point; **c** diffuse bulb; **d** fracture with a semi-abrupt transverse inclination and a *languette* development; **e** sub-parallel elongated retouch negative with a large initiation; **f** residual indentations on the notch edge visible from the ventral face of the microburin

Table 11 Macro-and-mesoscopic features of 100 microburins observed at low magnification from SU8 of Mondeval de Sora (VF1—sector I)

Contact point morphology	*n*	Bulb morphology	n	Profile delineation	n
Isolated	1	Absent	53	Well developed *languette*	49
Linear	9	Diffuse	32	Slightly developed *languette*	35
Elongated	4	Pronounced	5	No *languette*	11
Small	22	Compact	4	N.D.	5
Large	2	Broken	4	-	-
Multiple	-	N.D.	2	-	-
Absent	55	-	-	-	-
Broken	5	-	-	-	-
N.D.	2	-	-	-	-

- Modality 4, *a* and *b* variants
- Modality 4 applied by a left-handed knapper using the "A" holding modality for removing the first microburin (*c* variant)

A few double microburins (1.90%) indicate that two geometric armatures, one distal and one proximal, were occasionally obtained from one single blank when this was long enough (modality 3). Among them, two different types were identified: the first one is characterised by two notches located on the same side (variants *a* and *b*), whereas the second one has two notches located oppositely (variants *c* and *d*).

When analysing microburins with a stereomicroscope, most of them do not show any contact point and bulb (Table 11, Fig. 8a). These two features on the same microburin are highly indicative of a pressure technique. Also, the rest of the assemblage analysed presents features consistent with the microburins experimentally produced by pressure, such as linear contact point (Fig. 8b), diffuse bulb (Fig. 8), and fractures with a transverse inclination < 70° and a *languette* development (Fig. 8d). On the other hand, features compatible with a percussion technique are rare or even absent, *e.g*. multiple contact points, pronounced bulbs, and abrupt fractures without a *languette* development (Table 11). Moreover, notches show clear residual indentations visible from the ventral face (Fig. 8e), a fresh edge, and sub-parallel, flat, and regular scars with large initiations (Fig. 8f). The combination of these features confirms the use of a pressure technique applied by an organic compressor (POT) as the main backing technique for shaping notches. No incipient cones located far from the edge, diagnostic of SSPA, or extremely rounded edges, diagnostic of PSS, were recorded.

Among the 43 microburins analysed through a high-power approach, only 3 present micro-traces, perhaps related to the notch fabrication. They consist of linear polishes on the ventral face near the notch edge with a transverse or oblique orientation (Fig. 9). Their morphology resembles those experimentally produced by an antler retoucher (see also illustrations in Fasser *et al*., 2024), although none of such polishes is perfectly comparable, leaving some uncertainties. However, no

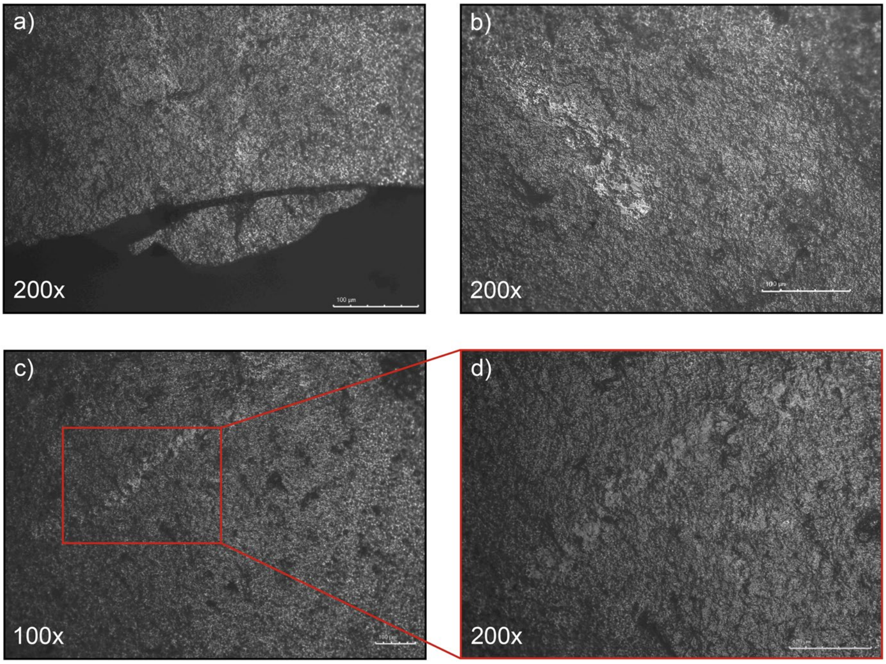

Fig. 9 Archaeological microburins from SU 8 of Mondeval de Sora (VF1—sector I) showing micro-traces on the ventral face near the notch edge similar to those experimentally produced with an antler retoucher

archaeological microburins show micro-traces even similar to those produced by a stone retoucher. The reason why backing micro-traces were not consistently identified on the archaeological microburins can be attributed to two main factors: (a) the reduced thickness of the blanks used to produce geometrics. As a matter of fact, the finer the pieces, the fewer traces are formed; (b) the residue nature of some micro-traces that might not survive the post-depositional processes in an archaeological context, as already observed in a previous work (Fasser *et al.*, 2024b).

It is important to highlight that around 1200 microburins were recovered from SU 8; therefore, the sample selected for this study might not be representative of the variability of such an amount.

Transformation Phase

Geometric microliths are mainly manufactured on the mesial/distal portion of the blank. The butt and the bulb were systematically removed by the microburin blow or by simple retouching. The reduction process was carried out by applying deep and direct retouches that shaped two oblique truncations for triangles and a convex back for crescents. Marginal backed retouches are attested only on the distal truncation when geometrics were produced in correspondence with the distal portion of the blank. A crossed retouch is extremely rare and related to the thickest items with values of 2–3 mm. The backed retouch almost systematically reaches the maximum transverse thickness of the blank. The back angle tends to be semi-abrupt, varying between 45° and 70°. Hardly ever, it is around 90°.

Only 37.5% of geometrics show at least one extremity characterised by a *piquant trièdre*. Often, it is partially resumed by few marginal detachments, while it is rarely left unretouched. Seldom, both extremities have a visible *piquant trièdre* (12.5%), attesting to the sporadic use of more than one microburin blow for shaping geometrics (modality 2). For the rest of the sample, it can be assumed that the backing process covers the *piquant-trièdre* fracture completely. The edge opposite to the back is systematically rectilinear. To achieve such a delineation, in half of the assemblage, marginal, direct, and semi-abrupt, sometimes even flat, retouches were applied all along the edge or on the blank extremities.

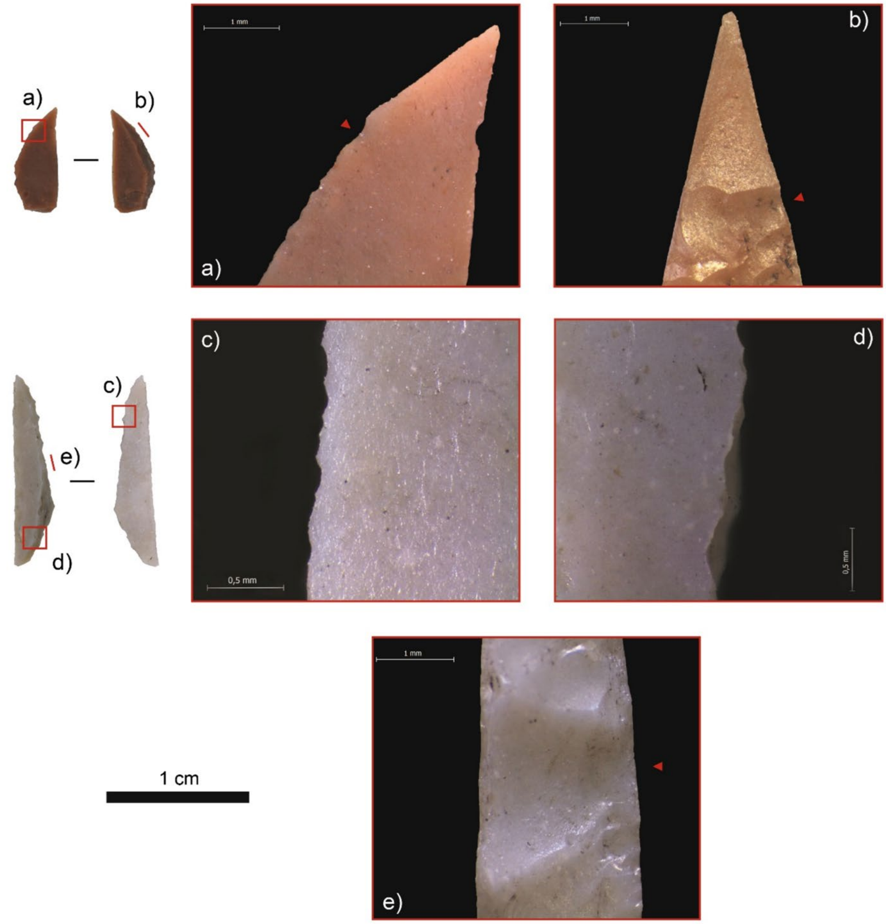

Fig. 10 A crescent and a scalene triangle from SU 8 of Mondeval de Sora (VF1—sector I) shaped by pressure applied with an organic tool (POT): **a**, **c**, and **d** residual indentations visible on the retouch platform; **b** retouch negative with a bending initiation; **e** sub-parallel elongated retouch negative with a large initiation

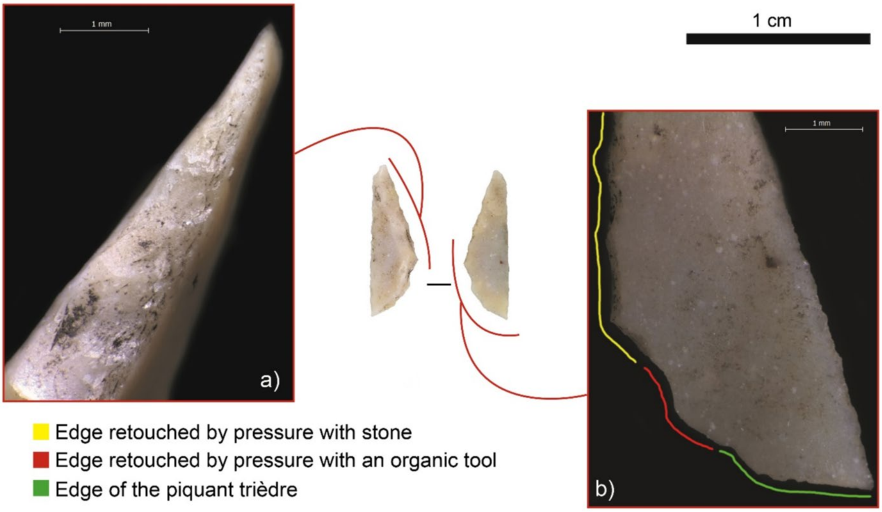

Fig. 11 Scalene triangles from SU 8 of Mondeval de Sora (VF1—sector I) shaped with a mixed backing technique: **a** backed retouch characterised by a rounded edge associated with regular and sub-parallel removals with punctiform initiations retouched using pressure with a soft stone (PSS); **b** scalene triangle visible from the ventral face. Red line indicates the fresh edge with residual indentations on what is left of the notch produced by pressure with an organic tool (POT). The yellow line indicates the rounded edge of the distal truncation produced by pressure with soft stone (PSS). The green line indicates the *piquant trièdre* edge

The most employed backing technique is POT (Fig. 10): the majority of geometrics analysed have residual indentations visible from the ventral face (Fig. 10a, c, d), a fresh backed edge and regular and sub-parallel removals with diffused bulb negatives and large initiations (Fig. 10e); in some cases, even bending (Fig. 10b). PSS seems to be only occasionally used. For instance, Fig. 11 shows a scalene triangle shaped by a distal truncation displaying features typical of PSS. The truncation is opposite to a *piquant trièdre*, where residual indentations diagnostic of POT are visible on what is left of the notch.

The preference of using an organic rather than a lithic compressor when applying pressure technique could depend on several factors. Firstly, since both the notch production and the microburin fracture were achieved by pressure with an organic retoucher, it stands to reason that the shaping process was carried out without changing the retoucher. Moreover, thanks to the use of the microburin blow and in relation to the small dimension of the selected blanks, the backing process needed to reach the required geometric dimension was relatively brief, making irrelevant the major disadvantage of the POT, namely a low operating speed. PSS was perhaps used when a more intensive reduction process was necessary, taking advantage of the higher operating speed of this technique, while still maintaining a good degree of precision. PSSA was detected only on three pieces with thickness from 2 to 3 mm. Complementary retouches on the edge opposite to the back were systematically produced through a pressure technique.

Morpho-types

Geometrics analysed can be divided into three main types: scalene triangles, isosceles triangles, and crescents (Table 12). Their dimension is presented in Table 13. Scalene triangles are the most attested ones. For this type of microlith, the backing process involves the manufacturing of two oblique truncations characterised by different lengths and orientations aimed at creating two tips, one more pointed than the other. Normally, the former is distal, whereas the latter is proximal. The width-length ratio defines two different sub-types: short scalene triangles (width-length ratio ≤ 1:2) (Fig. 12 n. 1–4) and elongated scalene triangles (width-length ratio > 1:2) (Fig. 12 n. 5–8).

Isosceles triangles are characterised by two truncations with an equal orientation and length. Considering the width-length ratio, two different morphologies were detected also in this case: elongated isosceles triangles and short isosceles triangles. The former has a width-length ratio of at least 1:3 (Fig. 12 n. 12–14), whereas the latter has a width-length ratio lower than 1:3 (Fig. 12 n. 9–11). Half of the isosceles triangles ($n = 7$) show a double *piquant-trièdre*, suggesting an important use of a double microburin blow (modality 2) for producing this type of item. Their dimensions do not show any significant differences compared to scalene triangles, except for a slight minor length (Table 13).

Depending on the back delineation, three different types of crescents were detected: symmetric, asymmetric, and wide. The first one has an elongated shape with two symmetric apexes and a backed retouch with a symmetric curvature along the morphological axis of the blank (Fig. 12 n. 19–20). Asymmetric ones have a backed retouch with an asymmetric curvature delineating two asymmetric apexes, with the more pointed one positioned distally (Fig. 12 n. 15–18). Wide crescents are characterised by an extremely curved back and no apexes. The width-length ratio is around 1:2 (Fig. 12 n. 21–22).

Discussion

The Microburin Blow

The experimental activity presented here allowed verifying the efficacy of different microburin blow techniques to reach a *piquant trièdre* fracture. Among them, pressure applied with an organic tool seems to be the most reliable. First, it has a low unintentional fracture index and a higher probability of controlling the exact moment and location of the fracture compared to stone percussion. Secondly, the higher degree of precision and elasticity of an organic compressor compared to a stone one makes it possible to handle both thin and thick blanks.

Table 14 synthesises the macro- and mesoscopic criteria useful for distinguishing the experimented techniques. However, as illustrated in Tables 5, 6, 7, and 8, the majority of such criteria must be considered either as morphologies that appear more frequently with one technique rather than others (*i.e.* bulb and butt

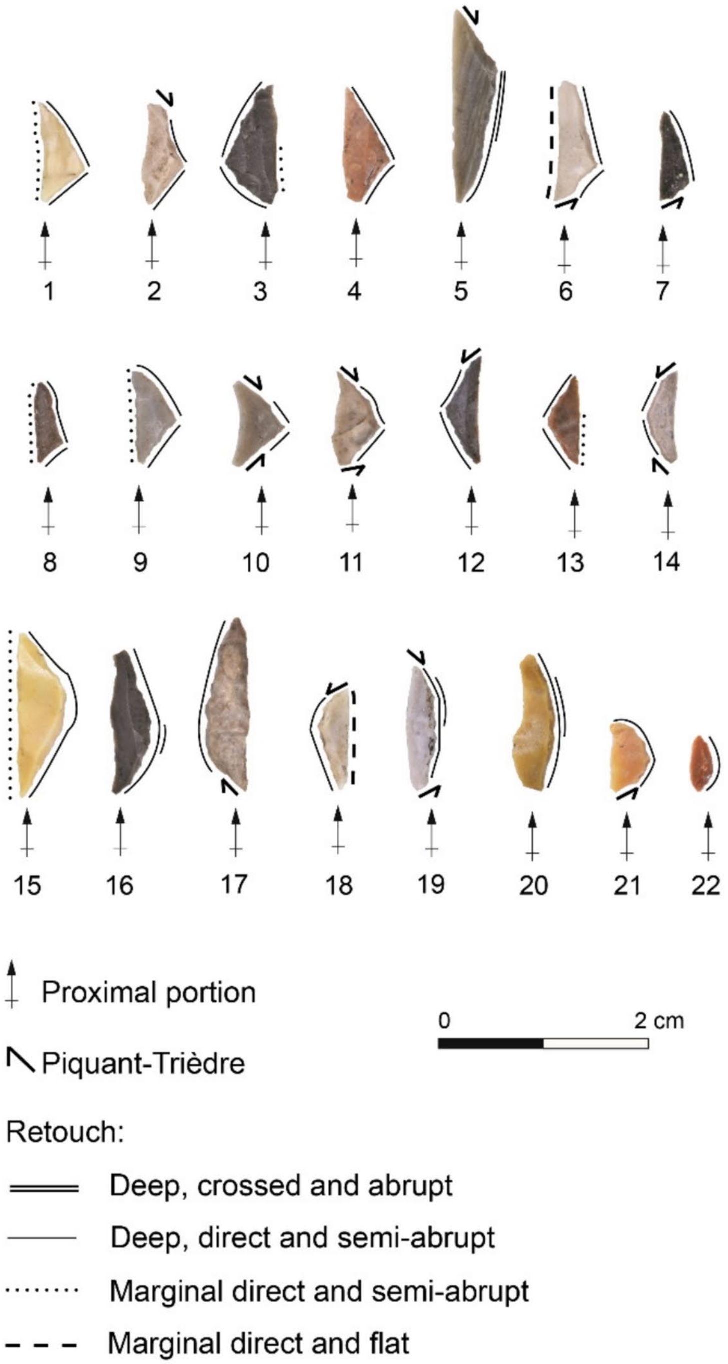

Fig. 12 Geometrics from SU 8 of Mondeval de Sora (VF1—sector I): 1–4 short scalene triangles; 5–8 elongated scalene triangles; 9–11 short isosceles triangles; 12–14 elongated isosceles triangles; 15–18 asymmetric crescents; 19–20 symmetric crescents; 21–22 large crescents

Table 12 Geometrics from SU 8 of Mondeval de Sora (VF1—sector I) distributed according to different morpho-types

Geometric sub-types	*n*
Short scalene triangles	35
Elongated scalene trianlges	12
Generic scalene triangles	4
Short isosceles triangles	11
Elongated isosceles triangles	4
Symmetric crescents	10
Asymmetric crescents	13
Wide crescents	4
Trapezoidal crescents	2
Crescents/isosceles triangles	5
Total geometrics analysed	100

Table 13 Dimensions of geometrics from SU 8 of Mondeval de Sora (VF1—sector I) recorded according to different types

	Scalene triangles			Isosceles triangles			Crescents		
	Len	Wid	Th	Len	Wid	Th	Len	Wid	Th
Min. value	6	2	1	6	2	1	6	2	1
1st quartile	8	3	1	7	3	1	8	3	1
Med. value	9.7	3.4	1.4	8.5	3.58	1.42	10.37	3.35	1.72
Median	10	3	1	9	3	1	10	3	2
3rd quartile	11	4	2	9.75	4	2	12	4	2
Max. value	14	5	3	13	6	3	15	5	3
SD	2.1	0.8	0.5	1.82	1.2	0.6	2.5	0.8	0.6
Total measurements	50	53	53	14	14	14	25	30	30

morphology) or as features related to the blank position during the application of the microburin blow (*i.e.* transverse inclination). In some cases (*i.e. languette* development), they may even be related to both aspects. Thus, in most cases, the recognition of the applied microburin blow technique, as is also the case for backing and debitage techniques (*e.g.*Damlien, 2015; Fasser *et al.*, 2019; Pelegrin, 2000), requires the identification of more than one criterion per piece and should ideally be applied to large collections. To obtain more precise information about the raw material of the retoucher (mineral vs. organic), a high-magnification analysis may be effective. In fact, the blind test performed by combining both the low and high power approaches demonstrated a good recognition rate (Table 10). The blind test has also shown that individual variability can affect the formation of some criteria, especially those related to blank position during notch fabrication (*e.g.* inclination and *languette* formation). This variability must be considered during the analysis of the archaeological material.

Table 14 Combination of macro-and mesoscopic criteria useful to distinguish different techniques to apply a microburin blow

	Fracture features				Notch features		
	Contact point	Bulb	Transverse inclination	Profile delineation	Edge	Scars initiations	Incipient cones
Stone percussion	Systematically visible; Multiple; Ring crack	Compact; Pronounced	Generally abrupt but it depends on blank position	Slight *languette* development or any	Large notches with a rearward and rounded edge	Punctiform	Located far from the edge or marginal.
Pressure by organic tool	Absent; Linear	Diffuse; Absent	Generally low but it depends on blank position	*Languette* development	Narrow notches with fresh edge and sharp residual indentations	Large or even bending	Marginal
Pressure by stone	Absent; Linear	Diffuse; Absent	Generally low but it depends on blank position	*Languette* development	Large notches with a rearward and rounded edge	Punctiform	Marginal

Another important aspect that emerged during our experiment is the strong connection between notch lateralisation on microburins and the production modality used to shape geometrics, providing an important tool for inferring the number of microburins and geometrics obtained from a single blank. Other authors have already addressed this issue, considering it a possible cultural marker among prehistoric societies (Byrd, 1987; Henry, 1974; Neeley & Barton, 1994). For example, D. O. Henry (1974) and B.. F. Byrd (1987) explored the intensity in the use of the microburin blow through the ratio between microliths and microburins, while M.P. Neeley and C.M. Barton 1994) compared the lengths of full debitage lamino-lamellar blanks with those of geometrics. However, tool production and abandonment might not occur on the same site, influencing the geometrics–microburins ratio. Moreover, the microburin blow is not the only way to reduce blank length (*e.g*. simple retouching), which affects the reliability of a comparison exclusively based on length. Thus, notch lateralisation must also be considered.

For Mondeval de Sora, we could reliably identify the primary production modality: modality 1 (Fig. 2). This was achieved by combining data regarding microburin lateralisation (proximal microburin-right notch and distal microburin-left notch), microburin length (interquartile range: 7–11.5 mm), length of the full debitage lamino-lamellar blanks (< 30 mm), and length of geometrics (interquartile range: 8–11 mm). In most cases, the microburin blow seems to have been applied only once for removing one blank extremity, while the other one was reduced by retouching. Indeed, the ratio of geometrics to microburins from SU 8 is close to 1:1 (Fontana *et al*., 2009). Furthermore, low and high-power approaches revealed that the microburin blow was mainly performed using a pressure technique applied with an organic tool (antler?), and the same technique was observed for the backing process.

Comparison with Other Sauveterrian Sites

Despite the recently obtained radiocarbon dates for SU 8 of Mondeval de Sora, sector I, spanning from 10,700 to 10,400 cal B.P. and suggesting a short time range during the Late Preboreal, comparisons with the classical chrono-cultural division of the Mesolithic in NE Italy (Broglio, 1980; Broglio & Kozlowski, 1984) assign this occupation to the Middle Sauveterrian, with a possible extension into the early part of the Recent Sauveterrian (Fontana *et al*., 2009). The main traits of the Middle Sauveterrian regarding the geometric microliths production are the higher percentage of long and narrow crescents as opposed to short and wide ones and the lower number of isosceles in favour of scalene triangles (Table 12, Fig. 12), while the Recent Sauveterrian is suggested by the occurrence of some long scalene triangles with three retouched sides. Also, from a wider technological perspective, a certain homogeneity can be observed with the other North-Eastern Italian sites dated to the Late Preboreal and the beginning of the Boreal. Full debitage lamino-lamellar blanks are mainly shorter than 30 mm (Fontana & Guerreschi, 2009; Flor *et al*., 2011; Visentin, 2018), the thickness seems the most controlled parameter in blanks selection for microliths production (Flor *et al*., 2011; Fontana & Guerreschi, 2009; Wierer, 2008), and the backing process occurs exclusively by direct retouches, while a crossed backed retouch is hardly ever documented (Cusinato *et al.*, 2004; Wierer, 2008; Bassetti *et al.*, 2009; Visentin, 2018). As far as the backing technique is concerned, the only data referred to the Sauveterrian are those collected by L. Chesnaux (2014) through the analysis of the armatures from the French sites of Paris-15e "62 rue Henry-Farman", La Grande Rivoire (Isère), and the collection 1 and 3 of Saint-Lizier à Creysse. This author proposed that a pressure technique using an organic tool was applied, providing evidence for the widespread use of this technique throughout the Sauveterrian techno-complex. The Preboreal sites from N-E Italy in which information about notch lateralisation is reported (*e.g.*, Casera Lissandri 17 and La Cogola layer 16) show a trend similar to Mondeval de Sora: proximal microburins mainly have a right notch, whereas distal microburins have a left one (Cusinato *et al.*, 2004; Visentin, (2018). Furthermore, Peresani and Miolo (2012) report a decrease in lateralisation of proximal microburins along the Sauveterrian sequence of N-E Italy: from a right notch to a more variable lateralisation. Unfortunately, the lack of data concerning distal microburins (intentionally excluded from the analysis) does not allow one to fully understand the significance of this trend: is it related to a change in the number of geometrics obtained per blank, or is it merely connected to an increased variability of holding modalities while applying a single microburin blow? This might be an interesting topic to further investigate in the future.

Typological Issues in Sauveterrian Geometric Microliths Classification

During the experimental production of Sauveterrian geometrics, we could evaluate how the adoption of an exclusively typological approach (*e.g.*, Broglio & Kozlowski, 1984; G.E.E.M., 1969; Laplace, 1964) may be highly misleading, as this approach does not take into account the effects of production modalities on the final shape of the item. Blank morphologies, retouch techniques, or simply inaccurate retouch caused by the minimal dimensions of the microliths can easily result in switching from one type of microlith to another or creating meaningless types. In this regard, trapezoidal segments (Gm2) of Laplace's typological list (1964), sinusoidal segments in Broglio and Kozlowski (1984), and the asymmetric crescents of G.E.E.M (1969) are perfect examples. In the Italian Sauveterrian, the former are generally pieces resumed or abandoned during construction, while the second ones are probably related to an inaccurate retouching process. The latter, normally considered as a segment sub-type, actually have strong similarities with scalene triangles (Fig. 12), such as dimensional variability, morphology (two asymmetric apexes), orientation with respect to the morphological axis of the blank, and the frequent occurrence of complementary retouches. The only difference is represented by a rounded convergence between the two truncations. As seen during our experiments, this difference may be related to unintentional factors. The same occurs with isosceles triangles and some symmetric/large crescents, where the convergence between truncations is not particularly sharp or the truncations are insufficiently rounded, resulting in ambiguous types (*e.g.* crescents/isosceles triangles). To cause further confusion, some artefacts may be assigned to different types (crescents vs. triangles) depending on which face (dorsal or ventral) they are observed from. This problem might be related to the retouching process and, in particular, to the backing technique applied. PSS sometimes produces slightly rounded edges that prevent the formation of a sharp angle between the two truncations, as seen from the ventral face. By contrast, POT, especially in case of thickness values > 2 mm, can produce micro-overshots that result in rounding the angle between the two truncations, as seen from the dorsal face. Thus, to avoid classification issues arising from technical constraints rather than from the knapper's deliberate choices, we suggest complementing the traditional classification of geometrics with two morphological categories that follow an easier parameter to be controlled by the knapper, namely symmetry. The first group is composed of symmetric and large crescents and isosceles triangles. The second one includes asymmetric crescents and scalene triangles. Doing so, in the site of Mondeval de Sora (SU 8), asymmetric geometrics (64%) are more frequent than symmetric ones (36%). In the near future, it will be interesting to analyse this dichotomy (symmetric vs. asymmetric geometric microliths) at other sites and to evaluate its significance from a functional perspective.

Conclusions

Thanks to our experimental activity, we were able to identify diagnostic micro-meso-macroscopic criteria for distinguishing the different techniques used to apply the microburin blow. The application of these experimental results to the archaeological series from the SU 8 of Mondeval de Sora (Belluno, Italy) allowed the identification of one specific technique, namely pressure with an organic tool applied by Sauveterrian groups. This technique was used to retouch the notch, reach the fracture, and shape the geometric. Further studies on the microburin blow method using this protocol will allow verifying whether the variability in applied techniques and production modalities can represent useful keys to distinguish different technical traditions in both spatial and diachronic terms among European Mesolithic groups.

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Data Availability No datasets were generated or analysed during the current study.

Declarations

Competing Interests The authors declare no competing interests.

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