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SEARCHING FOR MACROFRACTURES CAUSED BY MODIFYING FLAKES INTO MOUSTERIAN POINTS

ABSTRACT

This article investigates impact fractures, fractures commonly referred to as DIFs (diagnostic impact fractures), that occur during the knapping process of Mousterian points in order to better understand and distinguish fractures caused by use versus those formed during knapping. A knapping experiment was conducted with an inexperienced and an experienced knapper, using decorticated cores of similar sizes and chert as the raw material. The study aimed to identify the types and causes of fractures caused by impact, compare fracture typology between knappers, explore the influence of knapper experience on fracture formation, and investigate to what extent macrofractures occur during the knapping process. The results show that the inexperienced knapper produced a higher percentage of fractures compared to the experienced knapper, with step-terminating fractures being the most common type in the inexperienced knapper's assemblage. Fractures on the proximal dorsal side were mainly caused by a bad striking angle, while fractures on the lateral side were attributed to flakes hitting the ground. On the experienced knapper's assemblage, the most common fractures were the impact notch and burin-like fractures. The experiment also identified diagnostic impact fractures and assessed their presence. The results proved that various fractures could be formed by the same causation, which further leads to the problem of equifinality. Overall, the research provides insights into fracture formation during knapping and highlights the importance of accurately interpreting lithic assemblages based on fracture characteristics.

KEYWORDS: STONE TOOLS, IMPACT FRACTURES, DIFs, MOUSTERIAN POINTS, MACROFRACTURES.

INTRODUCTION

When processing lithic material from Palaeolithic sites, such as waste flakes, blades, points, and scrapers, a significant number of impact fractures, including diagnostic ones (DIFs), can be identified (Goval 2016; Guardiola and Urbina 2022; Lazuén 2012; Lombard 2005; 2007; Moore *et al.* 2023; Rots 2009; 2013; Sano 2009; Yaroshevich 2013).

Pargeter's study (Pargeter 2011) on macrofractures is a significant contribution to the understanding of lithic material. Macrofractures, including both diagnostic and non-diagnostic fractures, can provide insights into how stone tools were used. Pargeter's work discusses the importance of distinguishing between fractures caused by use and those generated during the manufacturing process.

Rots' research (Rots 2013) also delves into the formation of impact fractures in lithic material. The study may emphasise the potential for confusion between use-wear-related fractures and those created during knapping. Differentiating between these types of fractures is essential in order to draw accurate conclusions about tool function.

Lazuén's work (Lazuén 2012) could offer insights into the methods and criteria used to identify impact fractures, helping researchers distinguish between fractures resulting from use and those from other processes.

Lombard's studies (Lombard 2005; 2007) discuss the broader context of lithic analysis and its importance for understanding past human behaviour. The work addresses issues related to tool use and the formation of impact fractures.

While many of these fractures are created by impact, they do not necessarily indicate if the stone tool was used as a projectile or a hand-held weapon; they could have been formed during the knapping process itself. Understanding and distinguishing between impact fractures caused by use and those caused during knapping are crucial for accurately interpreting lithic assemblages and inferring past human behaviour.

THE RESEARCH AIMS OF THE KNAPPING EXPERIMENT

In order to gain an insight into the macrofracture propagation, the executed knapping experiment aimed to identify the types of DIFs that occur on stone tools and flakes during the knapping of Mousterian points. The experiment sought to compare the differences in fracture typology, quantity, and causes between an experienced and an inexperienced knapper. It also aimed to explore the influence of knapper experience on fracture formation, the correlation between impact fracture types and knapping variables, and the potential of identifying a knapper's experience based on impact fractures.

The key questions this experimental research aimed to answer are:

Which impact fractures, categorised as DIF (diagnostic impact fractures), can be identified as products of knapping incidents?

Which types of impact fractures, both diagnostic and non-diagnostic, can be attributed to a knapping incident?

Is it possible to infer the knapper's level of experience based on the characteristics of the impact fracture?

Is it possible to differentiate between the impact fractures caused by use, and those caused by knapping incidents?

MATERIALS AND METHODS

To ensure approximately controlled conditions, the knapping experiment utilised decorticated cores of similar sizes, and chert was used as the raw material. Both an inexperienced knapper (the author of this article) and an experienced knapper (Dr Marta Arzarello) knapped five Mousterian points each. The Mousterian points were made by retouching any suitable decorticated blanks (Bordes 1961: 804). The flakes were labelled and processed to identify the presence or absence of impact-like fractures, and after each strike, the flakes were analysed for damage to determine the cause of fracture formation. The inexperienced knapper worked with a core measuring 124 x 94 x 69 mm, while the experienced knapper utilised a core measuring 129 x 91 x 67 mm. In order to limit the variables, chert was the sole raw material employed in the experiment. Although the raw material plays a significant role in fracture formation, its influence is considered less important compared to use and taphonomy, as highlighted by Lombard (Lombard 2004) and Pargeter (Pargeter 2011; 2013). Both knappers used the same hard hammerstone, and the flakes were allowed to fall only onto a stone floor covered with plastic wrap. Each flake was carefully labelled and examined to determine the presence or absence of macrofractures and DIFs (Fisher 1984; Lombard, 2005; Pargeter 2011). To prevent any confusion or misinterpretation regarding the cause of damage formation, the flakes were analysed for damage after each strike. Any fracture identified as being caused by the impact was analysed using a low-magnification stereoscopic microscope (Leica LAS EZ) at 8x magnification, in addition to macroscopic analysis. Descriptive statistical methods were employed to interpret the identified damage.

RESULTS

The inexperienced knapper produced a total of 385 flakes during the knapping process of five Mousterian points. On the other hand, the experienced knapper generated 213 flakes while working on the same number of Mousterian points.

Fractures were present in 10.9% of the inexperienced knapper's assemblage (**Table 1**). The

Comparison Factor	Inexperienced knapper	Experienced knapper
Time	45 minutes	16 minutes
Flakes knapped	385	213
Fractures present	42 (10.9%)	19 (8.92%)
Predominant fracture area	proximal dorsal	lateral
Predominant fracture cause	bad striking angle	hitting the ground
Predominant fracture type	step-termination	impact notch/burin-like
Diagnostic impact fractures	8 (2.07%)	7 (3.28%)

Table 1. Results of experimental knapped assemblage.

Fracture type	Inexperienced knapper	Experienced knapper
Spin-off fracture > 6mm	4 (1.03%)	3 (1.4%)
Burin-like fracture	4 (1.03%)	4 (1.87%)
Bifacial spin-off	0	0

Table 2. Diagnostic impact fractures (DIFs) present in the knapped material.

Fracture Type	Frequency	Percent
Step-terminating bending fracture	13	31
Spin-offs> 6mm	4	9.5
Spin-offs	5	11.9
Impact notch	6	14.3
Crushing fracture	10	23.8
Burin-like	4	9.5
Total	42	100

Table 3. Macrofractures present in the inexperienced knapper's assemblage.

Fracture cause	Frequency	Percent
Retouching	13	31
Platform preparation	6	14.3
Hitting the ground	8	19
Poor striking angle	15	35.7
Total	42	100

Table 4. Fracture cause in the inexperienced knapper's assemblage.

Fracture type	Frequency	Percent
Step-terminating bending fracture	3	15.8
Spin-offs> 6mm	3	15.8
Spin-offs	2	10.5
Impact notch	4	21.1
Crushing fracture	3	15.8
Burin-like	4	21.1
Total	19	100

Table 5. Macrofractures present in the experienced knapper's assemblage.

Fracture cause	Frequency	Percent
Retouching	2	10.5
Platform preparation	3	14.3
Hitting the ground	9	47.4
Poor striking angle	5	26.3
Total	19	100

Table 6. Fracture cause in the experienced knapper's assemblage.

Fracture type	Frequency	Percent
No fractures	1	20
Crushing fracture	1	20
Step-terminating bending fracture	2	40
Spin-offs> 6mm	1	20
Total	5	100

Table 7. Fractures present on the Mousterian points - inexperienced knapper's assemblage

Fracture type	Frequency	Percent
No fractures	2	40
Spin-off	1	20
Crushing fracture	1	20
Spin-offs> 6mm	1	20
Total	5	100

Table 8. Fractures present on the Mousterian points - experienced knapper's assemblage

assemblage created by the inexperienced knapper exhibited a higher percentage of fracture presence compared to the experienced knapper's assemblage when knapping five Mousterian points (**Tables 1, 3, 4, 7 and 8**). Among the fractures observed in the inexperienced knapper's assemblage, the most common type was the step-terminating fracture, accounting for 31% (**Tables 1 and 3**). The majority of fractures formed on the proximal dorsal side of the flakes, amounting to 47.6% (**Table 1**). The variable that predominantly caused fractures was identified as a bad striking angle, responsible for 35.7% of the fractures (**Table 1**).

In the experienced knapper's assemblage, the most common fracture types were the impact notch and burin-like fractures, both occurring with a frequency of 21.1% (**Tables 1 and 5**). The lateral side of the flakes exhibited the highest occurrence of fractures, representing 52.6%. The primary cause of fracture formation was the flakes hitting the ground after being knapped from the core, accounting for 47.4% of the fractures (**Table 6**). Fractures were present in 8.92% of the experienced knapper's assemblage (**Table 1**). The identified diagnostic impact fractures (DIFs), such as spin-off fractures bigger than 6mm and burin-like fractures are presented in **Table 2**.

In the analysis of Mousterian points specifically, both knappers' assemblages exhibited a crushing fracture. Two points in the experienced knapper's assemblage did not have any formed fractures (**Table 8**), while one point knapped by the inexperienced knapper had no identified fractures (**Table 7**). Both knappers produced one example each of spin-off fractures larger than 6 mm (**Tables 7 and 8**).

Visualisation of the data was employed to gain a better understanding of the variables. The figure (**Figure 1**) presents fracture areas and types for both knappers. It was observed that platform preparation contributed to fracture sizes ranging from 4-6 mm for the inexperienced knapper and 2-7 mm for the experienced knapper (**Figure 2**). For both knappers, the impact notch measured 2-5 mm. The step-terminating-bending fracture ranged from 1-10 mm for the inexperienced knapper and 6-10 mm for the experienced knapper. Spin-off fractures measured 2-11 mm in the experienced knapper's assemblage and 5-13 mm in the inexperienced knapper's assemblage (**Figure 3**). Impact notches occurred on flakes measuring 5-10 mm thick for the inexperienced knapper and 2-5 mm for the experienced knapper. Spin-off fractures with step-terminating-crushing fractures occurred on flakes measuring 5-18 mm for the inexperienced knapper and 10-19 mm for the experienced knapper. Step-terminating fractures occurred across a wide range of flake thicknesses in the inexperienced knapper's assemblage, spanning from 2 to 17 mm, while measuring 8-11 mm in the experienced knapper's assemblage (**Figure 4**).

A comparison of fracture causes and types is presented in **Figure 5**. Additionally, data regarding fracture area and cause is visually depicted in **Figure 6**. **Figures 7 and 8** showcase examples of fractures obtained from both knapping assemblages in this experimental research.

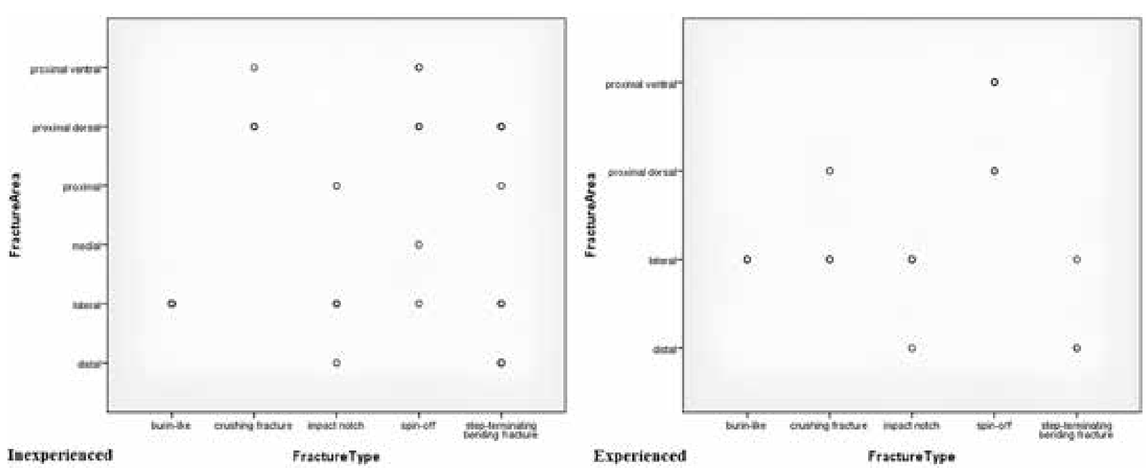

Figure 1. Comparison of the fracture area and fracture type (done using IBM SPSS Software).

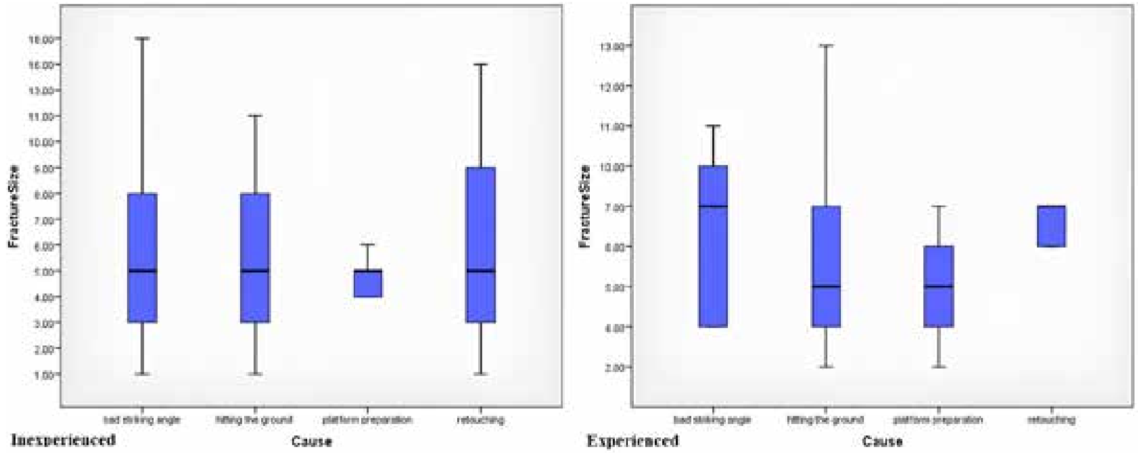

Figure 2. Comparison of the fracture size and fracture cause (done using IBM SPSS Software).

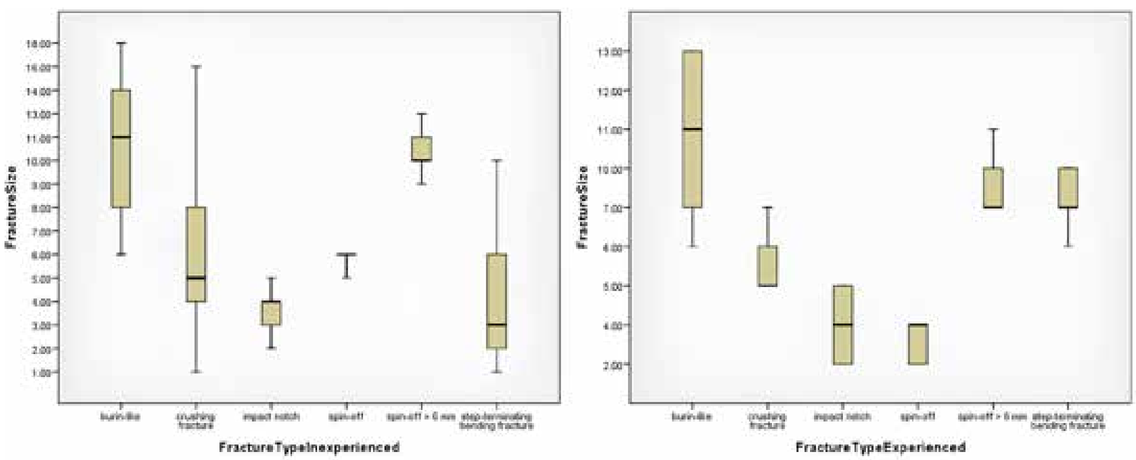

Figure 3. Comparison of the fracture size and fracture types (done using IBM SPSS Software).

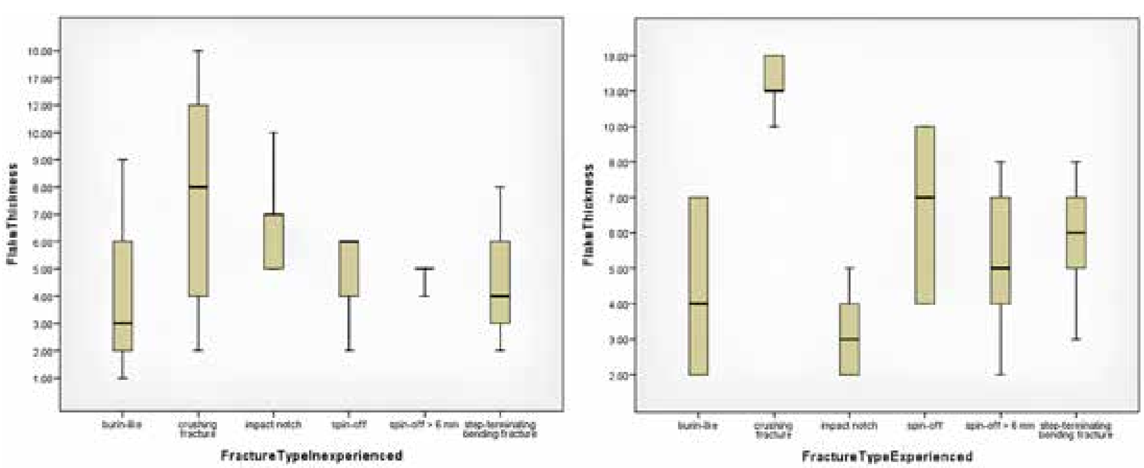

Figure 4. Comparison of the flake thickness and fracture (done using IBM SPSS Software).

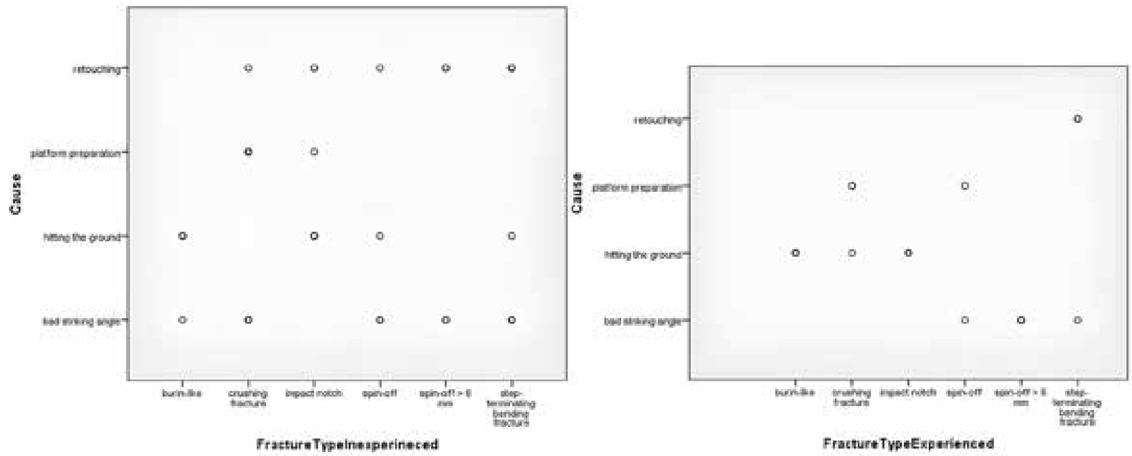

Figure 5. Comparison of the fracture type and fracture cause (done using IBM SPSS Software).

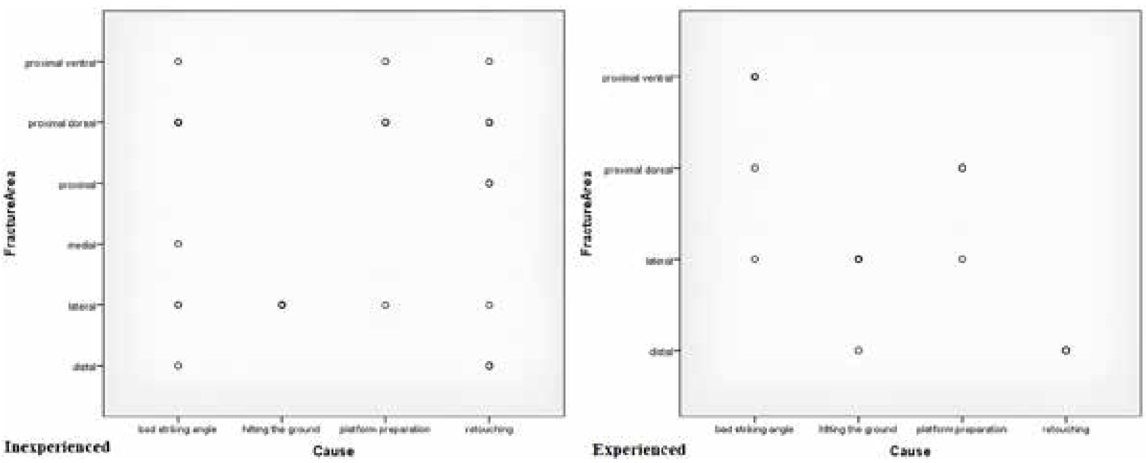

Figure 6. Comparison of the fracture cause and fracture area (done using IBM SPSS Software).

Fractures that resulted from a poor striking angle

The most prevalent fracture in the inexperienced knapper's assemblage was the step-terminating fracture, which was primarily caused by a bad striking angle (**Table 1**). In the experienced knapper's assemblage, crushing, burin-like fractures, and impact notches were not attributed to a bad striking angle. It is well established that the angle of the flake determines its size, rather than the striking force (Dibble and Rezek 2009: 1952). Due to the inexperienced knapper's limited ability to control the angle of each strike, there was significant variation in fracture types. On the other hand, the experienced knapper demonstrated much better control over the striking angle, resulting in the identification of only three fracture types: spin-off, spin-off larger than 6 mm, and step-terminating fractures.

Fracture causation due to accidental dropping or flakes hitting the ground

Fractures observed on the lateral and distal sides of the flakes were likely caused by impact with the ground, as no evidence of retouching, bad striking angle, or platform preparation was found. Both knapping assemblages exhibited the presence of burin-like fractures and impact notches, while spin-offs and step-terminating-bending fractures were only identified once in each assem-

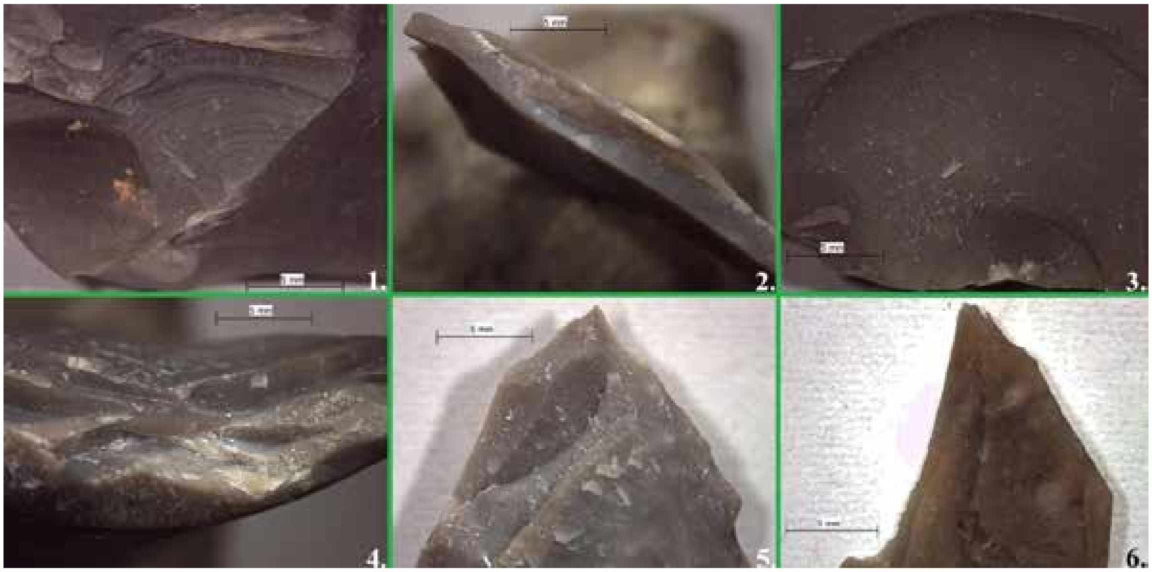

Figure 7. Damage identified in inexperienced knapper's assemblage: 1) Spin-off fracture > 6mm with step-termination caused by platform preparation; 2) Flake broken in half caused by a bad striking angle; 3) Spin-off fracture > 6 mm caused by platform preparation; 4) Crushing fracture caused by a bad striking angle; 5) Spin-off > 6 mm followed by step-terminating bending fracture caused by a bad striking angle while retouching; 6) Burin-like fracture caused by flake hitting the ground after being knapped (photo by the author).

Figure 8. Damage identified in experienced knapper's assemblage: 1) Crushing fracture caused by a bad striking angle; 2) Spin-off fracture caused by retouching; 3) Spin-off fracture > 6 mm caused by retouching (photo by the author).

blage. One instance of a crushing fracture was observed in the experienced knapper's assemblage. It is important to note that a direct comparison between these findings and the experiments conducted by Hutchings (2011) is not appropriate since Hutchings's experiment involved hafted stone tools used as spear-thrower darts, rather than being a dedicated knapping experiment. It should also be noted that the stone floor was not a common surface for the flakes to fall onto.

Retouching as a fracture cause

The application of retouching on the Mousterian points resulted in the occurrence of specific fractures. In the inexperienced knapper's assemblage, this retouching technique led to one crushing fracture, two step-terminating fractures, and one spin-off larger than 6 mm (**Figure 5**). Similarly, in the experienced knapper's assemblage, retouching caused the formation of one crushing fracture, one spin-off, and one spin-off larger than 6 mm (**Figure 5**).

DISCUSSION

In Pargeter's (2011: 2885) experiments, 4% of diagnostic impact fractures (DIFs) were identified in the knapped assemblage. In our experiment, we identified 2.07% DIFs in the inexperienced knapper's assemblage and 3.28% DIFs in the experienced knapper's assemblage. However, it should be noted that step-terminating fractures were not considered DIFs in these results (Iovita *et al.* 2014: 8). If step-terminating fractures were included, the percentage of DIFs would be 5.45% in the inexperienced knapper's assemblage and 4.69% in the experienced knapper's assemblage.

As expected, the inexperienced knapper required more time to produce five Mousterian points compared to the experienced knapper. Additionally, the inexperienced knapper produced more waste flakes, resulting in a higher number of macrofractures. The ratio of knapped flakes to macrofractures was not expected to be similar for both knappers. The percentage of all macrofractures produced by the inexperienced knapper was 10.9%, while it was 8.92% for the experienced knapper (**Table 1**). This result implies that the level of experience does not directly influence macrofracture formation during the knapping process.

In the inexperienced knapper's assemblage, DIFs were predominantly present on the proximal dorsal side of the flakes, and the cause was attributed to a bad striking angle. In contrast, fractures were mainly observed on the lateral side of the flakes in the experienced knapper's assemblage, caused by the flakes hitting the ground after being knapped. This difference can be explained by variations in striking force and angle control. The experienced knapper had better control over the striking force and angle, resulting in impact-like fractures occurring when the knapped flake hits the ground, rather than experiencing step-terminating or crushing fractures on the proximal dorsal side, as observed in the inexperienced knapper's assemblage due to poor striking angles.

The results of this experiment shed light on which fractures can be considered a result of weapon use and which should be interpreted cautiously. Step-terminating bending fractures were once regarded as "the simplest" DIFs, formed due to longitudinal pressure from the distal and proximal ends of the stone tools (Fisher, 1984; Lombard, 2005: 115). However, Iovita and colleagues (2014: 8) challenged this claim through their experiments, arguing that the use of step-terminating bending-initiated longitudinal fractures as a diagnostic of impact is not entirely justified. According to their findings, these fractures occur as a result of a load distributed over a larger surface rather than concentrated at one point.

Equifinality poses a significant challenge in understanding the propagation of impact fractures. The same fracture type can occur due to trampling, knapping, hafting, or hunting damage (Fernandez-Marchena and Oll, 2016; Jayez and Nasab 2016; Knutsson *et al.* 2015; Ollé and Vergès 2014; Paixao *et al.* 2021; Pargeter, Shea and Utting 2016; Stemp, Watson, Evans 2016; Wilkins *et al.* 2012). Step-terminating fractures were identified in 3.37% of the inexperienced knapper's flakes and 4.69% of the experienced knapper's flakes. Based on these results and previous experiments, step-terminating fractures should be completely disregarded as DIFs (Iovita *et al.* 2014: 8; Pargeter 2013: 8).

Spin-off fractures, particularly those larger than 6 mm, have been considered reliable DIFs (Fischer, Hansen and Rasmussen 1984; Lombard 2005; Pargeter 2013; Pargeter, Shea and Utting 2016; Sano 2009). In our research, spin-off fractures larger than 6 mm were identified in 1.03% of the inexperienced knapper's assemblage and 1.4% of the experienced knapper's assemblage. Although spin-off fractures are less frequent than step-terminating fractures, the area of the fracture can help differentiate the cause (**Figure 1**). Fractures that are not caused by hunting are more likely to occur on the proximal parts of the stone tool (Villa *et al.* 2010; Thulman and Fenerty 2023), but the issue of hafting damage on the proximal sides of the stone tools leading to spin-off fractures remains a challenge (Rots, 2010; 2011; 2013; 2014). Burin-like fractures were identified on four flakes in both knappers' assemblages, accounting for 1.87% in the experienced knapper's assemblage and 1.03% in the inexperienced knapper's assemblage. This fracture type has been observed in previous knapping experiments, but it appears to be a reliable DIF only when another fracture is present on the same stone tool (Pargeter 2011; 2013). The results suggest that the only highly reliable DIF is the bifacial spin-off fracture, which was also noted in Pargeter's experiment (Pargeter 2011), and it was not identified in either knapping assemblage (**Table 2**).

CONCLUSION

In recent years, there has been growing interest in macrofractures, particularly those resulting from impact. With each experiment, we make progress in understanding the propagation of impact fractures. However, fracture equifinality remains a significant challenge. Calculating the percentage of fracture types and their causation provides valuable information, but it is not sufficient to draw solid and definitive conclusions. To make progress in impact fracture analysis, we require a more extensive collection of experimental data. Step-terminating-bending fractures should be completely excluded from the DIF category as their formation could be the result of multiple causes, such as, hunting, trampling, knapping, etc (Iovita *et al.* 2014: 8; Pargeter 2011: 2885). Furthermore, since step-terminating fractures are present in large numbers in almost all experimental assemblages, rather than ignoring them entirely, we should focus more on understanding the propagation of this fracture type, which should be the aim of future experiments. Additionally, even spin-off fractures larger than 6 mm, which were previously considered one of the most reliable DIFs, should be interpreted with caution in the future. Currently, the only highly reliable DIF is the bifacial spin-off fracture, as it was not identified in either knapping assemblage.

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REZIME

TRAGANJE ZA MAKRO-PRELOMIMA UZROKOVANIM MODIFIKACIJOM KAMENIH ODBITAKA U MUSTERIJANSKE ŠILJKE

KLJUČNE REČI: KAMENO ORUĐE, UDARNA OŠTEĆENJA, DIJAGNOSTIČNA UDARNA OŠTEĆENJA, MUSTERIJENSKI ŠILJCI, MAKRO-PRELOMI.

Ovaj eksperiment je za cilj imao ispitivanje preloma tj. oštećenja nastalih prilikom udara i dijagnostičkih tragova preloma na kamenim alatkama kao posledice okresivanja musterijenskih šiljaka.

U eksperimentu su učestvovala dva okresivača kamenih alatki, različitog stepena veštine okresivanja, sa ciljem da naprave po pet musterijenskih šiljaka korišćenjem jezgara od rožnaca sličnih dimenzija. Svaki odbitak je detaljno analiziran nakon svakog odbijanja od jezgra radi detektovanja oštećenja na alatkama nastalih prilikom udara. Uzrok formiranja svakog oštećenja je dokumentovan. Takođe, detaljno su dokumentovani tipovi, veličina i mesto oštećenja radi što detaljnije interpretacije rezultata.

Rezultati su pokazali da je neiskusni okresivač proizveo veći procenat oštećenja. Najviše zastupljeno oštećenje u materijalu neiskusnog okresivača su bile stepenaste terminacije koje su bile primarno prouzrokovane lošim uglom udara platforme. Sa druge strane, iskusni okresivač je imao bolju kontrolu nad udarom platforme i time proizveo drugačije tipove oštećenja koji su dominirali u njegovom materijalu. Uglavnom je reč o dletolikim prelomima i nazubljenjima na lateralnim stranama odbitaka nastalih plikom odbijanja o tlo. Rezultati eksperimenta su takođe pokazali da se prilikom okresivanja kamenih alakti mogu formirati i neka od dijagnostičkih oštećenja (DIF).

U arheološkom materijalu prisustvo ovakvih preloma se može pogrešno interpretirati kao posledica korišćenja određenih kamenih alatki kao vrste oružja za lov. Takođe, ovaj eksperiment pokušava da odgovori na pitanje da li je prisutna razlika u oštećenjima nastalim prilikom udara, upoređivanjem alatki koje su napravili iskusni i neiskusni okresivači kamenih alatki u laboratoriji. Pokušano je uspostavljanje korelacije između svih varijabli koje mogu uticati na formiranje oštećenja nastalih kao posledica udara. Sveobuhvatno, ovaj eksperiment predstavlja jedan korak napred ka shvatanju formacije oštećenja nastalih prilikom udara tokom okresivanja musterijenskih šiljaka i ukazuje na važnost opširnije analize i interpretacije litičkog materijala.

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