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Shoulder and Knee Arthroscopy Access Point: Prospective Comparison of Sonographic and Palpatory Detection – Which Method is Better for Novices?

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ABSTRACT

Purpose Arthroscopy is one of the most common interventions in orthopedics. Hence it is important to train users early in order to ensure the safest possible identification of access portals (AP). This prospective study aimed to compare a palpatory (PalpMethod) with a sonographic (SonoMethod) method for AP location in the shoulder and knee joints.

Materials and Methods The study included trainee doctors (n = 68) attending workshops (lasting approx. 90 minutes). In these workshops a teaching video initially demonstrated the PalpMethod and SonoMethod of AP identification. An experienced operator first marked the access portals on the test subject with a UV pen (determined ideal point [DIP]). Adhesive film was then affixed to the puncture regions. Subsequently participants marked on shoulders and knees first the point determined by palpation, then the point determined by sonography. Analysis involved DIP visualization with a UV lamp and employed a coordinate system around the central DIP. In addition, participants completed an evaluation before and after the workshop.

Results The analysis included 324 measurements (n = 163 shoulders and n = 161 knees). The majority of participants had not previously attended any courses on manual examination (87.9 %) or musculoskeletal ultrasound (93.9 %). Overall, the markings participants made on the shoulder using the SonoMethod were significantly closer to the DIP than those

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made by the PalpMethod (Palp 18.8mm ± 14.5mm vs. Sono 11.2mm ± 7.2mm; $p < 0.001$). On the knee, however, the markings made by the PalpMethod were significantly closer to the DIP overall (Palp 8.0mm ± 3.2mm vs. Sono 12.8mm ± 5.2mm; $p < 0.001$).

Conclusion The results show that the SonoMethod produces more accurate markings on the shoulder, while the PalpMethod is superior for the knee.

Background

Importance of shoulder and knee arthroscopy and current training concepts

The development of arthroscopy was a key milestone in the field of joint surgery [1]. Arthroscopy is one of the most common minimally invasive interventions [2]. In addition, joint punctures/injections account for a large proportion of the diagnostic and therapeutic procedures carried out in orthopedic/trauma surgery, rheumatology, and radiology. Therefore, it is of utmost importance to train users early in order to ensure they perform interventions with as few complications as possible. At present, clinical education of arthroscopic surgeons mainly takes place as part of specialist training and through participation in certified courses or clinical attachments [3]. Training is supported by the use of (online) simulators, models, and cadaveric specimens as well as analog and digital teaching materials [3].

Advantages and disadvantages and avoiding complications of shoulder and knee arthroscopy

Shoulder and knee arthroscopy has the advantage of being a tissue-conserving method compared to open surgical techniques. Nevertheless, the possible complications of the procedure should not be disregarded [4, 5]. These include nerve and vessel damage caused by incorrect placement of arthroscopy instruments or multiple punctures and injuries to internal joint structures [5, 6]. These complications are caused partly by insufficient preoperative diagnostics [5, 6], a lack of palpation knowledge to detect the soft spots/access windows/portals for correct placement of trocars/puncture needles [7–9] and a general lack of surgeons' experience. To avoid some of these complications, ultrasound is also used as a supportive diagnostic tool [7, 8, 10–13], including for puncture procedures [14–16] and for arthroscopic interventions [10–13].

Research problem and question

The access windows/portals for introducing trocars/puncture needles continue to be determined mainly by palpation. This study, therefore, aimed to compare the palpation method with an ultrasound technique for optimally locating access windows/portals for shoulder and knee arthroscopy in a group of inexperienced trainee doctors (medical students) who underwent a video training course. The principal question of the study is whether these methods can be learned through video training ("suitability") and which method delivers markings that are as close as possible to access points previously determined by experts. Secondary questions focus on the acceptance of video-assisted training and on the attitude/motivation with which possible (ultrasound) educational concepts are received in the specialty of orthopedics and trauma surgery.

Materials and Methods

Study design, participant recruitment, study sequence

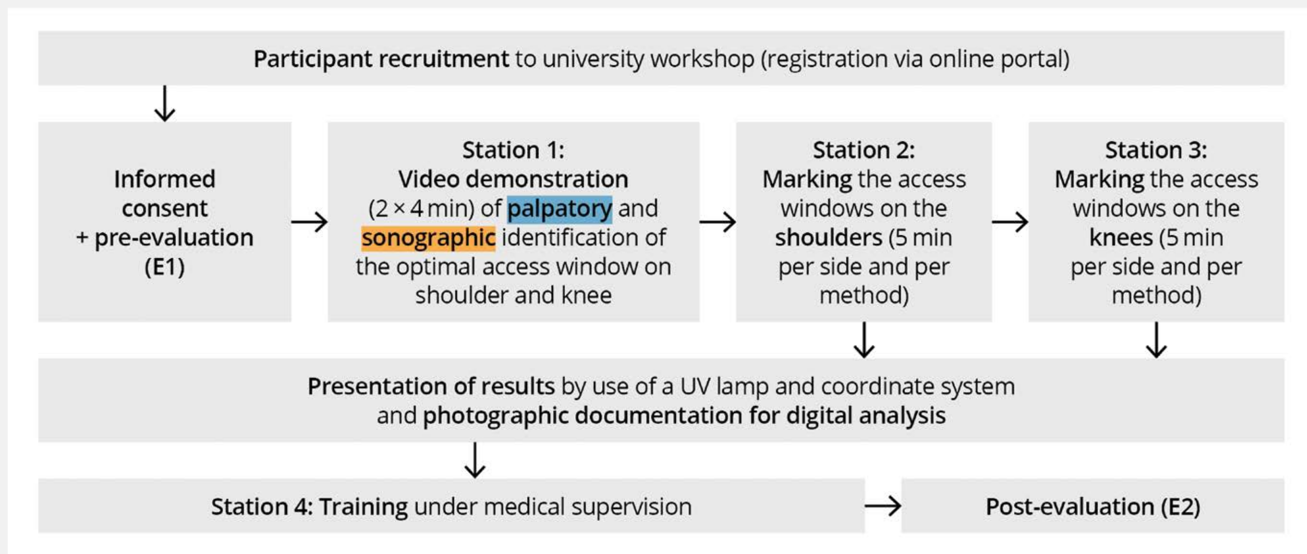
This clinical trial was developed prospectively (see ▶ **Fig. 1**). As part of a voluntary workshop (lasting approx. 90 minutes), medical students starting from the third year in 2022 were included. Participants registered for the workshop via an online portal. The workshop was structured as a cycle of stations (stations 1–4). Successful completion of the first state exam (early stage of medical school) was defined as an inclusion criterion.

After providing consent to participate in the study, participants completed a digital evaluation form (E1) at station 1; subsequently they watched a total of two teaching videos, each lasting approximately four minutes, describing the palpatory and sonographic marking of soft spots/access points for knee and shoulder arthroscopy – each video was watched twice (see ▶ **Fig. 2**). Certified ultrasound experts and experienced shoulder and knee surgeons demonstrated the method in the videos according to the current literature [4, 17–21].

A certified shoulder surgeon and sonographer had previously determined the reference points on the test subjects (determined ideal points = DIP). The relevant site was marked with a UV pen and covered with transparent adhesive film (see **Suppl. 1**). The reference points were determined by ultrasound, and then the follow-up check was done by palpation according to the methods depicted in ▶ **Fig. 2**. In addition, the reference points were approved by a second expert. Specialists and residents in orthopedics and trauma surgery as well as final year medical students supervised the marking process.

Participants then had the task of locating this joint space (shoulder: dorsal portal; knee: high anterolateral access) on healthy subjects (similar body mass index, no anatomical peculiarities or extremes) firstly by palpation (PalpMethod), then by ultrasound (SonoMethod) as shown in the video training. They had 5 minutes per region and per method in which to do this. They first marked the points on the subjects' shoulders at station 2, then on the knees at station 3. While this study was conducted, participants did not receive feedback on how accurately they had placed the points.

After this section of the study, the participants practiced sonographic and palpatory examination of the knee and shoulder under medical supervision (station 4; approx. 60 min.) and completed the post-course evaluation (E2).



▶ **Fig. 1** Illustration of the study sequence within the workshop. It consisted of 4 stations that were completed chronologically. An evaluation (E1, E2) was completed before and after the workshop.

Study material

To conduct the study, we used transparent adhesive film/wound dressing, paper clips, water-soluble markers, ultraviolet lamps + markers and grid film, and we carried out photographic documentation. The SonoMethod involved using a linear transducer with a variable ultrasound frequency of 7–15 MHz in each case on equivalent GE F8 machines (General Electric Health Care Company, Chicago, IL, USA).

Measuring method and evaluation

Participants had to locate the access points/portals according to the techniques demonstrated in the video. These were based on current recommendations [4, 17–19, 21] and DEGUM guidelines [20] and were additionally derived from the technique of Konermann et al. [22] and Cicak et al. [21]. Participants marked the points determined by palpation (PDP) and points determined by sonography (PDS) on the film using a UV marker pen. They first applied the PalpMethod then the SonoMethod in order to minimize bias from potential learning effects [23].

We used a coordinate system (x and y axis in mm) to collect the results and document the deviations between markings made by participants (PDP and PDS) and the DIP. Visualization with a UV lamp was photographically documented. Photographic documentation, which the participants did not watch, took place between individual markings.

Subsequently, all documented measurements underwent digital analysis. Considering the participants' markings, we plotted the diagonals and distances along the x and y axes, starting from the coordinate origin (DIP) (in mm). In addition, we formed and numbered four quadrants: the craniolateral quadrant was numbered 1, caudolateral 2, caudomedial 3, and the craniomedial quadrant was 4.

Evaluations

Participants completed two digital questionnaires (E1 and E2). Questions covered the following subjects with the aid of several sub-items: "baseline", "motivation", "use of digital teaching media", "previous experience", "competency assessment", "teaching video evaluation", and "future prospects", mainly using a seven-point Likert scale (1 = fully agree; 7 = do not agree at all) as well as dichotomous questions ("yes"/"no").

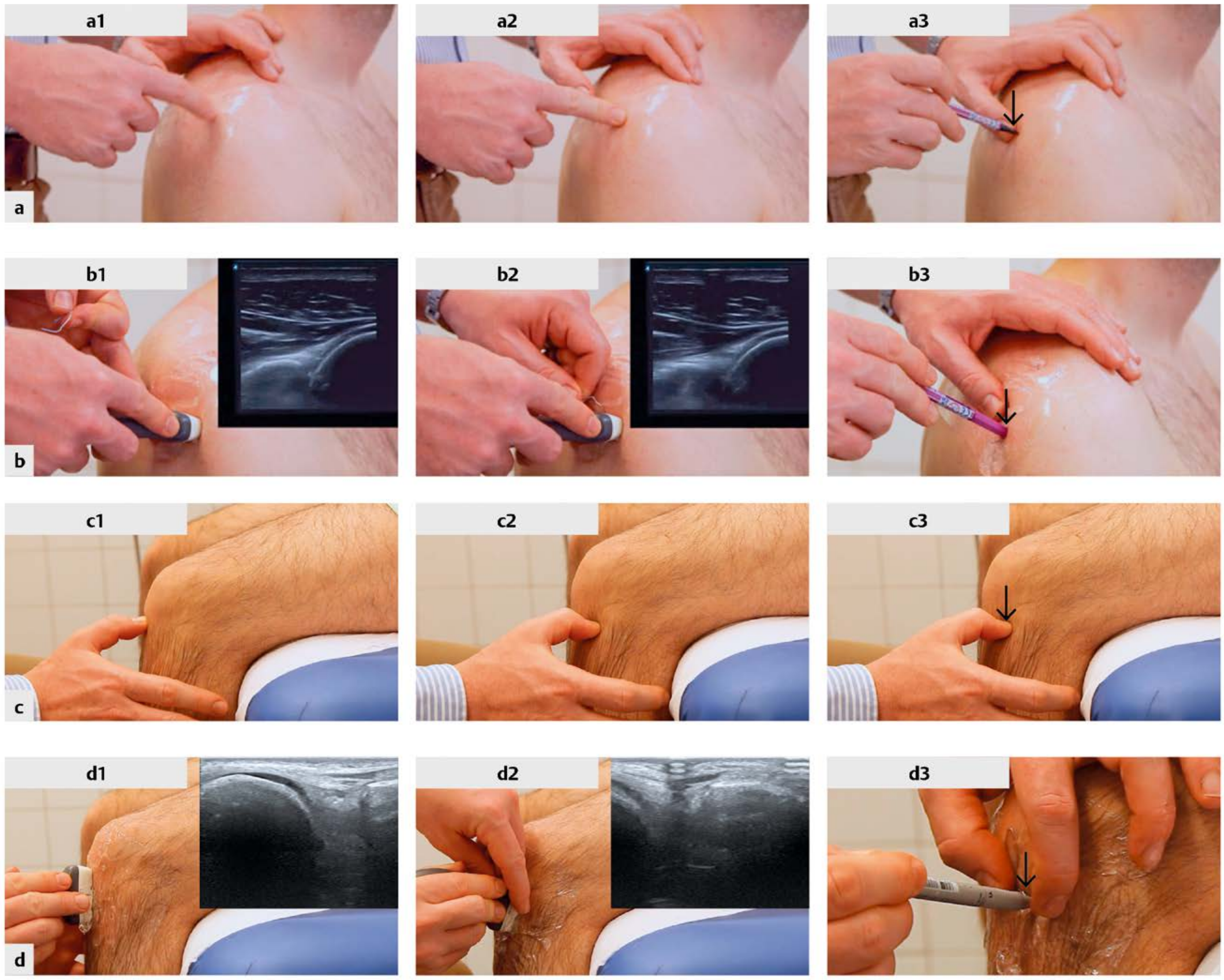
Statistical method

We conducted all statistical analyses and produced all graphics using R studio (RStudio Team. RStudio: Integrated Development for R. 2020.) with R 4.0.3 (R Foundation for Statistical Computing. A Language and Environment for Statistical Computing.). Binary and categorical baseline parameters are expressed as absolute numbers and percentages. Continuous data are expressed as median and interquartile range (IQR) or as mean and standard deviation (SD). The mean values of the diagonal of the PalpMethod and the SonoMethod were compared. We tested data distribution using the Shapiro–Wilk test. As the variables were not normally distributed, we compared the continuous error measures with the Mann–Whitney test given a variety of binary groups (left side/right side; SonoMethod/PalpMethod; shoulder/knee). Additionally, we applied chi square distribution tests in the direction of deviation in which the errors occurred. P-values < 0.05 were considered statistically significant.

Results

Group characterization and results of evaluations

The analysis included 66 out of a total of 68 registered participants; 2 participants failed to appear for the workshop (baseline charac-



▶ **Fig. 2** PalpMethod (a+ c) and SonoMethod (b+d) for determining the optimal access points to the joint spaces (methodology created according to (9, 31-38). a) Shoulder palpation technique (PalpMethod Shoulder): The posterior lateral corner of the acromion, which is located on the right shoulder, is identified. Approximately 2 cm caudally and 1 cm medially from this point, the "Soft Spot"= muscle gap between the infraspinatus muscle and the teres minor muscle, is palpated and highlighted with a water-soluble marker pen. b) Shoulder ultrasound technique (SonoMethod Shoulder): A transverse view of the shoulder is obtained. The key landmarks on the ultrasound image are being explained. The paper clip is bent, adapted to the transducer and pushed under it. The acoustic shadow of the paper clip is positioned above the joint. The transducer is removed and the position of the puncture in the middle of the paper clip is highlighted. c) Knee palpation technique (PalpMethod Knee): The apex of the patella of the left knee is palpated. Approximately 1 cm caudally and laterally from this point, the "Soft Spot"= high anterior lateral access point is palpated and highlighted with a water-soluble marker pen. d) Knee ultrasound technique (SonoMethod Knee): The doctor obtains an infrapatellar longitudinal view on the patellar tendon. The transducer is moved slightly laterally towards the femoral condyle, until the tibia is also demonstrated. The key landmarks on the ultrasound image are being explained. The paper clip is bent, adapted to the transducer, and pushed under it. The acoustic shadow of the paper clip is positioned above the joint. The transducer is removed and the position of the puncture in the middle of the paper clip is highlighted.

teristics see **Suppl. 2**). The study group (mean age: 24.5 ± 3.9 years) was predominantly female (63.6 %), and most of the participants (85.7 %) were in the 5th to 7th semester of medical school. According to information provided by the participants, the majority had no previous experience in orthopedics and trauma surgery (77.3 %), had not seen any arthroscopies (65.2 %), and had not yet attended any courses on manual physical examination (87.9 %) or musculoskeletal ultrasound (94.0 %).

When questioned about their "attitude to digital teaching media", most participants stated that they used digital teaching media in medical school (96.9 %) and had already had contact with digital ultrasound digital teaching media (71.2 %). A total of 68 % rated the combination of textbook and e-learning as highly motivating in terms of preparing for a training course.

At the start of the workshop the participants' subjective assessment of their own skills was very poor (see **Suppl. 2**) in manual examination (shoulder 5.6 ± 1.7 vs. knee 5.2 ± 1.8) and ultrasound examination (shoulder 6.1 ± 1.3 vs. knee 6.2 ± 1.3). They gave a slightly better assessment of their general ultrasound knowledge (4.33 ± 1.63). In both joint regions their self-assessment of specific ultrasound knowledge was significantly lower than for manual examination skills (shoulder $p = 0.035$; knee $p = 0.003$).

After the workshop, these numbers flipped, and participants felt more comfortable performing ultrasound marking of shoulder access points than they did performing palpatory marking (SonoMethod 3.1 ± 1.3 vs. PalpMethod 4.1 ± 1.3; p = 0.003). In the case of the knee, they rated their comfort level with regard to marking by palpation better than they did for ultrasound marking (SonoMethod 4.4 ± 1.5 vs. PalpMethod 2.6 ± 1.4; p < 0.001).

Furthermore, participants advocated the integration of an in-depth musculoskeletal ultrasound course into the curriculum (1.7 ± 0.8) and rated the teaching videos positively (2.9 ± 1.1).

Shoulder and knee markings

▶ **Fig. 3** presents the number of markings recorded and analyzed. Participants examined a total of 163 shoulders (PalpMethod 82 and SonoMethod 81) and 161 knees (PalpMethod 81 and SonoMethod 80). The distribution between the right and left side was almost equal.

Quadrant distribution

▶ **Fig. 4** and **Supplementary Figures 3–7** combine the results or deviations of the palpatory and sonographic markings performed within the defined quadrants 1–4.

The multiplot graph (see ▶ **Fig. 4**) very clearly shows the trending directions of the deviations. The PalpMethod for the shoulder and the SonoMethod for the knee have the largest outliers. For the shoulder, the points marked using the PalpMethod and SonoMethod mainly deviate in the craniomedial direction (quadrant 4: 61.3 % PalpMethod and 48.8 % SonoMethod) and only very rarely in the caudolateral direction (quadrant 2: 5.0 % PalpMethod and 7.5 % SonoMethod). For the knee, most points were placed in the craniolateral direction (quadrant 1: 34.1 % PalpMethod and 50.0 % SonoMethod) and the craniomedial direction (quadrant 4: 25.60 % PalpMethod). The fewest points were marked in the caudolateral (quadrant 2: 18.3 % PalpMethod) and craniomedial (quadrant 4: 2.4 % SonoMethod) directions.

Distances from the determined ideal point (DIP)

▶ **Table 1** shows the results of the mean distances (in mm) recorded in the study between the DIP and the points determined by palpation (PDP) and the points determined by sonography (PDS) on shoulder and knee.

Overall, participants placed shoulder markings significantly closer to the DIP with the SonoMethod than with the PalpMethod (Palp 18.9 ± 14.5mm vs. Sono 11.2 ± 7.2mm; p < 0.001). This applied for both sides: right (Palp 19.2 ± 14.3mm vs. Sono 12.3 ± 6.8mm; p = 0.007) and left (Palp 18.5 ± 13.9mm vs. Sono 10.1 ± 6.7mm; p = 0.001).

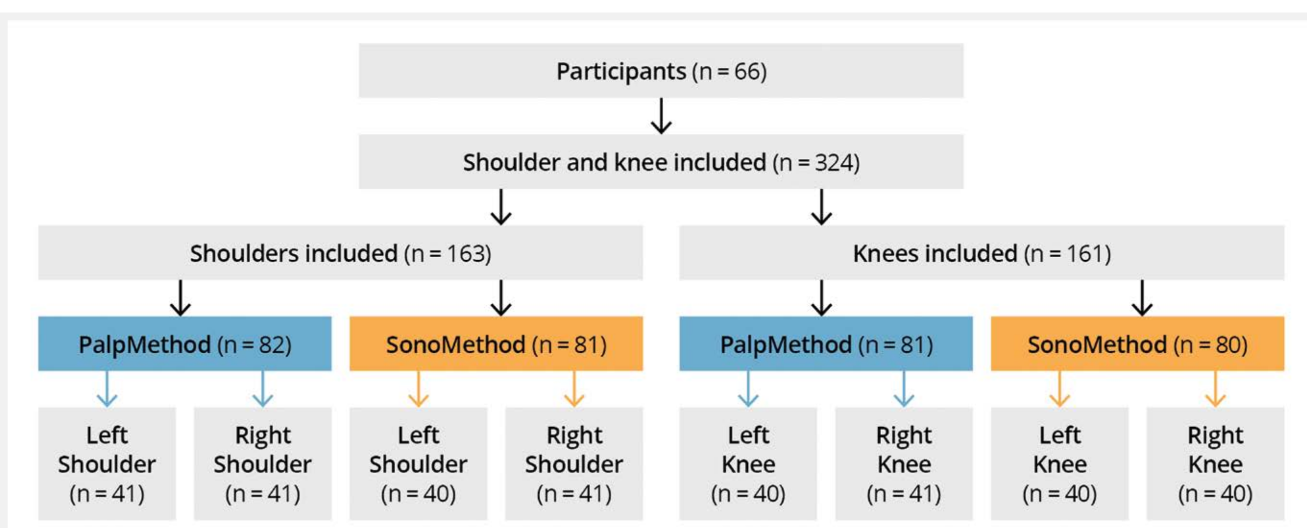
On the knee, however, the markings by the PalpMethod were significantly closer to the DIP overall (Palp 8.0mm ± 3.2mm vs. Sono 12.8mm ± 5.2mm; p < 0.001). This applied for both sides: right (Palp 7.8 ± 3.5mm vs. Sono 12.3 ± 4.2mm; 0.001) and left (Palp 8.24 ± 4.27mm vs. Sono 13.34 ± 6.74; p < 0.001).

Analysis of the quadrants (see ▶ **Fig. 4**) shows that the largest deviations from the DIP on the shoulder were for the PalpMethod in quadrant 4 (22.4 ± 16.2mm) and for the SonoMethod in quadrant 3 (13.0 ± 6.9mm). For the knee the highest mean deviations from the recorded DIP were also for the PalpMethod in quadrant 4 (9.0 ± 3.0mm) and the SonoMethod in quadrant 1 (14.3 ± 5.7mm).

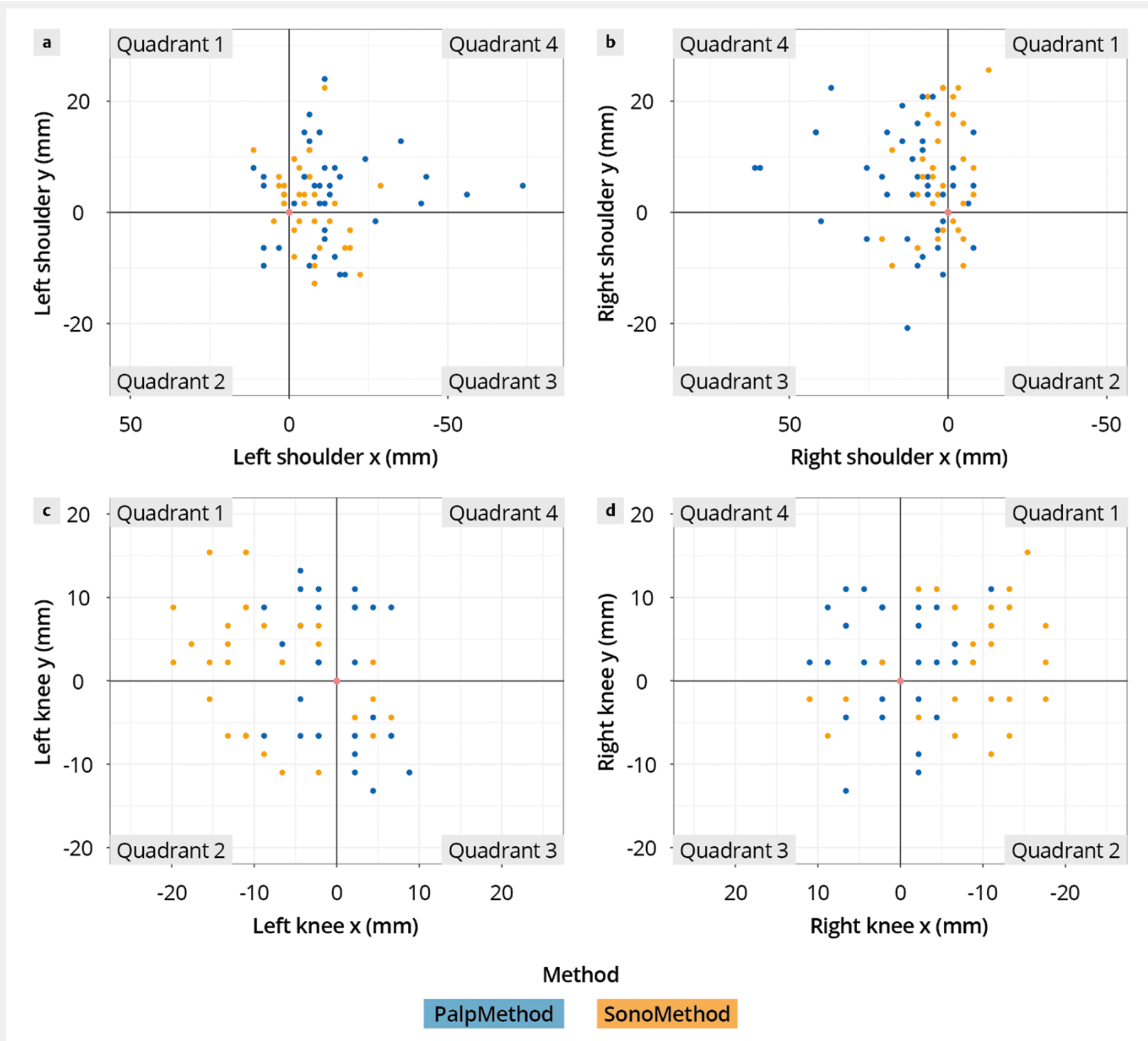
With regard to possible differences between the left and right side, we found no significant differences for the PalpMethod and the SonoMethod (see **Suppl. 8**).

Discussion

The results of this prospective study show that training videos enable inexperienced users to locate previously determined arthroscopy access points properly by palpation and ultrasound. The SonoMethod produced significantly more accurate markings on the shoulder. On the knee, however, more accurate markings were placed with the PalpMethod. The subjective assessments of competency and participants' comfort level acquired as a result of the



▶ **Fig. 3** Distribution of included measurements.



▶ **Fig. 4** Deviation of the markings from the ideal points. Multiplot presentation of the performed palpatory (blue) and sonographic (orange) markings. The following body regions are shown: left (a) and right (b) shoulder as well as right (c) and left (d) knee; Quadrant 1 = craniolateral; quadrant 2 = caudolateral, quadrant 3 = caudomedial, quadrant 4 = craniomedial; the direction of view to the shoulders is from dorsal and the direction of view to the knees is from ventral.

training also reflect this trend. Furthermore, participants advocated the integration of an in-depth musculoskeletal ultrasound course into the curriculum, making use of the possibilities of digitalization.

Learnability

The use of ultrasound or palpation to detect anatomical landmarks has already been addressed in various studies [7, 8, 14, 15, 23–25]. Our study aims to complement existing research by assessing the learnability of these methods among inexperienced users. Our data show that participants were able to learn the PalpMethod and SonoMethod and apply them to the shoulder and knee after just a short video training course. The affinity of the young group of users for digital educational media ("digital natives") might have had a positive influence. The techniques of palpation as well as ultrasound are firmly embedded in medical studies as teaching content. Therefore, the kind of training described here might also have great potential for skills acquisition in other specialties.

Accuracy

A variety of studies have described the use of ultrasound to increase the accuracy of points identified by palpation [7, 8, 24]. However, no direct comparisons of the methods with regard to accuracy have been made. In our study, participants rated the musculoskeletal-specific baseline level of their skills similarly for both examination methods. As a result of the video training, the ultrasound

▶ **Table 1** Results of the measured distances to the determined ideal point including t-test calculations of the PalpMethod (Palp) vs. SonoMethod (Sono) at the shoulder as well as the knee.

Shoulder									
Variable	**Method**	**N**	**Mean (mm)**	**SD (mm)**	**Difference (mm)**	**p-value**	**t-value**	**95 % confidence interval Lower Upper**	
Distance Diagonal (mm)	Palp both sides	82	18.85	14.51	7.62	< 0.001	5.31	5.58	12.2
	Sono both sides	81	11.23	7.24					
Distance Diagonal (mm)	Palp left shoulder	41	18.46	13.92	8.36	0.001	3.46	3.51	13.2
	Sono left shoulder	40	10.10	6.71					
Distance Diagonal (mm)	Palp right shoulder	41	19.23	14.34	6.9	0.007	2.78	1.93	11.86
	Sono right shoulder	41	12.33	6.83					
Knee									
Variable	**Method**	**N**	**Mean (mm)**	**SD (mm)**	**Difference (mm)**	**p-value**	**t-value**	**95 % confidence interval Lower Upper**	
Distance Diagonal (mm)	Palp both sides	81	8.04	3.21	4.77	< 0.001	7.07	3.26	5.79
	Sono both sides	80	12.81	5.24					
Distance Diagonal (mm)	Palp left knee	40	8.24	3.38	5.1	< 0.001	4.27	2.71	7.49
	Sono left knee	40	13.34	6.74					
Distance Diagonal (mm)	Palp right knee	41	7.84	3.49	4.44	< 0.001	5.17	2.73	6.15
	Sono right knee	40	12.28	4.20					

method delivered more accurate markings on the shoulder. On the knee, however, more accurate markings were placed using the palpatory method. This coincides with the results of previous studies [8, 23] in which participants were able to mark landmarks by palpation better on the knee than on the shoulder.

More frequent craniomedial deviation at the shoulder (with both methods) might be explained by possible orientation towards the scapular spine. In the case of the knee, by contrast, orientation towards the external tibial plateau might be responsible for the higher frequency of craniolateral placement of access points. The fact that ultrasound can visualize soft tissues (muscles/tendons) and deeper-lying structures effectively might have facilitated better sonographic orientation to the shoulder compared with palpation. In the case of the knee, however, the more superficial anatomical landmarks and the distinct soft spot might explain the more accurate results achieved by palpation.

Topographical conditions/anatomical structures at the joint space can be altered/shifted slightly by changes of position (e. g., the lateral decubitus position or the beach-chair position or one knee raised) [9]. This is why follow-up studies should evaluate the accuracy of the SonoMethod and PalpMethod under operating conditions (positioning and relaxation by anesthesia).

Added value and risks (clinical benefit)

Ultrasound compared with/in addition to palpation can improve the detection of pathologies and achieve a higher level of safety in the interventional setting [15, 16]. Advantages with regard to avoiding complications of arthroscopic interventions to the shoulder, hip, and knee joints have also been demonstrated [10–13]. Based on and complementing these findings, in our study using video-based training, we demonstrated added value, i. e., more accurate marking by the ultrasound-supported method applied to the shoulder.

Structures most at risk during shoulder arthroscopy are the suprascapular artery and nerve (SSA and SSN), the cephalic vein, and the axillary nerve [4]. According to Meyer at al., the mean distance from the posterior soft spot portal is about 29mm to the SSN and about 30–49mm to the axillary nerve [26]. Medial placement of the soft spot portal can harm the SSN, while lateral placement can injure the axillary nerve. In our study, most of the markings were placed/ deviated in a craniomedial direction (in quadrant 4) irrespective of the method used. The palpatory method produced considerably more outliers > 29mm, which means this method carries a greater risk of injury to the SSN. As there were far fewer laterocaudal markings (quadrant 2) irrespective of the method, injury to the axillary nerve seems less likely overall.

The anterolateral portal structures most at risk during knee arthroscopy include the medial patellar tendon, cranial femoral condyles, and caudal meniscal anterior horns. The harm of cartilage damage should also be noted [5]. With regard to absolute deviation from the determined ideal point, in the context of our study, ultrasound offers no advantage over purely palpatory marking of access points on the knee. However, when we consider the direction of deviation (quadrants), the sensitive structures in quadrants 3 + 4 (patellar tendon, menisci) are less at risk when ultrasound is used because the deviation is predominantly craniolateral (quadrant 1) towards the femur.

Since safety should be the primary aim, the SonoMethod needs to be used more intensively for the shoulder in the future.

(Time) expenditure

Every participant managed to perform the task within the given time of 5 minutes. This additional time window could easily be incorporated into the clinical setting [11]. It should be noted that the SonoMethod requires appropriate technical equipment and allowance needs to be made for slightly longer preparation time. Follow-up studies should more closely examine the time aspect of implementation and also consider the influence on more comprehensive training.

Integration into everyday clinical practice and transferability

Physical examination is an integral part of clinical diagnostics [17, 18] and has hitherto been the standard method for locating access portals in shoulder and knee arthroscopies. In many outpatient departments and operating theaters, ultrasound is also used on a daily basis as a diagnostic tool and in order to support interventions and operations [13, 27, 28]. There have been technological advances, and the availability of portable ultrasound units is on the rise. Ultrasound diagnostics is thus gaining relevance as a physician's "right-hand man" [29]. On those grounds and considering past studies, integration of the SonoMethod used by us into clinical settings seems to be a real possibility [10–13]. It could be implemented not only preoperatively (in consulting rooms, at the bedside, or in the anesthesia room) but also intraoperatively on the operating table. Staff operating the equipment and support teams will need to be trained in order to optimize processes. The use of sonography for identification/better localization of other (uncertain) arthroscopy portals in other joint areas might be equally helpful for avoiding complications [4, 5].

Training prospects

Based on the results of this study, arthroscopy training curricula should increasingly include ultrasonography in the future [30]. The acceptance and successful use of video training should also give rise to greater use of digital teaching methods during the course of training [31].

Coordination between the various arthroscopy and ultrasound professional associations would be desirable [30]. It is of utmost importance to develop uniform training concepts, which incorporate the content of national and international learning objective catalogs [32]. Skill levels could be checked by the use of direct observation of procedural skills (DOPS) tests [33]. Consolidating the skills gained during clinical traineeships might, as a result of early exposure, also have a positive effect on students' eventual choice of specialty, thereby preventing existing or imminent staff shortages in the field of surgery [34].

Limitations

The fact that measuring points were not always placed on exactly the same test subject is a limitation. As a result, potential minor anatomical differences might have made it simpler or more difficult to depict the "orientation points"/"soft spots". A more systematic bias might have arisen from the study sequence because participants always performed the PalpMethod first, then the SonoMethod and on the shoulder first, then the knee. In the SonoMethod, the paper clip was pushed under the transducer and then, after removal of the transducer, had to be kept in place until marking was carried out. This might have resulted in small deviations due to the paper clip slipping, which might have led to slight deviations in the measured values. The "palpation instrument" in the PalpMethod was the participants' fingers. Minor deviations/inaccuracies might also have arisen here because of the different sizes of participants' finger surfaces (approx. 0.5–1cm^2) and the subsequent thickness of the marker pen (approx. 0.1 cm). In both settings, however, the deviation does not seem relevant as a potential source of error.

Conclusion

Trainee doctors (medical students) are able to apply a video-based palpation and ultrasound training course efficiently and to properly implement the methods demonstrated. Ultrasound allows significantly more accurate markings of the dorsal soft spot to be made on the shoulder than palpation. Thus, arthroscopy training curricula should increasingly include ultrasonography in the future. On the whole, palpation of the knee is more accurate because of the superficial location of the anatomical landmarks. Follow-up studies should investigate long-term learning success and evaluate other user groups with more extensive training.

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Conflict of Intrest

The authors declare that they have no conflict of interest.

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