The impacts of lateral obliqueness and edge angle on Levallois point morphology

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Abstract:

The study of Levallois points is important as it combines themes relating to Levallois technology in general (such as cognitive evolution, standardisation, and cultural transmission) with discussions on the specific function of stone tools (for example, the notion of points as spear tips). Many Levantine Middle Palaeolithic assemblages feature a strong focus on Levallois point production. Traditionally, this phenomenon has been studied from a typological perspective, while more recent technological approaches have added layers of understanding, such as the recognition of the frequently recurrent Levallois character of point production in the area. Likewise, use-wear and residue analyses have led to changing perceptions of the function of Levallois points. Here we explore how two quantifiable aspects of Levallois points - cross-section angles and lateral angles - relate to the morphology of Levallois points. By combining experimental knapping with an analysis of Levallois points from Yabroud I, Syria, we show that the obliqueness of lateral preparatory removals has a significant impact on the morphology of Levallois points, particularly in terms of the feature of a *Concorde*-shaped profile. Likewise, we show that the lateral edge angle influences the length of the points produced. Not only does this study improve of our understanding of Levallois points, but it highlights the importance of angles in studying lithic technology. We emphasize that this study aims to investigate the impact of oblique preparatory removals on the morphology of Levallois points generally, through an initial case study of one assemblage, allowing future multivariate analysis of multiple assemblages to test our hypotheses.

Keywords: Middle Palaeolithic; Levant; Levallois point; morphology; technology; standardisation; lateral obliqueness; Yabroud; Syria

1. Introduction

Levallois points are one of the iconic stone tool forms of the Middle Palaeolithic (MP) and Middle Stone Age. Along with other triangular flakes and retouched points they have been part of extensive discussions about hafting modifications and whether points performed

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specific functions such as spear or projectile tips (*e.g.*, Douze *et al.* 2020; Plisson & Beyries 1998; Scerri 2013; Scott 2011; Shea 1988; 2006; Shea & Sisk 2010; Sisk & Shea 2009; 2011; Villa & Lenoir 2006; Wilkins *et al.* 2012).

The East Mediterranean Levant is a region in which abundant Levallois points are found in certain assemblages (*e.g.*, Dibble & Whittaker 1981; Groucutt 2014; Hauck 2013: 99; Henry 2003: 72-73; Hovers 2009: 56; Meignen 2019; Shea 2003; Zaidner & Weinstein-Evron 2020). These have often been linked to hunting behaviours, a perspective supported by findings such as a Levallois point embedded in the vertebra of a wild ass (*Equus africanus*) at Umm el Tlel in the Syrian Desert (Boëda *et al.* 1999). However, it is likely that Levallois points were used for various functions (see, for example, Douze *et al.* (2020) for a southern African perspective on point function). In this paper we are not interested in the function of Levallois points, merely in the ways in which the points were made. Specifically, the technical reasons that resulted in varied or standardised morphologies of Levallois points. We attempt to determine to what extent particular technical behaviours, represented by obliqueness of the preparatory lateral removals and their convergence or parallel direction, affect the morphology of Levallois points.

2. The definition of Levallois point production

Technologically, the methods of Levallois point production have been a matter of debate and discussion for many decades. In the Levant, point production appeared during the whole MP. While they were less frequently observed in the early stages of the MP, points with elongated blade proportions were more commonly manufactured (*e.g.*, Misliya cave, Zaidner & Weinstein-Evron 2012; Hummel site, Hauke 2013). Moreover, in the middle MP, there are instances where Levallois points were discovered at a relatively high frequency, such as in Layer 15 of Qafzeh cave (Hovers 2009: 66-79). However, the peak of Levallois points production in the Levant occurred in the late MP, which were produced mainly by unidirectional convergent methods, both preferential and recurrent, while bidirectional flaking also occurs (Boëda *et al.* 1990; Demidenko & Usik 1993; 2003; Groucutt 2014; Henry 2003: 68-74; Meignen 1995; 2019; Rust 1950: 52-63; Shimelmitz & Kuhn 2018). It has also been argued that typologically Levallois points can sometimes be the product of non-Levallois reduction methods (*e.g.*, Boëda 1995; Inizan *et al.* 1999: 68; Marks & Volkman 1983). Unlike in Levantine and some African assemblages, Levallois points are generally only present in small quantities in the MP European assemblages (Goval *et al.* 2016; Hérisson *et al.* 2015).

The lateral preparatory removals of Levallois points came under increasing attention from the early 1960s onwards. Bordes (1961: 31-37) first pictured the flaking of a Levallois point using cores and points discovered in Seine Maritime and Somme sites in France and Abu Sif site in Judean Desert . He is also the first who defined the production of Levallois points based on the preparatory lateral removals; one was produced after detaching unidirectional convergent removals from the same striking platform of the Levallois point and the second was obtained after detaching unipolar divergent removals from an opposite striking platform (Bordes 1980).

Recent focus on the Nubian Levallois reduction method raises questions on how this relates to other forms of Levallois point production, such as the unidirectional-convergent method which is dominant in the Levant (*e.g.*, Blinkhorn *et al.* 2021; Groucutt 2020; Rose *et al.* 2011; Usik *et al.* 2013;). It has long been recognised that within the category of Nubian Levallois cores there is sometimes a focus on two or more divergent removals from the distal end, while in others there is a more centripetal focus to reduction (*e.g.*, Guichard & Guichard 1965; Bordes 1980). Inizan *et al.* (1995: 68; 1999: 69) indicates that the pattern of arrises exhibited by the core determines the precise delineation and morphology of a Levallois point.

Boëda's (1982; Boëda *et al.* 1998: 249) distinction between "three hits" points (*trois coups*) and "constructed" points, which distinguished by the number and directionality of preparatory scars. Additionally, Levallois points were divided into technomorphological groups, which were defined by Boëda (1982; Boëda *et al.* 1998) on the basis of different scar patterns. Boëda (1982) suggests roughly 30 theoretical patterns of Levallois "three hits" point production, based on an experimental corpus (Boëda 1982; Boëda *et al.* 1998), a strategy that Crew (1975) had previously developed. Crassard & Thiébaut (2011) elaborate five schemes of flaking surface preparation in Hadramawt (Yemen) resulted in two types of Levallois points; the so-called "classical" points and "constructed" points. The latter have more than three removals, and they are not all from a proximal platform and lack the majority of typical features seen in classical Levallois points that have an almost perfectly triangular outline, the greatest width at the base, *Concorde*-shaped profiles, inverted-Y shaped dorsal arris patterns formed by three overlapping negatives, and a *Chapeau de gendarme* striking platform. The constructed Levallois points feature varying numbers of these features. The negatives of points observed on the cores in Hadramawt are rather heterogeneous and the dimensional data (lengths and widths) for each method of production group does not distinguish particular morphometric groups.

Mirroring this dichotomy, Meignen & Bar-Yosef (1991) argued for a narrow definition of the term Levallois point, and more recently Meignen (2019) distinguishes Levallois points *sensu stricto* and Levallois points *sensu lato* at Kebara.

As this brief review highlights, there is considerable variability in both Levallois points themselves and the methods that archaeologists use to analyse and describe these points and the ways they were made. One way to advance this debate is to look at specific technological features that can be quantified. As a case study in exploring the variability of Levallois points and the reduction methods used to produce them, in this paper we explore the hint from Meignen (1995: 367; 2019: 35) that *en Concorde*-shaped profiles are partially the result of the obliqueness of the preparatory lateral removals and the highly pronounced distal convexities. A *Concorde* profile is a typological character describing the shape of the distal termination of some Levallois points, named after the shape of the *Concorde* aeroplane.

In this study, our primary objective is to investigate how the obliqueness of the two preparatory removals contributes to the morphology of Levallois points. Specifically, our analysis aims to examine the impact of this obliqueness on two specific technical features: the formation of *Concorde*-shaped profiles and the achievement of a perfect triangular outline in Levallois points. As a result, we deliberately refrain from incorporating any previous classifications associated with Levallois points, such as distinctions between classical and constructed points, in this paper. Instead, we make a distinction between Levallois points with *Concorde*-shaped profiles and those without, exploring their respective influences on the triangular outline of Levallois points.

Exploring such aspects offers a specific and quantifiable way to explore the diversity of Levallois points. We evaluate more widely the impacts of the ways in which debitage surfaces were shaped to produce particular shapes of Levallois points, such as the lateral edge angle, which reflects the angle at which convergent removals were struck. Our study represents an initial exercise based on a single site, and our aim is to generate hypotheses which can be tested by a larger-scale, multi-site, analysis.

3. Materials and methods

The Yabroud I Rockshelter is situated in northern Damascus in Syria at an approximate elevation of 1400 meters asl. It has revealed a substantial sequence (25 archaeological layers) in which Mousterian occupations employing Levallois reduction techniques are located at the uppermost layers, from 10 to 1 (Rust 1950: 41-63). The Mousterian occupations present in finely uniform sediments comprised of cave debris, with no significant interruptions in the sequence (de Heinzelin 1966; Farrand 1965). The available palaeoenvironmental data for this site proposes a reconstruction of an arid climate, characterized by an alternation between steppe and desert vegetation, during the Upper Pleistocene period in the region (Dodonov *et al.* 2006). For this paper we analysed 102 Levallois points from the Yabroud Shelter I (henceforth YSI) assemblage 4 (Al Kassem 2021: 178). Following this, we incorporate an additional 53 Levallois points sourced from assemblages 2, 3, 5 and 6. This strategic inclusion aims to augment the overall size of our sample, enhancing the robustness and representativeness of our study.

Taking into consideration that the lithic material of YSI might have been selected by Rust, the selection of our sample (155 Levallois points) aims to include different morphologies of Levallois points. Therefore, we include both finely-shaped and more crude Levallois points distinguished in the assemblages 2, 3 4, 5 and 6 randomly (*i.e.*, we have not 'cherry-picked' only the most perfect forms). We also recorded data on experimentally produced points.

YSI is one of the most important Middle Palaeolithic sites in the Levant, containing 25 layers and is considered a key site for understanding the succession of Palaeolithic cultures in the region. It is located in Syria, 60 kilometres north of Damascus, on the slope of Skift valley, at an elevation of 1420 m a.s.l (Rust 1950: 4-5). The uppermost levels (*i.e.*, 2, 3, 4, 5, and 6) were attributed to the late Middle Palaeolithic. Briefly, all collections are marked by the prevalence of the Levallois method. Assemblage 6 is characterized by the production of triangular products and flakes. Assemblage 5 is characterized by predominance of quadrangular/oval flakes with a predominance of slightly elongated products. In assemblage 3, the percentage of quadrangular/oval flakes is slightly higher than those in assemblage 4 which is characterized by predominance of triangular products (Al Kassem 2021: 148). The industries of assemblage 2 consist of laminar flakes with a convergent distal part. Triangular products are also present (Pagli 2015). All lithics of Yabroud Shelter I are hosted at the Institut für Ur- und Frühgeschichte, Universität zu Köln.

3.1. Cross-section angles of Levallois points

It is worth noting that the principal objective of this study is not to verify the effectiveness of the unidirectional convergent method in producing perfect or imperfect Levallois points at YSI. Instead, the primary focus is to examine the significance and impact of the obliqueness of two preparatory removals on the morphology of Levallois points. The utilization of materials from YSI is based on their easy accessibility. Additionally, the presence of a high frequency of fine-shaped and more crude Levallois points. In order to determine the technological factors that causes *Concorde*-shaped profile and regular-shaped outline, the cross-section angles of 155 Levallois points from YSI assemblages 2, 3, 4, 5 and 6 were measured with a goniometer (with a single arm that's attached to the semi-circle with the angle degrees on it) in order to associate the obliqueness of the two preceding convergent removals with these two technological features (Figure 1). To define the technological factors that caused *Concorde*-shaped profile, the measurement was applied to the distal third of the Levallois points between the upper surface and the lateral oblique side as this is the least concave section of the medial scar pattern on the Levallois point (Figure 1). Meignen (1995) mentioned that the *Concorde* profile displays a clear break or discontinuity at a certain point that aligns with the arris, rather than merely the standard curve found in many Levallois items "*The profile is not simply curved like many Levallois products, but presents a rupture at a point corresponding to the Levallois arris*" (Meignen 1995: 367).

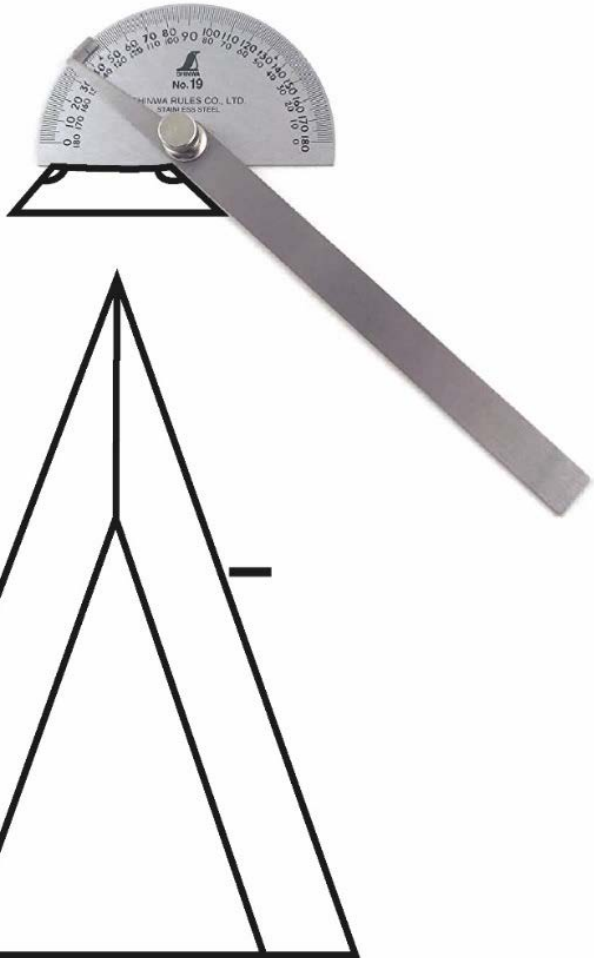

Figure 1. Using a goniometer to measure the cross-section angle.

The measure of cross-section angles is significant because these angles are defined by the oblique lateral "*débordant*" removals. In other word, the obliqueness of the preparatory lateral removals not only plays a role in forming and determining the cross-section angles, but also is responsible for the angle of these removals. When the ventral surface is flat, it is certainly possible to measure the angles between the lower face (ventral surface) and the lateral oblique side. But curved profiles make the measurement procedure more difficult in the case of a *Concorde*-shaped profile.

The shorter arm of the goniometer, in some cases, rests on the opposing ridge of the cross-section rather than the medial scar surface itself. However, the goniometer still gives the cross section angle given that these ridges were set up by the oblique lateral removals and the medial scar has no effect on the measurement process. Except in the case of where the medial scar is convex, which we did not encounter.

The contact goniometer is a commonly used tool in archaeological analysis (Dibble 1997; Gould, Koster *et al.* 1971; Kuhn 1990; Režek *et al.* 2018; Scerri *et al.* 2016;Yerkes *et al.* 2016). While there can be issues with goniometers, they are frequently employed on striking platforms characterized by complex surfaces. In contrast, the angles measured in this study are more straightforward as they pertain to straight surfaces.

3.2. Lateral angles of Levallois points

In order to explore the technological factors that result in short, broad-based or elongated Levallois points, we measured the angle between the lateral edges and the base of 93

Levallois points using a protractor from assemblages 4 and 6 of YSI. We followed a triangle that connects the three points of the elongated and broad-based Levallois points (Figure 2).

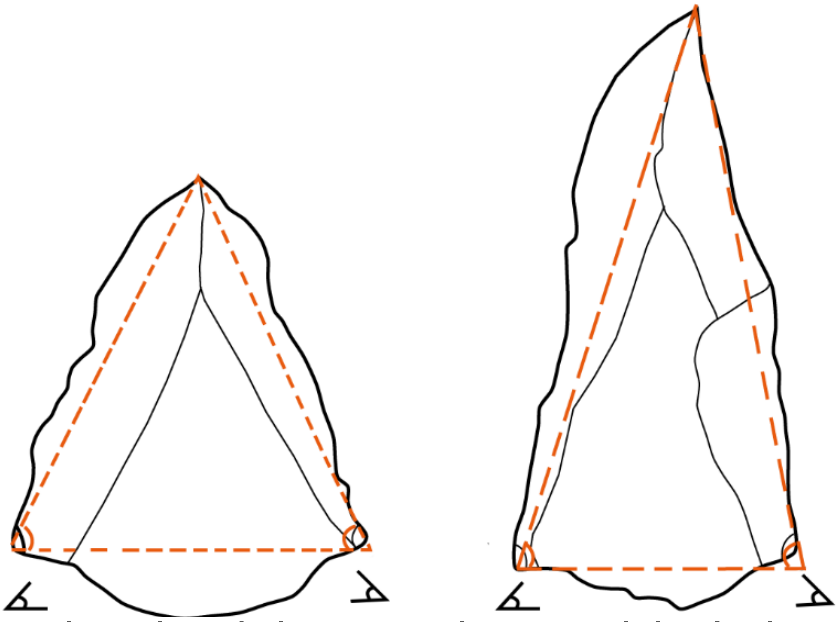

Figure 2. Drawing triangle according to the three points in order to measure the lateral angles.

3.3. Experimental work

One feature of many Levantine sites is that there are lots of Levallois points but few associated cores showing a Levallois method, so there is some ambiguity about the methods used. Our knapping experiments are therefore ways for us to explore some of the possible ways in which points were made. The obtained points are used to explore whether the cross-section angles and the angles of the lateral edges can be related to the typical features of *Concorde* profile and perfect triangular outline. The experimental work is confined to a few samples (6 samples), it is therefore not intended to be exhaustive, but merely to generate for initial analyses. The experimental work was applied to high-quality chert raw material imported from Fécamp in the Normandy region of north-western France (Figure 3), which is very similar in quality to the raw material from YSI. The experimental knapping was done using hard hammer percussion to generates points on which the angles described in the previous sections could be measured and compared to the points from YSI.

4. Results

4.1. The cross-section angles of Levallois points

The measurements suggest that within the 155 Levallois points analysed from YSI, the cross-section angles, especially on points distinguished by a regular triangular outline - marked by nearly symmetrical and equilateral shapes, along with *Concorde*-shaped profiles - vary between 130° and 145° (specifically, samples 1-61 in Table 1, and as illustrated in Figures 4 and 5.

Figure 3. The raw material used in the experimental work and examples showing the chert from Yabroud.

Table 1. Measurement of cross-section and lateral angle of broad-based Levallois points.

Concorde shape - left-right	N.	layer	ID	Cross section angle - left	Cross section angle - right	Regular outline - left-right
Concorde-shaped profile	1	4	2	145	143	yes-yes
	2	4	3	135	147	yes-yes
	3	4	5	145	140	yes-yes
	4	4	6	140	145	yes-yes
	5	4	7	144	141	no-no
	6	4	12	143	137	yes-yes
	7	4	13	146	143	yes-yes
	8	4	14	144	140	yes-yes
	9	4	16	138	139	no-no
	10	4	17	144	145	yes-yes
	11	4	22	140	144	yes-yes
	12	4	23	137	146	no-yes
	13	4	25	142	140	no-no
	14	4	30	146	135	yes-yes
	15	4	37	148	144	yes-yes
	16	4	40	146	146	yes-yes
	17	4	41	142	139	yes-yes
	18	4	43	142	145	no-no
	19	4	44	134	146	yes-yes
	20	4	45	144	145	yes-yes
	21	4	47	143	139	no-yes

Concorde shape - left-right	N.	layer	ID	Cross section angle - left	Cross section angle - right	Regular outline - left-right
	22	4	58	144	136	yes-yes
	23	4	60	138	140	no-retouched
	24	4	63	140	143	yes-retouched
	25	4	65	142	138	yes-yes
	26	4	69	132	131	yes-yes
	27	4	70	138	137	yes-yes
	28	4	116	145	135	yes-yes
	29	4	122	140	142	yes-yes
	30	4	154	147	137	yes-yes
	31	4	162	139	138	yes-yes
	32	4	166	140	142	yes-yes
	33	4	183	145	147	no-no
	34	4	195	126	133	no-no
	35	4	219	145	144	yes-yes
	36	4	450	129	135	yes-yes
	37	4	477	143	144	no-no
	38	3	4	145	128	no-yes
	39	3	12	145	130	no-yes
	40	3	23	146	145	yes-yes
	41	3	35	135	135	yes-yes
	42	3	36	142	140	no-no
	43	3	38	142	146	yes-yes
	44	3	49	146	140	retouched-yes
	45	3	50	133	143	yes-yes
	46	3	185	135	143	no-yes
	47	3	191	146	135	no-yes
	48	5	4	147	142	yes-yes
	49	5	8	139	146	yes-yes
	50	5	10	147	148	yes-yes
	51	5	17	147	136	yes-retouched
	52	5	18	145	146	no-yes
	53	5	30	143	145	yes-yes
	54	5	35	145	146	yes-yes
	55	5	36	147	147	yes-no
	56	5	38	137	138	yes-no
	57	5	41	144	146	yes-no
	58	5	43	147	148	yes-no
	59	5	54	137	147	yes-retouched
	60	5	82	143	145	yes-yes
	61	6	1	143	145	yes-yes
Concorde-shaped profile on the left edge	62	4	9	145	non	no-no
	63	4	24	143	159	yes-no
	64	4	50	147	153	yes-yes
	65	4	51	135	150	yes-no
	66	4	57	146	154	yes-no
	67	4	68	148	157	yes-yes
	68	4	73	144	150	yes-no
	69	4	98	132	150	yes-no
	70	4	107	140	160	yes-no

Concorde shape - left-right	N.	layer	ID	Cross section angle - left	Cross section angle - right	Regular outline - left-right
	71	4	160	132	155	no-no
	72	4	161	126	157	yes-no
	73	4	169	125	151	yes-no
	74	4	171	142	153	no-no
	75	4	177	146	157	yes-no
	76	2	48	141	150	no-yes
	77	2	53	144	153	yes-no
	78	3	186	142	153	yes-yes
	79	3	188	146	157	yes-no
	80	5	7	141	154	no-no
	81	5	12	135	156	yes-no
Concorde-shaped profile on the right edge	82	4	21	153	143	no-yes
	83	4	36	152	146	no-yes
	84	4	48	155	139	no-yes
	85	4	49	166	146	no-yes
	86	4	71	152	132	retouched-retouched
	87	4	72	153	146	yes-yes
	88	4	100	150	139	no-yes
	89	4	346	155	143	no-yes
	90	4	401	156	130	no-yes
	91	4	481	non	143	no-yes
	92	3	6	151	145	retouched-retouched
	93	3	7	non	146	no-yes
	94	3	27	154	130	no-no
	95	3	40	150	133	no-yes
	96	3	43	150	144	no-yes
	97	3	121	151	141	no-yes
	98	5	25	non	138	no-yes
non- Concorde-shaped profiles	99	4	4	156	160	no-yes
	100	4	8	156	153	yes-no
	101	4	11	150	153	no-no
	102	4	15	152	150	no-yes
	103	4	19	152	150	yes-yes
	104	4	20	156	154	no-yes
	105	4	26	154	151	no-no
	106	4	27	160	150	no-no
	107	4	28	150	150	no-no
	108	4	29	155	153	no-yes
	109	4	31	151	155	yes-yes
	110	4	32	160	155	no-no
	111	4	33	159	150	no-yes
	112	4	34	151	158	no-no
	113	4	38	156	157	no-no
	114	4	42	159	153	no-no
	115	4	52	159	157	no-yes
	116	4	56	159	150	no-yes
	117	4	59	152	151	yes-yes
	118	4	64	152	153	no-no
	119	4	67	154	161	yes-no

Concorde shape - left-right	N.	layer	ID	Cross section angle - left	Cross section angle - right	Regular outline - left-right
	120	4	76	156	152	yes-yes
	121	4	81	159	154	no-no
	122	4	101	153	160	no-yes
	123	4	104	157	non	yes-no
	124	4	106	164	153	yes-yes
	125	4	167	156	150	no-yes
	126	4	173	150	155	no-no
	127	4	178	160	154	no-no
	128	4	181	154	163	no-no
	129	4	182	151	150	no-no
	130	4	187	150	150	no-no
	131	4	190	153	158	no-no
	132	4	233	159	158	no-no
	133	4	330	154	150	no-no
	134	4	334	160	150	no-no
	135	4	406	155	160	no-no
	136	4	598	155	156	no-no
	137	4	600	159	158	no-no
	138	4	604	non	156	no-no
	139	4	639	150	152	no-no
	140	2	44	159	150	no-no
	141	2	45	152	151	yes-no
	142	2	51	151	150	no-no
	143	3	1	153	150	no-yes
	144	3	8	151	150	no-no
	145	3	9	150	157	no-yes
	146	3	15	152	151	no-yes
	147	3	25	151	150	yes-no
	148	3	28	159	152	no-yes
	149	3	29	159	154	no-no
	150	3	33	156	152	no-no
	151	3	34	155	157	no-no
	152	3	60	159	non	no-retouched
	153	3	167	153	155	no-no
	154	3	193	164	154	no-no
	155	5	31	154	152	retouched-yes

Although the more regular-shaped lateral edge is related to smaller cross-section angles in most instances, it is not a basic condition for it. For instance, N. 33 and 34 in Table 1 show *Concorde*-shaped profile, however, they have irregular-shaped outlines. Furthermore, observing a *Concorde*-shaped profile on a single edge can be reasonably expected when the Levallois point only has a single small cross-section angle (n. 62-98 in Table 1). Moreover, it must be noted that all edges with *Concorde*-shaped profile have an almost regular-shaped outline.

Consequently, *Concorde*-shaped profile and a regular triangular outline are, in most cases, associated with small cross-section angles, ranging between 130° and 145°-147, whereas regular-shaped lateral edges are related to all sizes of cross-section angles, with small cross-section angles predominantly (Figure 6).

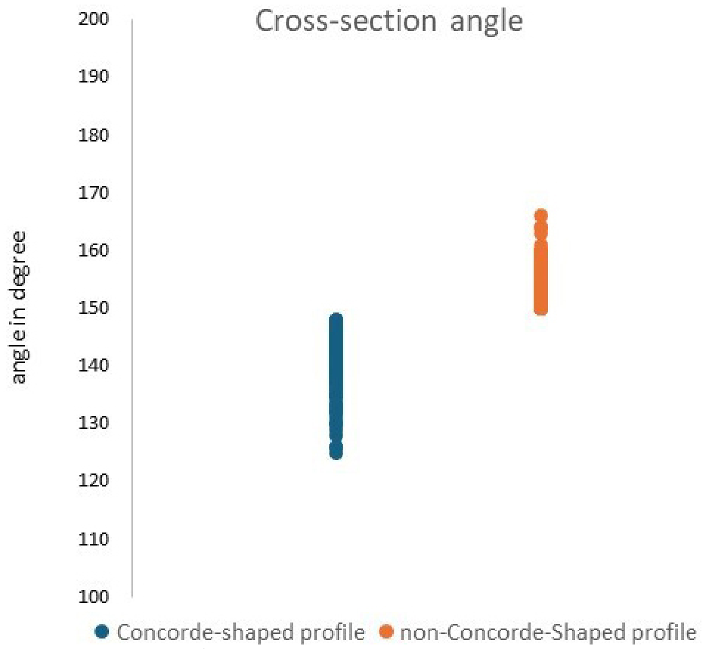

Figure 4. Cross-section measurement of 155 Levallois points.

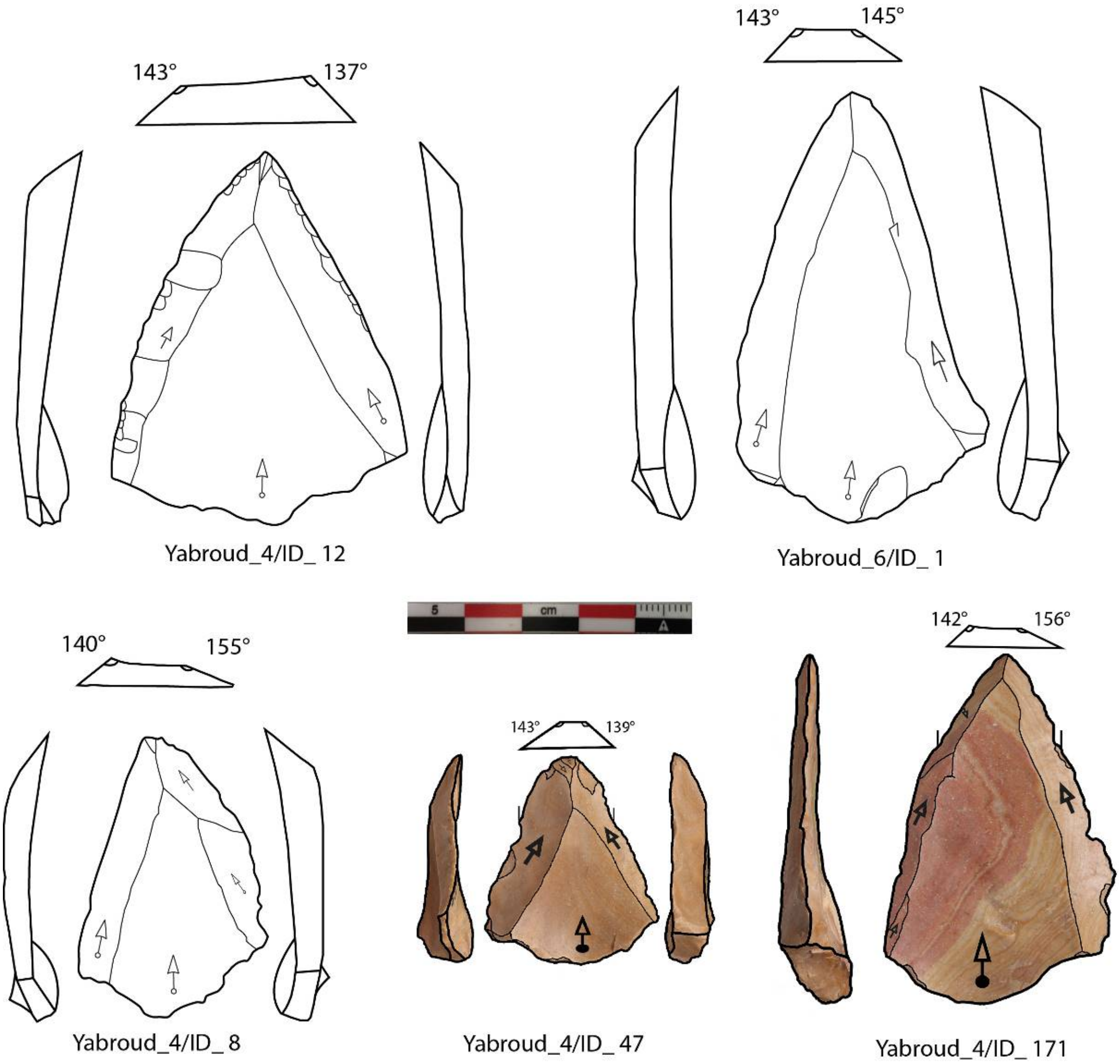

Figure 5. Levallois points which have *Concorde*-shaped profiles, and which have non-*Concorde*-shaped profiles.

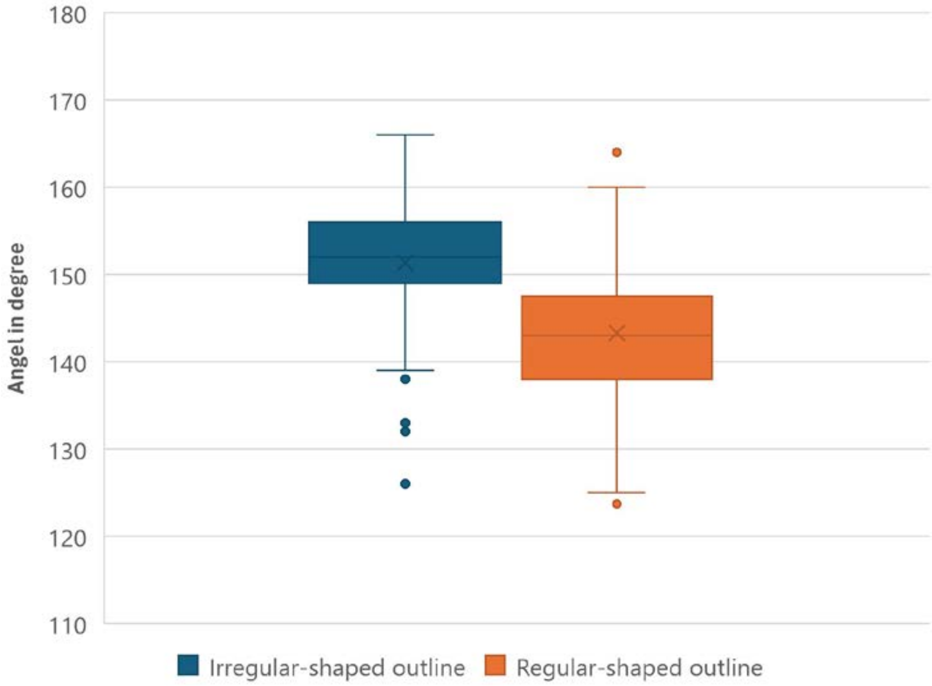

Figure 6. Cross-section angles of Levallois point in relation to the regular and irregular-shaped outline of Levallois points.

In contrast, Levallois points that exhibit irregular-shaped outlines and non-*Concorde*-shaped profiles are associated with cross-section angles greater than 150° (n. 99-155 in Table 1), (Figure 4) and an example is seen in Figure 5 .

Therefore, it can be suggested that the obliqueness of the two preceding preparatory removals plays major role in the predetermination of the outline and *Concorde*- shape of Levallois points. The smaller the cross-section angle, the more regular the shape of the lateral edges and more *Concorde*-shaped the profile of the Levallois point can be (Figure 6). It follows that the small cross-section angles measured on Levallois points resulted in *Concorde*-shaped profile and a more regular-shaped lateral edge, whereas the larger cross-section angles caused non- *Concorde*-shaped profile and irregular-shaped lateral edges.

Given the nature of our sample - a possibly somewhat selective collection from a single site - we emphasise here that we are not engaging in a formal quantitative study, testing for statistical significance. Rather we are highlighting the basic data and pattern that emerges in terms of descriptive statistics, and showing that important patterning seems to be present in terms of quantitatively measurable aspects that have previously been highlighted as being potentially significant. This prepares the ground for a larger scale formal comparative study which much larger sample sizes from multiple sites.

Consequently, measurements of the Levallois point cross-sections in our sample indicate that in most cases, the smaller the cross-section angles, the more regular the shape of the lateral edges (regular triangular outline). This demonstrates that the applied method cannot be the sole driver for the diversity or standardization of Levallois point characteristics.

4.2. The lateral angles of broad-based Levallois points vs. elongated points

In order to identify the technological factors that results in short, broad-based Levallois points, the angle between the lateral edges and the base of the 93 elongated and short, broad-based Levallois points from assemblages 4 and 6 of YSI were measured with a protractor. We followed a triangle that passes three angles of the elongated and broad-based Levallois points (Figure 2). The lateral angles of short broad-based Levallois point bases averaged 67° (Table

2 and Figure 7), whereas those of elongated Levallois points averaged 82° (Figure 7, Table 3). Examples of broad-based Levallois points and elongated points are shown in Figure 8. Consequently, the two preceding convergent removals obviously played the main role in identifying the base type of Levallois points. The lateral angles of short, broad-based Levallois points are closer to acute angles, whereas the lateral angles of elongated Levallois points are closer to right angles, greater than 75° in all instances. The more convergent the two preceding removals are, the broader the base of the Levallois point obtained. Additional, although the fundamental difference in morphology of Levallois points, they show similar overall sizes (Table 4).

Table 2. Broad-based Levallois points. Measurement of broad-based points lateral angles.

ID_layer 4	Lateral angle - left	Lateral angle - right	Mean of lateral angle
2	67	71	69
3	65	70	67.5
5	65	64	64.5
6	67	74	70.5
7	70	70	70
8	66	65	65.5
11	74	80	77
12	62	65	63.5
13	71	69	70
14	71	72	71.5
15	74	72	73
16	72	65	68.5
17	66	73	69.5
19	60	67	63.5
20	67	68	67.5
21	71	66	68.5
22	78	76	77
23	64	66	65
24	60	59	59.5
25	80	70	75
26	72	70	71
28	72	69	70.5
29	67	72	69.5
30	83	82	82.5
31	72	71	71.5
32	74	70	72
33	67	74	70.5
34	73	64	68.5
36	69	65	67
37	72	73	72.5
38	70	68	69
40	68	72	70
41	65	68	66.5
42	71	67	69
44	75	72	73.5
45	67	67	67
47	71	69	70
48	78	76	77

ID_layer 4	Lateral angle - left	Lateral angle - right	Mean of lateral angle
49	73	64	68.5
50	72	74	73
51	75	56	65.5
52	64	74	69
56	70	71	70.5
57	67	65	66
58	60	65	62.5
59	74	71	72.5
60	68	62	65
63	70	70	70
64	80	84	82
65	61	61	61
68	50	60	55
69	75	66	70.5
70	66	64	65
73	64	67	65.5
76	75	70	72.5
81	74	63	68.5
98	62	63	62.5
100	74	70	72
101	68	69	68.5
106	63	66	64.5
107	70	63	66.5
116	79	72	75.5
122	63	61	62
135	86	80	83
154	68	61	64.5
160	78	75	76.5
161	85	65	75
162	55	65	60
167	70	67	68.5
171	78	71	74.5
173	66	57	61.5
177	60	62	61
178	73	82	77.5
181	69	70	69.5
182	68	64	66
183	77	75	76
187	65	66	65.5
195	63	72	67.5

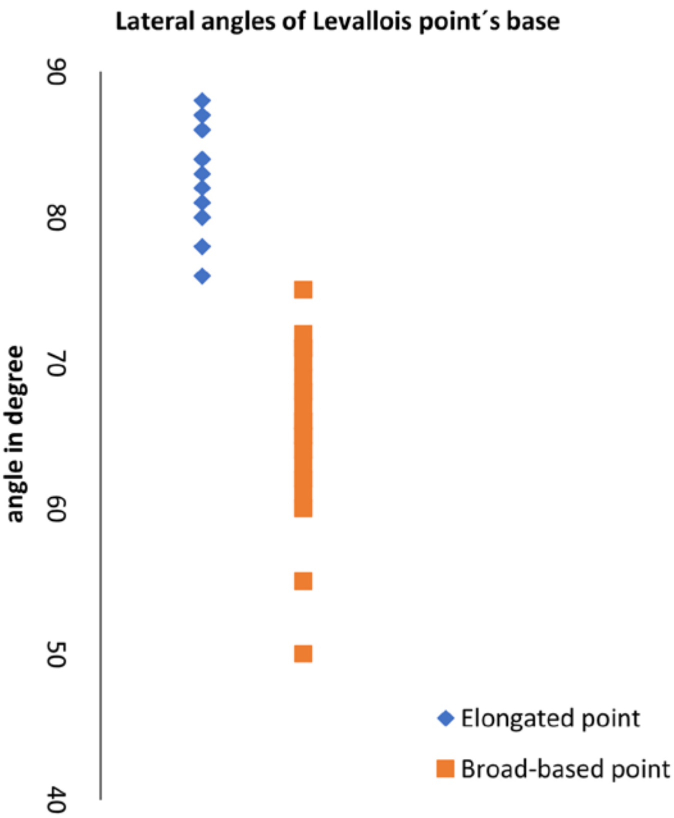

Figure 7. Measurements of the lateral angles of elongated and broad-based Levallois points.

Table 3. Elongated points. Measurement of elongated points lateral angles.

ID_layer	Lateral angle - left	Lateral angle - right	Mean of Lateral Angle
1_6	83	80	82.5
10_6	84	81	75
27_6	80	78	79
64_4	86	84	85
92_6	80	82	82.5
115_6	88	78	82
135_6	86	80	81
166_6	80	70	75
169_6	80	84	83
330_6	84	72	78
331_6	80	76	75.5
384_6	87	80	83
399_6	81	87	75
401_6	81	82	81.5
701_6	86	84	85

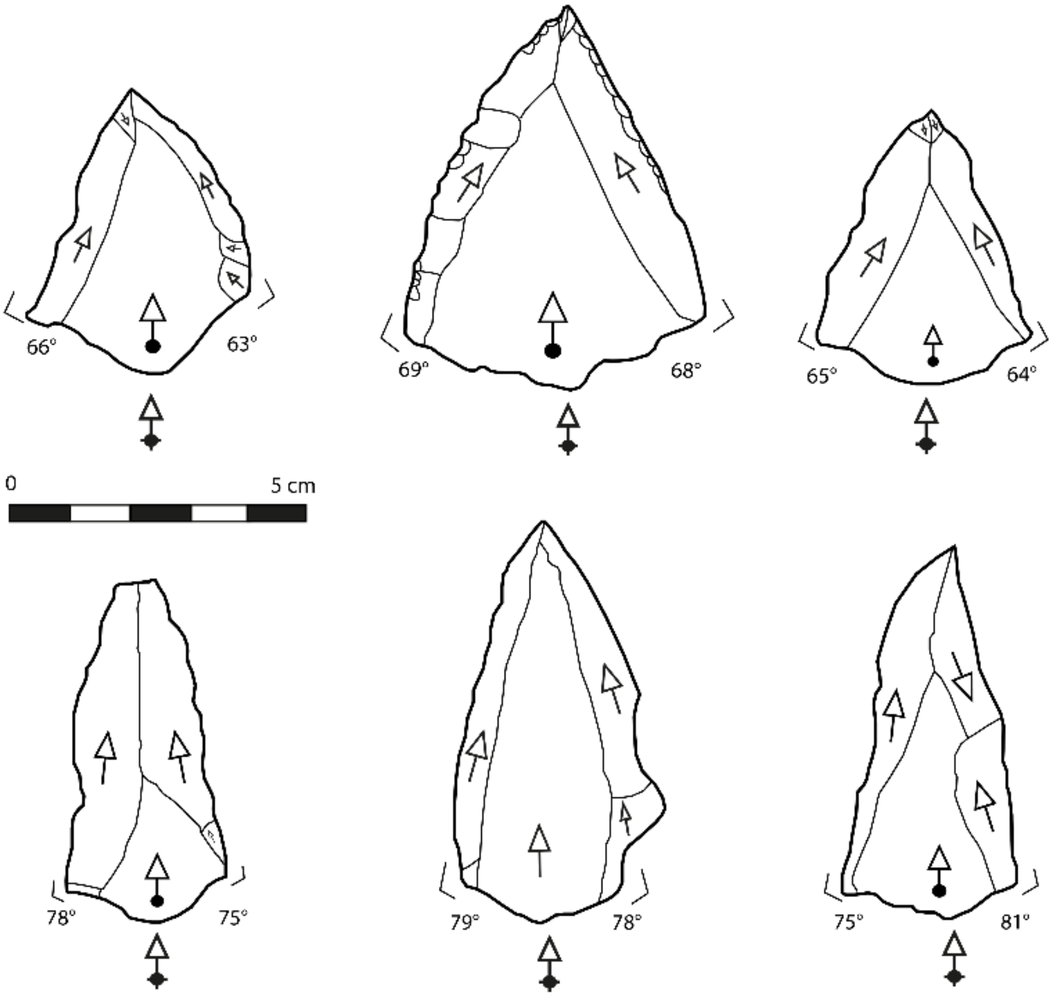

Figure 8 shows instances of measured lateral angles of broad-based Levallois points and elongated points.

Table 4. Levallois point mean (mm). Mean size of broad-based Levallois points and elongated. Abbreviations: LWR - Length to width ratio.

Point type	Length	Width	Thickness	LWR
Levallois point with Concorde-shaped profile and perfect triangular outline	55.0	36.8	7.0	1.4
Levallois point without Concorde-shaped profile and perfect triangular outline	57.9	37.5	7.	1.5
Elongated point	67.6	29.3	8.3	2.3

4.2.1. The experimental work

Based on the argument that points can be produced by multiple methods or even can also occur fortuitously during debitage (Boëda, 1995) and the impact of the two preceding preparatory removals on the morphology of Levallois point, our experimental work is not intended to validate the methods used in Yabroud assemblages for the production of Levallois points with and without *Concorde*-shaped profiles and having regular or irregular triangular outlines. Rather, our focus is on investigating the significance and impact of the obliqueness of two preparatory removals on the morphology of Levallois points regardless of the applied method.

4.3. Levallois points with Concorde-shaped profile

The first point was produced from the non-Levallois method. Two convergent removals have been carried out once the flaking surface is prepared. The negatives of these removals showed different obliqueness, based on the location of the impact point. The farther from the edge the impact point, the deeper the negatives of preceding removals can be. After preparing the striking platform in order to obtain a specific protrusion to receive the oriented blow, the strike invaded the flaking surface toward the distal termination and lateral edges of the block (Figure 9; b). It is important to be aware that the two preceding removals were adequately convergent in order to avoid production of an elongated point.

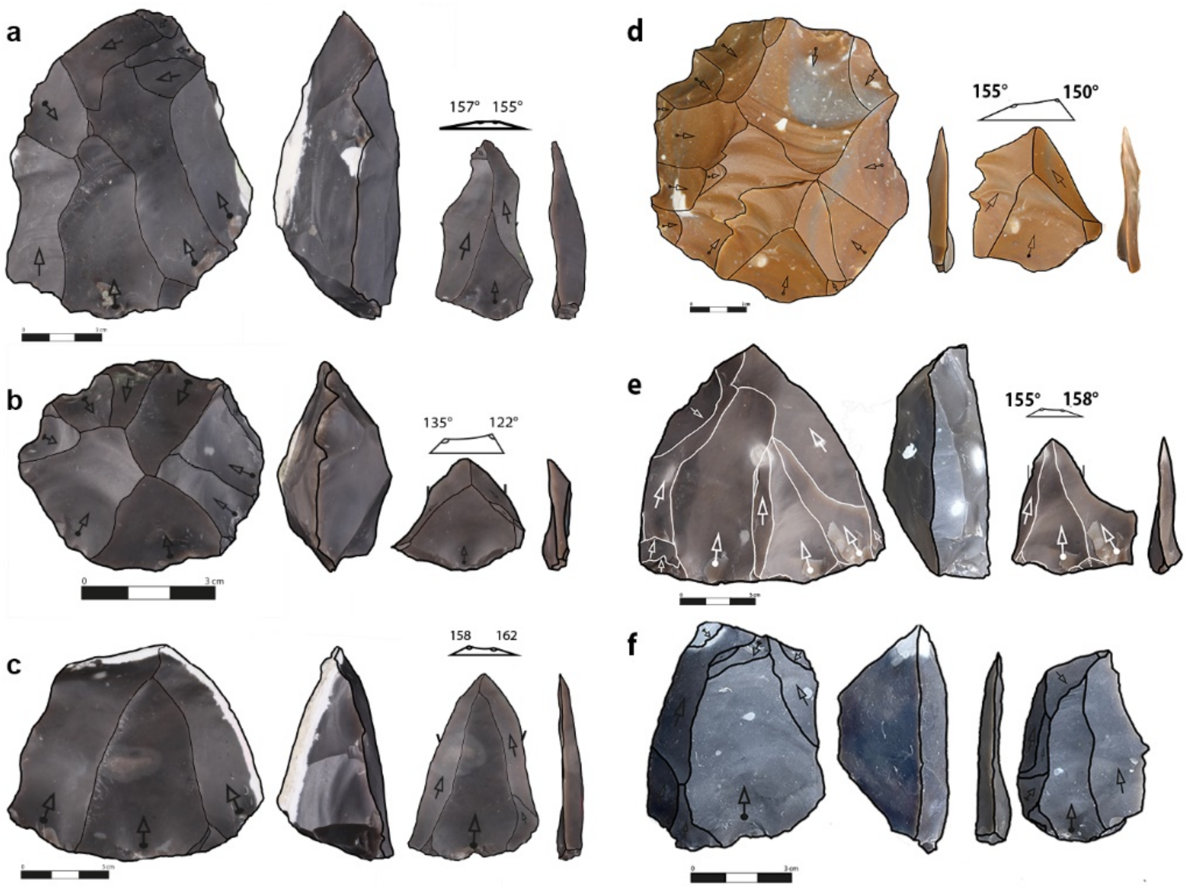

Figure 9. Various typologically Levallois points produced by different methods (a, b, c, d, e), showing different cross-section angles and (f) a Levallois flake. The experimental work was executed by Brenet and Al Kassem.

Owing to the fact that the two preceding convergent removals had different obliqueness, the Levallois point showed slightly different technological features in terms of the regular-shaped lateral edge and the *Concorde*-shaped profile. The cross-section angle was measured at 122° on the more regular shaped edge with *Concorde*-shaped profile, and 135° on the other edge exhibiting a *Concorde*-shaped profile and less regular shaped edge (Figure 9; b). The small cross-section angles of the Levallois points resulted in *Concorde*-shaped profile and a more regular shaped lateral edge, which corresponds to the result of the experimental work. Therefore, it can be confirmed that these two technological features are obviously related to the obliqueness of the two preceding convergent removals. The explanation for this phenomenon is that the obliqueness of one preceding removal hampered extension of the lateral edge, whereas the other preceding removal that was less oblique provoked further extension of the lateral edge. Accordingly, the more oblique removal resulted in a regular lateral edge, as well as a *Concorde*-shaped profile. As can be seen in Figure 9; b and based on the awareness that the two oblique preceding removals must be sufficient convergent, we got a short-based broad point with *Chapeau de gendarme* shape as well.

Finally, although the point was removed by non-Levallois method, the five typical textbook features are present. This is a caution that Levallois points can be made by non-Levallois methods.

4.4. Levallois points without Concorde-shaped profile

Levallois preferential, recurrent unidirectional convergent Levallois methods and another trial of non-Levallois method were applied in order to obtain Levallois points. When it comes to the recurrent unidirectional-convergent Levallois method, the flaking surface was prepared by detaching several preparatory removals from a single flaking surface. The flaking surface exhibited less convexity than the flaking surface of the non-Levallois core (Figure 9; d). In addition, the preparatory scar patterns were almost flat as opposed to the two oblique and convergent preceding removals of the non-Levallois core. The striking platform was carefully prepared to direct the impact blow. During the process of Levallois point removal, the preceding semi-flat removals allow an extension of the lateral edges or could cause an unregular shape of the lateral edges. Consequently, the removed Levallois points have an irregular-shaped outline in both cases (Figure 9; a and e). In addition, it lacks the *Concorde*-shaped profile. Although the base shows a semi-*Chapeau de gendarme*-shaped striking platform, the point appeared to be more to be elongated (Figure 9; a). The same process was applied to the preferential Levallois method, except only two convergent preceding removals were detached after preparing the flaking surface (Figure 9; c). Another non-Levallois method was applied. However, the two preceding preparatory removals were not oblique enough, furthermore, the flaking surface have badly prepared. Therefore, we failed to achieve our aim in producing Levallois point with a *Concorde* profile and perfect triangular outline (Figure 9; d). In Figure 9: f, a Levallois flake was the outcome.

The cross-section angles of both Levallois points and elongated points were greater than those of Levallois points with *Concorde*-shaped profile, measuring between 155° and 162° (Figure 9; a, c, d and e). In addition, as it can be seen in Figure 9; a and c, the two preceding removals are more likely to be slightly parallel than convergent, which causes the elongated Levallois point.

Briefly, Levallois points without *Concorde* profiles and other resulting end-products, such as flakes, often display feather terminations. However, in the case of Levallois points with *Concorde* profiles, the following process unfolds:

1. Flaking surface convexity varies across the core, with lower convexity on circumferential edges and higher in the medial parts of the core.
2. The removal process of the Levallois point starts with low convexity (proximal part of the core), progresses to high convexity, and then returns to low convexity on the opposite side (distal termination of the core), thereby adopting the morphology of the flaking surface.
3. Combined with two preceding oblique preparatory removals which have low convexity at the proximal part of the core, this sequence forms the distinctive *Concorde* shape.

As our aim is not to verify the method employed to produce the Levallois point in YSI, the experimental work reinforces our inference that the *Concorde*-shaped profiles, regular triangular outlines, and broad base of the Levallois point are associated with a particular method. Rather, it is linked with the obliqueness of the preparatory removals irrespective of the method used. The point with previous technical features was produced by a non-Levallois core. Whereas the others produced Levallois points lack *Concorde*-shaped profiles.

5. Discussion

Whereas some previous studies have linked variability in Levallois point morphology to different functions such as in Umm el Tlell site (Syria) - "*Indeed, the morpho-technical diversity of Levallois points from level VI 3b'l is due to the fact that this type of object can be associated with several different functions, as well as manners and contexts of function (fonctionnement)*" (Boëda *et al.* 1999: 397) - our study highlights how the technological aspects of the preparation process relate to the diversity in Levallois point morphology and provides additional technological reasons using explicitly concrete evidence to determine the characteristics of the Levallois points. Specifically, the obliqueness of two preceding preparatory removals is an important factor alongside the particular reduction methods used to produce Levallois points. The acute angle of the cross-section (equivalent to adequate convexity) helps to accelerate the detachment process of points from the flaking surface and prevents extension of the edges at a specific point, whereas the obtuse angle (equivalent to inadequate convexity) could allow either early detachment of the point, and thus, incomplete removals, or irregular outline shape as a result of lacking adequate obliqueness. For instance, it is well known that classical Levallois points can be produced by the preferential Levallois method (Boëda *et al.* 1990; Boëda 1995). However, although a high quantity of Levallois points in with *Concorde*-shaped profile and perfect triangular outline assemblage 4 of YSI, the recurrent unidirectional convergent Levallois method was the only method applied in this assemblage (Al Kassem 2021: 148).

Our results show that the *Concorde*-shaped profile is closely linked to cross-section angles regardless of the method applied and the direction of the preparatory removals. Meignen (2019) clarifies this shape of the profile is not simply curved, explaining a rupture process at a point corresponding to the Levallois Y-arris resulting in the distal part of the profile bending down at a striking angle. Boëda (1995) stipulates a condition of predetermination behavior through flaking surface preparation to obtain a predetermined shape in the Levallois concept. Our results are consistent with the findings of Meignen and Boëda, however, we add simple quantitative measures that show cross-section angles have a large impact on determining the point shape. Another technical feature that confirms the predetermination behavior as a condition for achieving the production of broad-based Levallois point or elongated point is the convergence of the two preceding removals. The more acute the angle of the lateral edges, the broader the Levallois point´s base, which means that the more convergent the two preceding predetermined removals, the broader and the shorter the base. While the more parallel the two preceding predetermined removals, the more elongated the point with a narrower base. Meignen (2019) discusses how the widely spaced guiding ridges allow the knapper to determine the morphology of the base: "*The locations of the two notches that create the chapeau de gendarme thus determine the morphology of the product*" (Meignen 2019: 53).

Levallois points are prominent in recent discussions of Levallois variability and its implications (*e.g.,* Crassard & Thiébaut, 2011), and the kind of simple quantitative measures we have presented here provide an important way of elucidating the meaning of morphological variability.

Analysis of lithic material of YSI assemblage 6 indicates shifting from the production of Levallois blades and elongated points in the first stage of core reduction into the production of shorter Levallois points in the second stage of core reduction (see more in Al Kassem 2021: 93, 187). Rather than continuing to detach unidirectional parallel removals, the knappers shifted to remove more convergent preparatory removals that help to reinstall a suitably shaped flaking surface for point production (Al Kassem 2021: 215). This highlights how different flake shapes can be produced from Levallois surfaces during the course of reduction (see also Shimelmitz and Kuhn 2018).

These simple quantitative measures could be used to examine different point types, for example, the leaf-shaped vs wide based Levantine Levallois points (*e.g.*, Meignen 2019). Such methods can also help elucidate the variability of Nubian Levallois technologies and how these relate to other point forms (Groucutt 2020).

6. Conclusion

The current study illustrates that the technical characteristics of the flaking surface of the core play a significant role in influencing the variability in the features of the Levallois point. We conducted measurement of cross section for 155 Levallois points from YSI 2, 3, 4, 5 and 6 in order to investigate the impact of the obliqueness of two preceding preparatory removals on the morphology of the Levallois points, specifically the *Concorde*-shaped profile and perfectly triangular outline. Also, we measured the angle between the lateral edges and the base of 93 Levallois points in order to investigate the role of the convergence of the two preceding removals in producing short, broad-based or elongated Levallois points. The measurements confirm that the character of the flaking surface is reflected in the Levallois point.

The vast majority of Levallois points showing *Concorde*-shaped profile and having a consistently triangular outline are typically linked to small cross-section angles, falling within the range of 130° to 145°-147°. On contrary, non-*Concorde*-shaped profile and irregular triangular outline is linked mostly to cross-section angle greater than 150°.

It is not only the obliqueness of the two preceding preparatory removals that effects the technical features of the Levallois points, but also the direction of these preparatory removals. The greater the convergence of the two preceding removals, the broader the base of the resulting Levallois point.

Apart from the method of production, we suggest for future work focusing on the impact of the angles produced by preparatory removals on debitage surfaces used to produce points that could identify the reason behind the variability vs standardisation in their morphologies.

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Conflicts of Interest

The authors declare they have no conflicts of interest.

Data accessibility statement

The authors confirm that the data supporting the findings of this study are available within the paper. For further information, please write an email to the corresponding author.

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Die Auswirkungen der laterale Schrägheit und Kantenwinkel auf die Morphologie der Levallois Spitze

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Zusammenfassung:

Untersuchungen an Levallois-Spitzen bieten Aufschluss über den Zusammenhang zwischen allgemeinen Aspekten der Levallois-Technologie (wie kognitive Entwicklung, Standardisierung und kulturelle Transmission) und spezifischen Funktion von Steinwerkzeugen (z. B. Überlegungen zu Spitzen als Speerspitzen). Zahlreiche mittelpaläolithische Fundstellen der Levante zeichnen sich durch einen starken Fokus auf die Produktion von Levallois-Spitzen aus. Traditionell wurde dieses Phänomen vor allem aus einer typologischen Perspektive untersucht, während neuere Ansätze verstärkt technologische Ebenen hinzufügten, wie etwa das häufige Auftreten von rekurrenten Levallois-Abbauschemata zur Spitzenproduktion in diesem Gebiet. Ebenso haben Gebrauchsspuren- und Residuen-Analysen zu einer veränderten Wahrnehmung der Funktion von Levallois-Spitzen geführt. In diesem Beitrag untersuchen wir, wie zwei quantifizierbare Aspekte von Levallois-Spitzen – Querschnittswinkeln und Lateralwinkeln – mit der Morphologie von Levallois-Spitzen zusammenhängen. Durch die Kombination von Schlagexperimenten mit einer Analyse der Levallois-Spitzen aus Yabroud I, Syrien, zeigen wir, dass die Winkel der lateralen Präparationsabschläge einen signifikanten Einfluss auf die Morphologie der erzeugten Levallois-Spitzen haben, insbesondere im Hinblick auf das Merkmal eines *Concorde*-förmigen Profils. Ebenso zeigen wir, dass die laterale Kantenwinkeln die Länge der produzierten Spitze beeinflusst. Diese Studie verbessert nicht nur unser Verständnis von Levallois-Spitzen, sondern unterstreicht auch die Wichtigkeit von Winkeln bei der Untersuchung lithischer Technologie. Wir betonen, dass diese Studie darauf abzielt, die Auswirkung der Winkel von Präparationsabschlägen auf die Morphologie von Levallois-Spitzen im Allgemeinen zu untersuchen, und zwar durch eine initiale Fallstudie eines Inventars, die zukünftige multivariate Analysen mehrerer Inventare zur Überprüfung unserer Hypothese ermöglicht.

Schlüsselwörter: Mittelpaläolithikum; Levante; Levalloisspitze; Morphologie; Technologie; Standardisierung; laterale Schrägheit; Yabroud; Syrien

التحضرية الجانبية وزواياها على شكل الحِراب تالازإلا نالیم ریثأت ةيزاولفـلا

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الخلاصة

إن دراسة الحربة الفلوازية أمر في غاية الأهمية كونها تجمع بين عدة قضايا متعلقة بتقنية التصنيع الفلوازية بشكل عام (مثال: تطور القدرة المعرفية بالانتقال من تصنيع أدوات حجرية بطرق بسيطة إلى معقدة، والتشابه الشكلي والحجمي وتقنية تصنيعها، وكذلك تناقلها كثقافة تصنيع بين المجموعات البشرية) ومحاولات تحديد وظائف الأدوات الحجرية المصنعة بهذه التقنية (مثال: التسليم بأنّ الحراب هي عبارة عن رؤوس سهام). تتميز العديد المواقع العائدة للعصر الحجري القديم الأوسط في المشرق بهيمنة إنتاج الحراب الفلوازية. تطرقت العديد من الدراسات التقليدية لهذه الظاهرة من منظور تصنيفها نمطياً، في حين ساعدت المناهج التقنية الحديثة في زيادة فهمنا للعديد من الجوانب المتعلقة بتصنيع الحراب الفلوازية مثل هيمنة استخدام الطريقة الفلوازية ذات اللإزالات الأحادية والمتقاربة الاتجاه في المشرق، وكذلك أدت تحليلات تآكل الحواف والبقايا المتواجدة عليها نتيجة الاستخدام إلى تغيير التصورات حول وظيفة الحراب الفلوازية. وهنا نسلط الضوء من خلال هذا البحث على العلاقة التي تربط بين جانبين قابلين للقياس في الحراب الفلوازية وهما: زوايا المقطع العرضي للجزء العلوي وزوايا الحواف الجانبية للحراب اللفلوزاية وبين شكل النهائي لها. استطعنا من خلال إعادة إنتاج حراب لفلوازية بنفس التقنية المستخدمة وكذلك تحليل مجموعة حراب لفلوازية من ملجأ يبرود الأول (سورية) إظهار تأثير ميلان الإزالات التحضيرية الجانبية لسطح التشظية للنواة الحجرية على الشكل النهائي للحراب الفلوازية وخاصة في تحديد شكل المقطع الجانبي لرأس الحربة والتي يطلق عليه تسمية " الكونكورد " (نسبة لشكل مقدمة طائرة حربية معروفة باسم الكونكورد). وبالمثل، تُظهر هذه الدراسة بأن زاويا الحواف الجانبية للإزالات التحضيرية لها تأثير على استطالة وقُصر الحراب الفلوازية المنتجة، فكلما كانت الإزالات التحضيرية متقاربة في نهايتها وبزوايا حادة كلما كانت الحراب قصيرة وذات قاعدة عريضة، والعكس صحيح، فكلما كانت الإزالات التحضيرية متطاولة وأقرب إلى متوازية وبزوايا أقرب إلى العمودية، كانت الحراب أطول وبقواعد ضيقة. وختاماً لا تعمل هذه الدراسة على تحسين فهمنا للحراب الفلوازية فحسب، بل إنها تسلط الضوء أيضاً على أهمية الزوايا في دراسة تقنيات تصنيع للأدوات الحجرية. ونؤكد أن هذه الدراسة تهدف إلى ضرورة التعمق والتحقيق في تأثير ميلان الإزالات التحضيرية على شكل الحراب الفلوازية بشكل عام من خلال دراسة حالة أولية لمجموعة واحدة والتي من شأنها أن تفتح المجال لتحليل مجموعات أخرى من الحراب الفلوازية من مواقع مختلف وذات متغيرات متعددة لاختبار مدى صحة فرضيتنا.

الكلمات المفتاحية: العصر الحجري القديم الأوسط؛ المشرق؛ الحراب الفلوازية؛ علم التشكل (مورفولوجيا)؛ التقنية؛ التشابه الشكلي والحجمي؛ تحدب/ميلان الإزالات الجانبية؛ يبرود؛ سورية.