

# MOSaiC Annotation Software Tutorial

Annotation of a training video

- Connect to the MOSaiC software using the following link:

<https://ext.mosaic.>

-> you will then arrive on this page:

MOSaiC

Help Login Signup

TX : 100%  
WT : 0.8  
TZ : -0.4  
THE - P  
G : 11  
C : 3

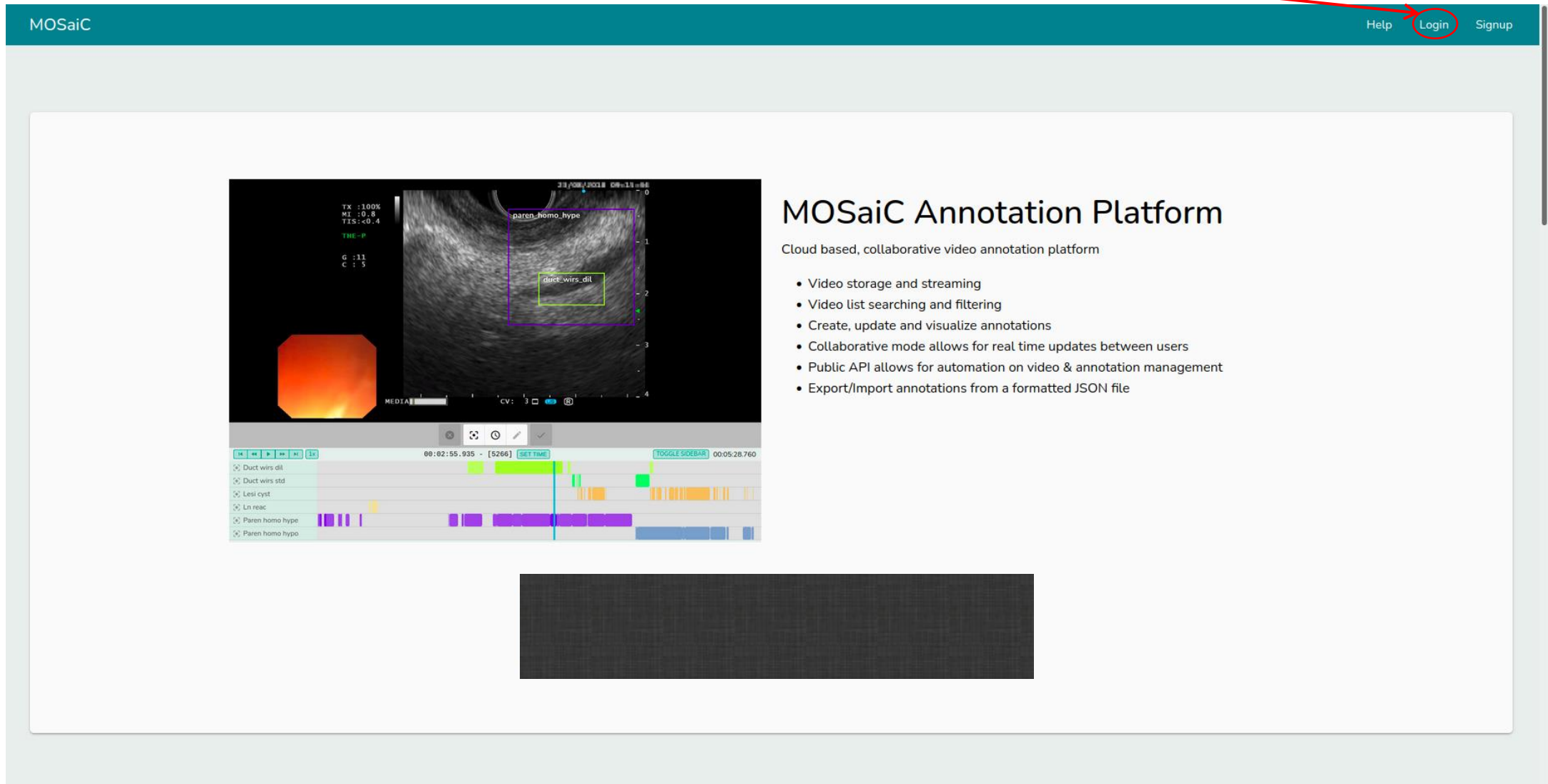
paren\_homo\_hype  
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### MOSaiC Annotation Platform

Cloud based, collaborative video annotation platform

- Video storage and streaming
- Video list searching and filtering
- Create, update and visualize annotations
- Collaborative mode allows for real time updates between users
- Public API allows for automation on video & annotation management
- Export/Import annotations from a formatted JSON file

- Click on « Login ».



MOSaiC

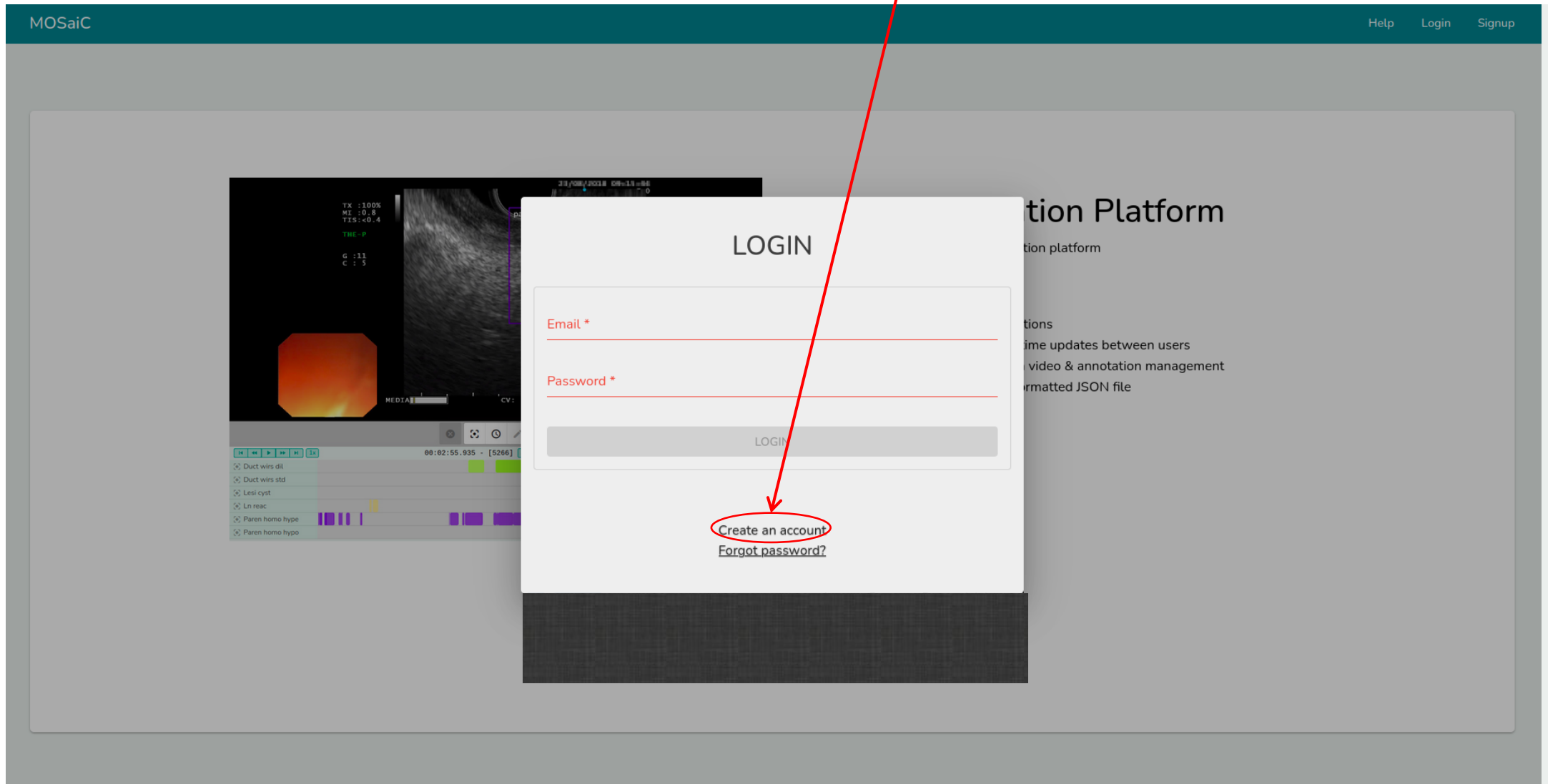
Help **Login** Signup

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- For a first connection, click on « Create an account ».



- Fill in the information « Full name », « Email », « Password », and « Repeat password », and then click on « SIGNUP ».

The screenshot shows the MOSaiC application interface. At the top, there is a dark teal header with the text 'MOSaiC' on the left and 'Help', 'Login', and 'Signup' on the right. The main content area is a light gray background. On the left, there is a video player showing a medical scan with various data points: 'TX :100%', 'MI :0,8', 'TTS:-0,4', 'TH: P', 'G :11', and 'C : 5'. Below the video player is a list of items with checkboxes: 'Duct wirs dil', 'Duct wirs std', 'Lesi cyst', 'Ln reac', 'Paren homo hype', and 'Paren homo hypo'. A 'SIGNUP' modal form is centered over the video player. The form has a title 'SIGNUP' and four input fields: 'Full name \*', 'Email \*', 'Password', and 'Repeat password \*'. The 'Password' field has a list of requirements: 'At least 8 characters', 'Uppercase letter', 'Special character', 'Number', and 'Lowercase letter'. Each requirement is preceded by a red 'X' icon. At the bottom of the form is a 'SIGNUP' button, which is circled in red. A red arrow points from the 'SIGNUP' button in the modal to the 'SIGNUP' text in the top right header. Below the form, there are links for 'Login with an existing account' and 'Forgot password?'.

- You must then wait for an administrator of the platform to validate your account; as soon as this has been done, an email will be sent to inform you.
- Once your account is validated, please send me an email so that I can add you to the working folder on the software.
- Now that your account is validated, you can return to the home page of the woftware (<https://ext.mosaic.██████████>).

- Click on « Login ».

MOSaiC

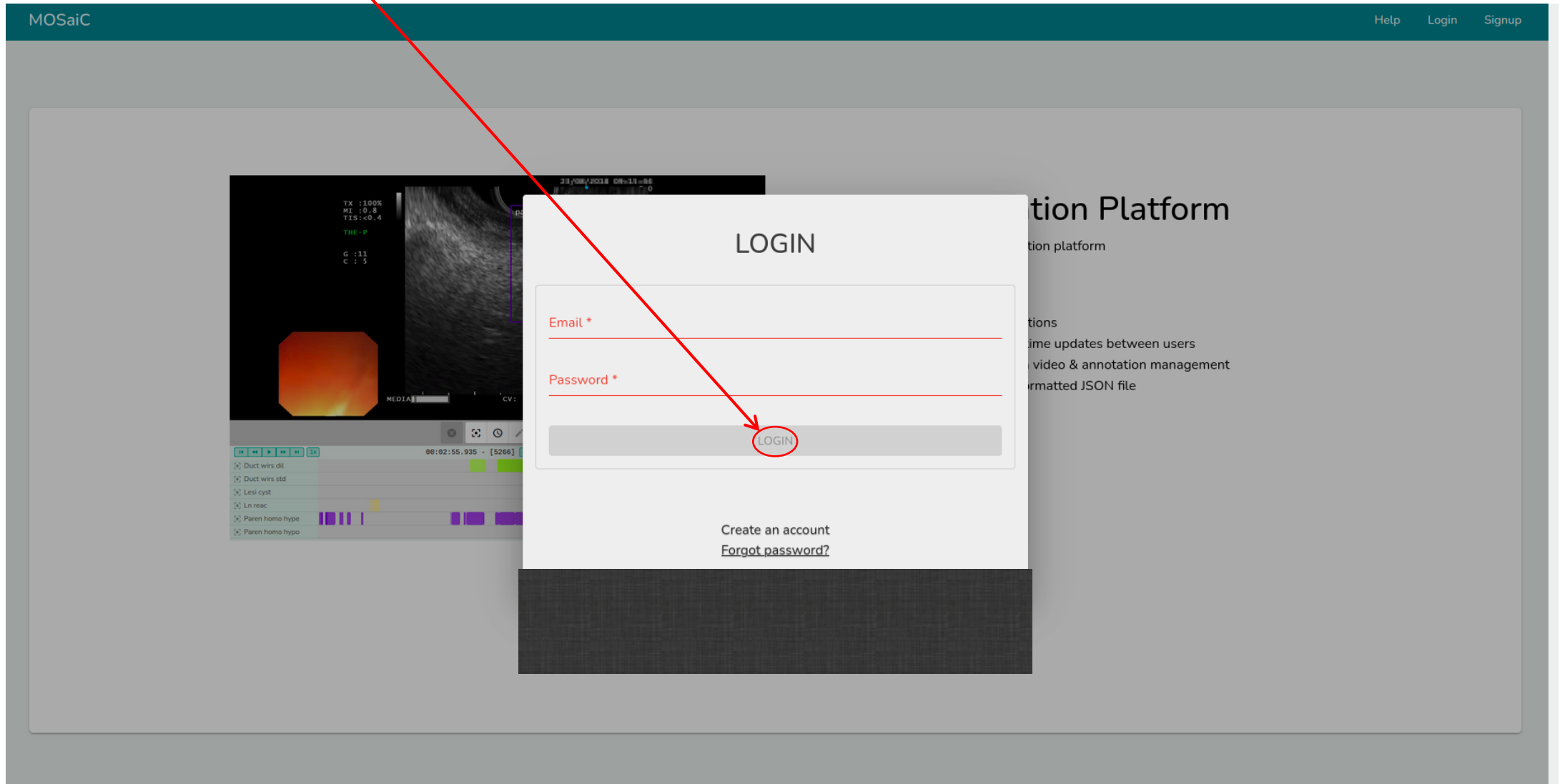
Help Login Signup

## MOSaiC Annotation Platform

Cloud based, collaborative video annotation platform

- Video storage and streaming
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- Collaborative mode allows for real time updates between users
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- Export/Import annotations from a formatted JSON file

- Enter you login information (« Email » and « Password »), and then click on « LOGIN».





- You will then arrive on the general page of the software (this may be slightly different from the image below as you will not have the same working folders).
- Click on the folder entitled « Entraînement à l'annotation ».

The screenshot displays the MOSaiC software interface. At the top, there is a navigation bar with 'MOSaiC', 'VIDEO GROUPS', and 'ONTOLOGIES'. Below this is a search bar and a '+ CREATE' button. The main content area is divided into two columns. The left column shows a list of video groups under the heading 'Private workspace'. The first group, 'Entraînement à l'ann...', is circled in red. It is owned by a user and has 1 video and 1 member. Below it are two other groups: 'Test d'annotations E...' and 'MIPO surgeries of D...'. The right column shows a grid of video thumbnails. The first row contains three thumbnails labeled '18.mp4', '19.mp4', and '20.mp4'. The second row contains three thumbnails labeled '21.mp4', '22.mp4', and '23.mp4'. Each thumbnail has a 'STATUS:' label and a 'NEW' button. A red arrow points from the text in the first bullet point to the 'Entraînement à l'ann...' folder.

- This field indicates the status of your video (new, to do, in progress or done); by default, it will be « TODO ».
- Click on this status to change it.






The screenshot displays the MOSaiC web application interface. At the top, there is a teal navigation bar with the MOSaiC logo, tabs for 'VIDEO GROUPS' and 'ONTOLOGIES', and user profile, settings, help, and information icons. Below the navigation bar, a search bar and a '+ CREATE' button are visible. The main content area is divided into a left sidebar and a central video player. The sidebar lists several video groups, including 'Private workspace', 'Entraînement à l'ann...', 'Test d'annotations E...', and 'MIPO surgeries of D...'. The central video player shows a video titled 'Video d'entraînement à annoter.mp4' with a thumbnail image of a surgical procedure. Below the video, the status is set to 'TODO', which is circled in red. A red arrow points from the text in the first bullet point to this 'TODO' button. Below the status, there is a 'MORE INFO' button.

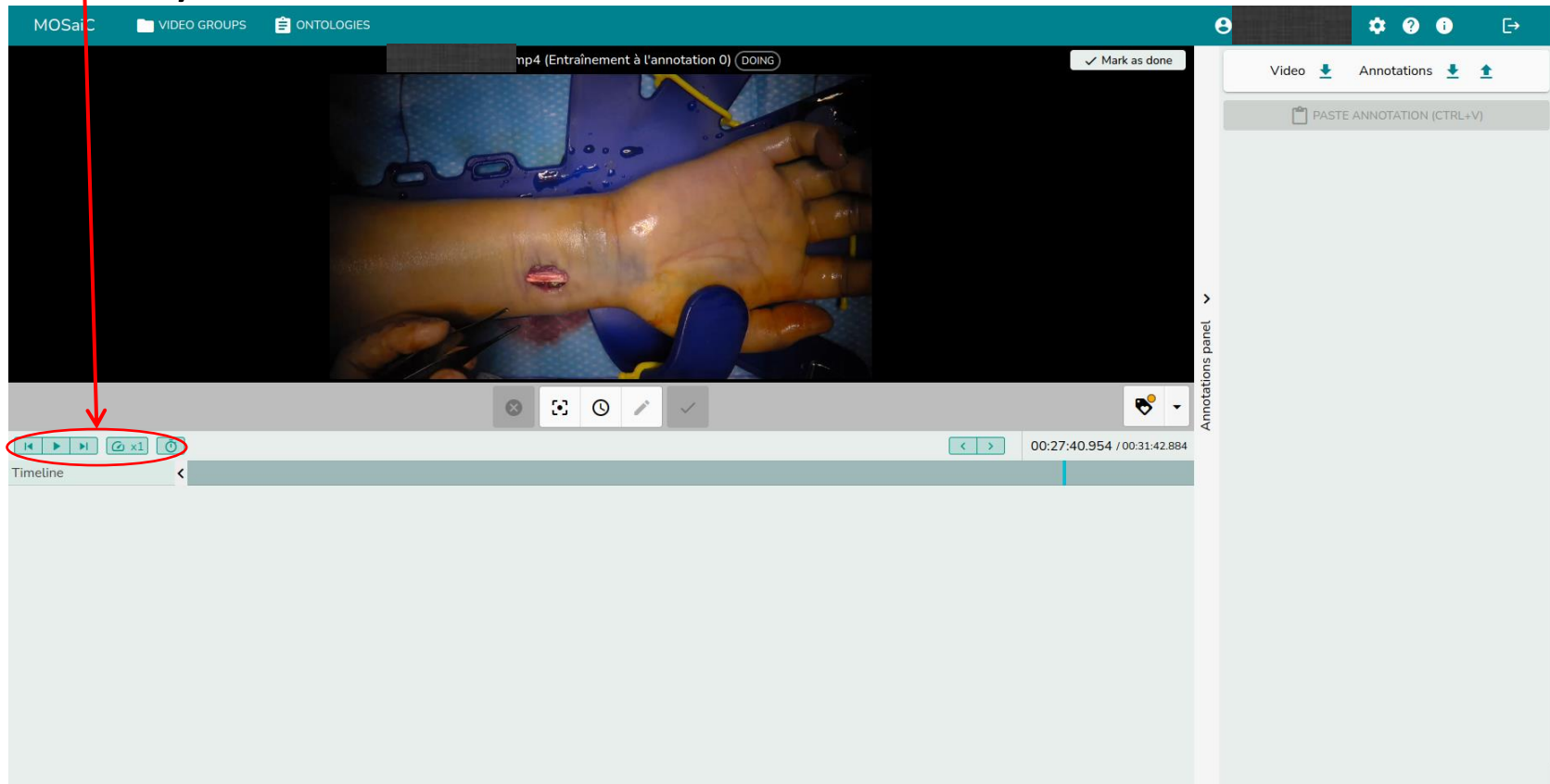
- When you are ready to start annotating your video, change the status of your video to « DOING ».



The screenshot displays the MOSaiC web application interface. At the top, there is a teal navigation bar with 'MOSaiC', 'VIDEO GROUPS', and 'ONTOLOGIES' on the left, and user profile, settings, help, and share icons on the right. Below the navigation bar, a search bar and a '+ CREATE' button are visible. The main content area is divided into a left sidebar and a central video player. The sidebar lists several video groups: 'Private workspace', 'Entraînement à l'ann...' (1 video, 1 user), 'Test d'annotations E...' (10 videos, 1 user, Collaborative), and 'MIPO surgeries of D...' (42 videos, 2 users, Collaborative). The central video player shows a video titled 'Video d'entraînement à annoter.mp4' with a thumbnail image of a hand. Below the video, the 'STATUS:' section has four buttons: 'NEW', 'TODO', 'DOING', and 'DONE'. The 'DOING' button is highlighted with a red circle, and a red arrow points to it from the text above. Below the status buttons is a 'MORE INFO' button.

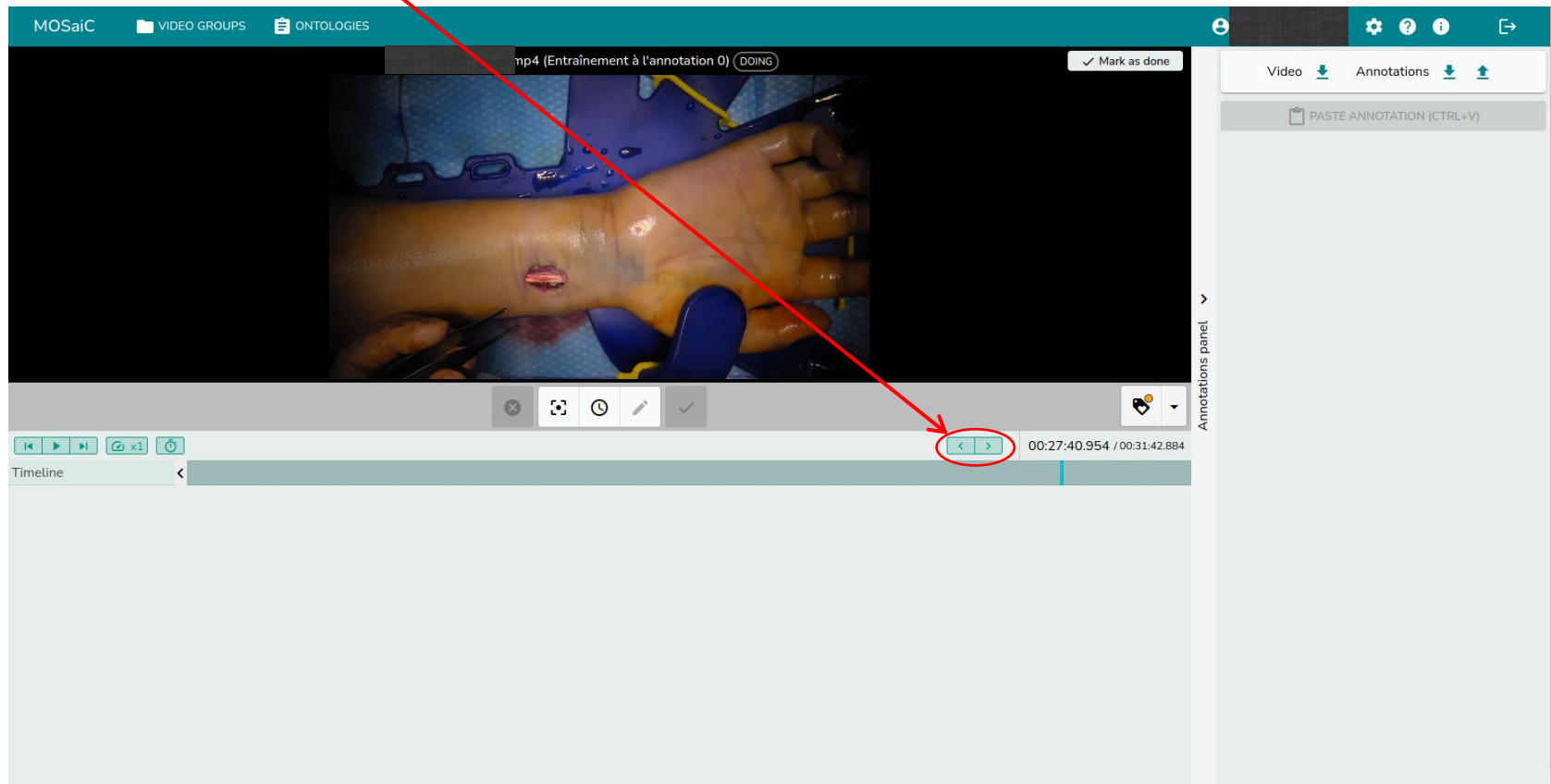
- To annotate your video, click on it.

The screenshot displays the MOSaiC platform interface. At the top, there is a teal navigation bar with 'MOSaiC', 'VIDEO GROUPS', and 'ONTOLOGIES' tabs. Below this is a search bar with a magnifying glass icon and a '+ CREATE' button. The main content area is divided into two sections. On the left, there is a 'Private workspace' section with three video groups: 'Entraînement à l'ann...' (1 video, 1 user), 'Test d'annotations E...' (10 videos, 1 user), and 'MIPO surgeries of D...' (42 videos, 2 users). On the right, there is a video player for 'Video d'entraînement à annoter.mp4'. The video player shows a close-up of a hand with a white bandage. A red oval highlights the video player, and a red arrow points from the text 'To annotate your video, click on it.' to the video player. Below the video player, there is a 'STATUS:' section with a 'DOING' button and a 'MORE INFO' dropdown menu.

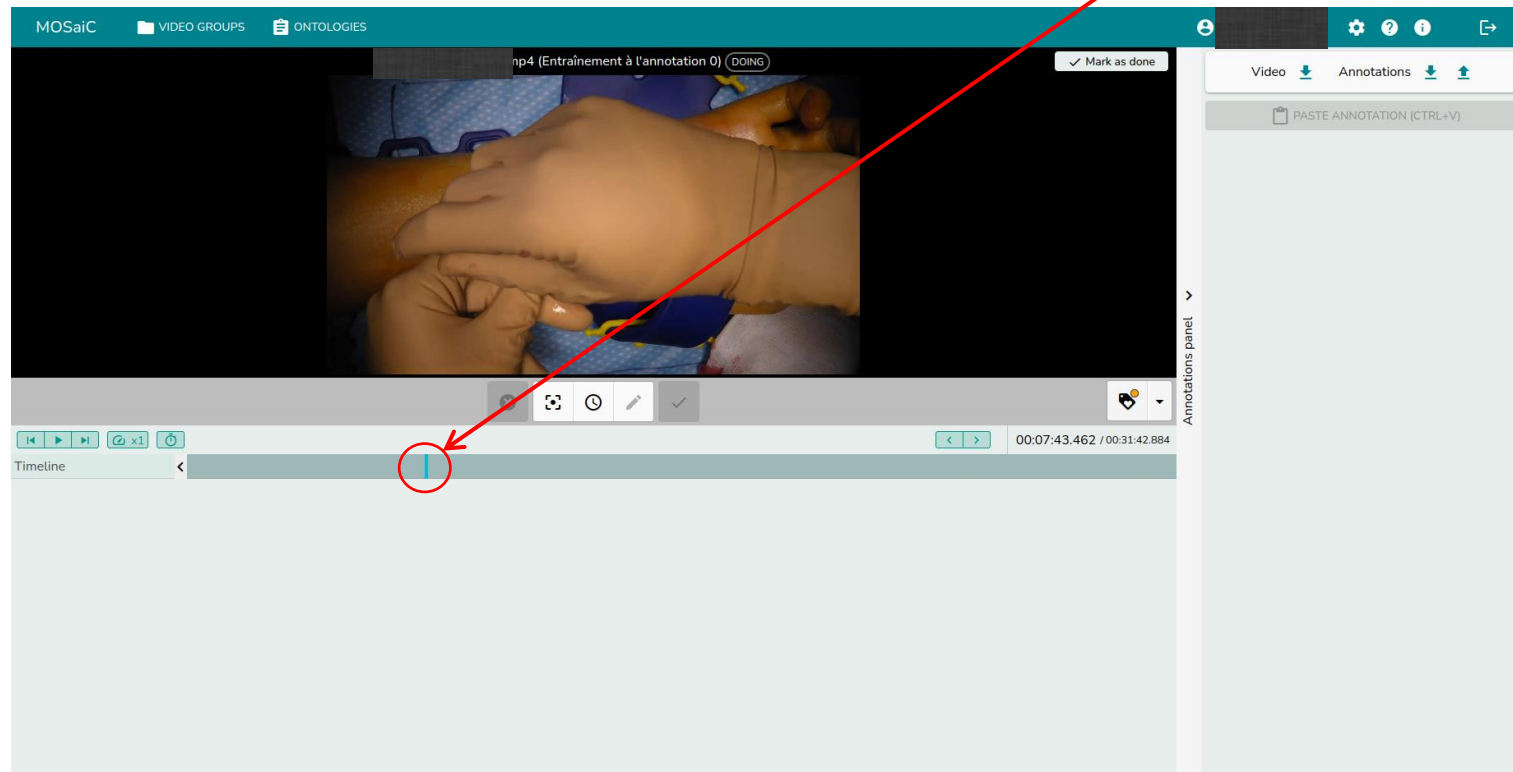
- These buttons allow you (in order):  to go to the beginning of the video,  to start the playback of the video,  to go to the end of the video,  to change the speed of the playback of the video (0.2x, 0.5x, 1x, 2x, 3x, 4x or 5x),  to choose a precise time of the video (indicating a time in hours/minutes/seconds/milliseconds or directly in milliseconds).



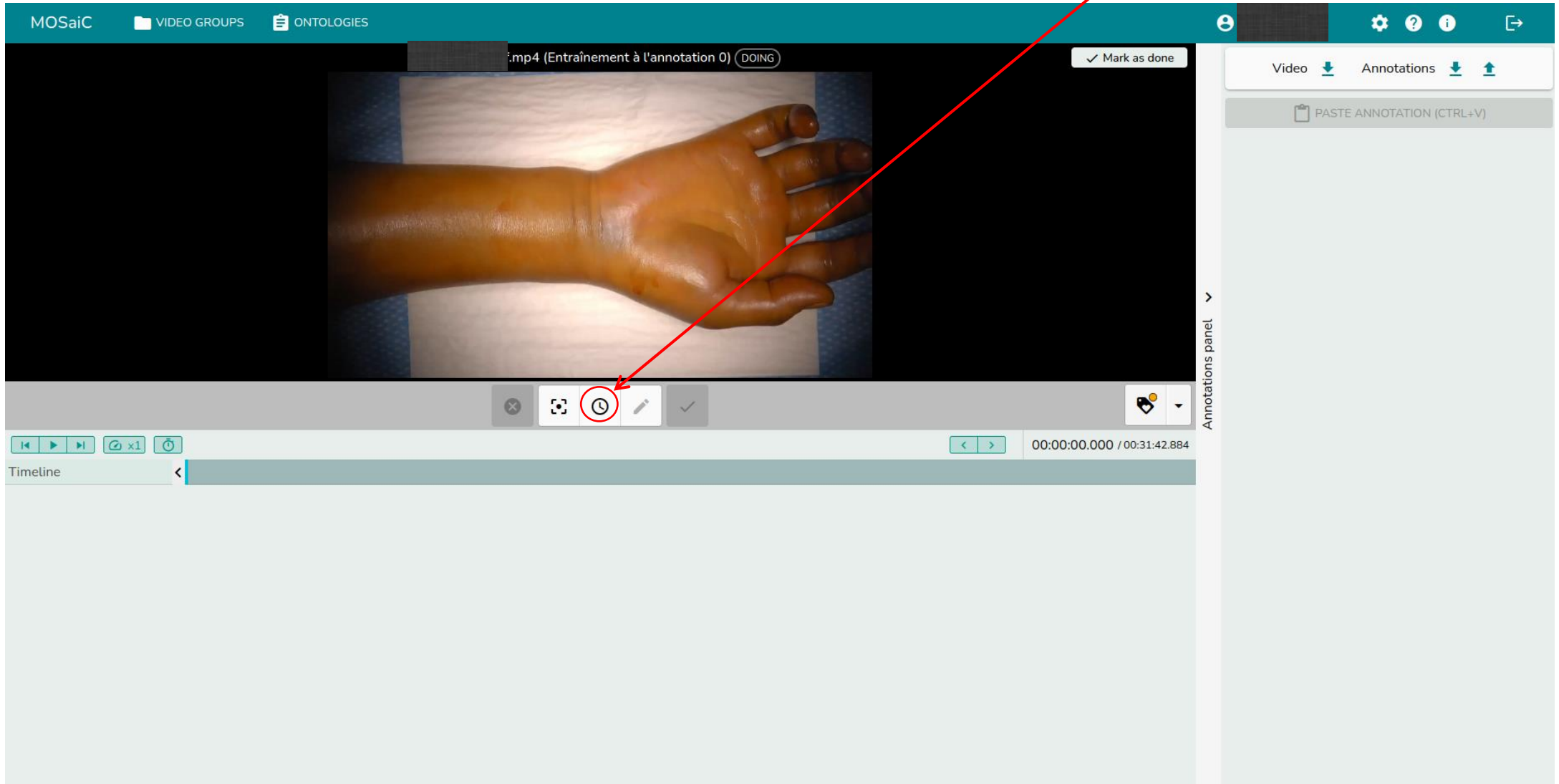
- These buttons allow you (in order):  to go to the beginning of the previous annotation (relative to the position of your time cursor), to go to the  beginning of the next annotation.



- You can move the time cursor of the video by moving this blue line with your mouse.
- You can also move it much more precisely (from frame to frame) by using the right and left arrows on your keyboard (←→ method to use to choose precisely the start and end limit when annotating a phase or an action).



- To add a new annotation, move your time cursor to the start of the phase or action to be annotated and click on the clock.





- Choose the label of the annotation that you want to add.

The screenshot displays the MOSaiC software interface. At the top, there are navigation tabs for 'VIDEO GROUPS' and 'ONTOLOGIES'. The main video player shows a surgical procedure. A 'Label selection' dialog box is open in the center, titled 'Label selection' with a clock icon. It has two tabs: 'Choose label' (selected) and '+ Create Label'. Under 'ontology labels', there is a grid of colored buttons representing different actions: 'Placement of a drill bit g...' (orange), 'Placement of a K-w...' (purple), 'Insertion of a scr...' (blue), 'Removal of a drill bit g...' (red), 'Motor drilling' (grey), 'Modification of the plate posi...' (brown), 'Introduction of the pl...' (yellow), 'Proximal fixation' (black), 'Distal fixation' (green), 'Fluoroscopic cont...' (magenta), 'Verification' (cyan), 'Fixation' (red), 'Approach' (light green), 'Installation' (yellow, circled in red), and 'Closure' (blue). Below the grid is a 'Search more labels' section with a 'Label name' input field. At the bottom of the dialog are 'Cancel' and 'Submit' buttons. The background interface includes a timeline at the bottom left, a 'Mark as done' button at the top right, and an 'Annotations panel' on the right side.

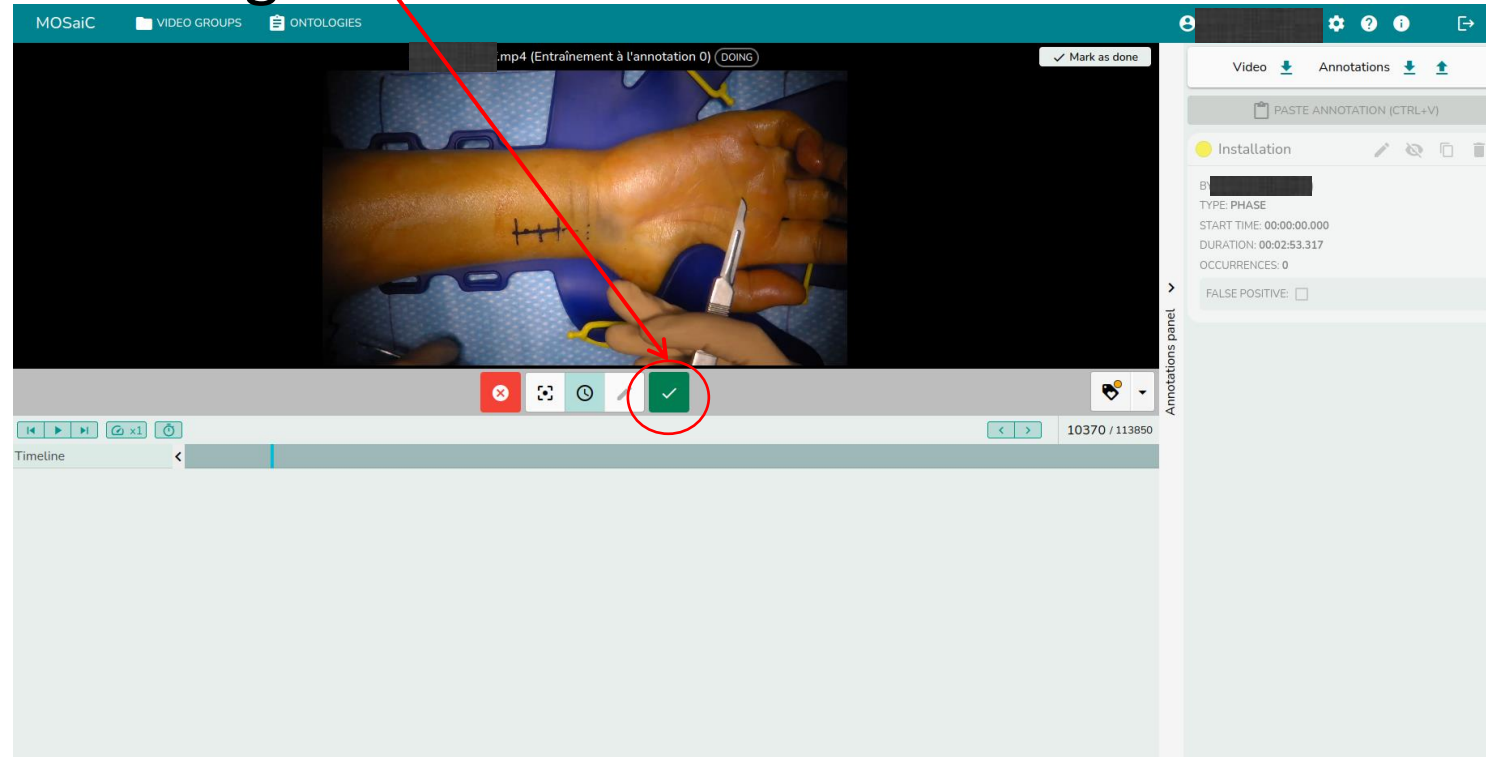
- As long as the selected annotation is not validated, it will appear in a transparent way on the right.

The screenshot displays the MOSaiC video annotation software interface. The main video player shows a close-up of a hand. The video title is ".mp4 (Entraînement à l'annotation 0) DOING" with a "Mark as done" button. The interface includes a top navigation bar with "MOSaiC", "VIDEO GROUPS", and "ONTOLOGIES". Below the video player is a control bar with icons for close, full screen, play/pause, zoom, and a green checkmark for validation. A timeline at the bottom shows the current time as 00:00:00.000 / 00:31:42.884. On the right, the "Annotations panel" is visible, containing a list of annotations. One annotation, titled "Installation", is highlighted with a red circle. This annotation is unvalidated, as indicated by its semi-transparent appearance and the presence of edit, delete, and copy icons. The annotation details are: BY [redacted], TYPE: PHASE, START TIME: 00:00:00.000, DURATION: 00:00:00.000, OCCURRENCES: 0, and FALSE POSITIVE: . A red arrow points from the text in the first bullet point to this unvalidated annotation.

- If you want to cancel the annotation of the current label, click on the red button.

The screenshot displays the MOSaiC video annotation software interface. At the top, the header includes 'MOSaiC', 'VIDEO GROUPS', and 'ONTOLOGIES'. The main video player shows a close-up of a hand with a yellow 'Installation' label overlaid. The video title is 'mp4 (Entraînement à l'annotation 0)' and it is in 'DOING' status. A 'Mark as done' button is visible in the top right of the video player. Below the video player is a toolbar with several icons: a red 'X' button (circled in red), a square icon, a clock icon, a pencil icon, and a green checkmark icon. Below the toolbar is a 'Timeline' section. On the right side, there is an 'Annotations panel' showing details for the 'Installation' annotation, including 'BY', 'TYPE: PHASE', 'START TIME: 00:00:00.000', 'DURATION: 00:00:00.000', 'OCCURRENCES: 0', and a 'FALSE POSITIVE' checkbox.

- To validate the annotation, move your time cursor until the image corresponding to the end of the phase or the action to annotate, and then click on the green button.



**Be careful**, for the actions, you must validate the annotation on the last image corresponding to the action (for example, for the fluoroscopic control, you must validate the annotation of the action on the last image where you see the plastic of the fluoroscope).

- Once the annotation validated, it appears below the video.

The screenshot displays the MOSaiC interface. At the top, there are navigation tabs for 'VIDEO GROUPS' and 'ONTOLOGIES'. The main video player shows a surgical procedure with a red arrow pointing to a yellow annotation bar at the bottom of the video frame. The annotation is labeled 'Installation'. Below the video player, there is a control bar with various icons and a progress indicator showing '10370 / 113850'. On the right side, the 'Annotations panel' is open, displaying the details for the 'Installation' annotation: 'BY: [redacted]', 'TYPE: PHASE', 'START TIME: 00:00:00.000', 'DURATION: 00:02:53.317', 'OCCURRENCES: 1', and a 'FALSE POSITIVE' checkbox.

- The list of all the labels that have been associated with a given moment in the video (the one where the time cursor is located) is on the right.

The screenshot displays the MOSaiC interface for video annotation. At the top, there are navigation tabs for 'VIDEO GROUPS' and 'ONTOLOGIES'. The main video player shows a surgical procedure with a 'DOING' status and a 'Mark as done' button. Below the video is a timeline with various colored bars representing different phases: Installation (yellow), Approach (light green), Fixation (red), Introduction of the plate (yellow), Distal fixation (light green), Proximal fixation (grey), Verification (cyan), and Closure (blue). A vertical blue line indicates the current time cursor. On the right, the 'Annotations panel' is open, showing two entries: 'Distal Fixation' (green dot) and 'Fixation' (red dot). Each entry includes the user name, type (PHASE), start time, duration, and occurrence count. A red circle highlights the 'Distal Fixation' entry, and a red arrow points from the text in the first bullet point to this entry.

Annotation Label	Type	Start Time	Duration	Occurrences
Distal Fixation	PHASE	00:07:41.931	00:10:04.825	1
Fixation	PHASE	00:06:55.814	00:17:53.687	1

- To delete an added annotation, press and hold the red bin of the annotation to be deleted.

The screenshot displays the MOSaiC software interface. At the top, there are navigation tabs for 'VIDEO GROUPS' and 'ONTOLOGIES'. The main video player shows a surgical procedure with a 'DOING' status and a 'Mark as done' button. Below the video is a timeline with various colored bars representing different phases: Installation (yellow), Approach (light green), Fixation (red), Introduction of the plate (yellow), Distal fixation (light green), Proximal fixation (grey), Verification (teal), and Closure (blue). On the right side, the 'Annotations panel' is visible, showing two annotations: 'Distal Fixation' and 'Fixation'. Each annotation includes details like 'BY', 'TYPE: PHASE', 'START TIME', 'DURATION', and 'OCCURRENCES'. A red bin icon is circled in red in the 'Distal Fixation' annotation's action menu, with a red arrow pointing to it from the text above.

- If you want to access the software documentation, click on the question mark.

The screenshot displays the MOSaiC software interface. At the top, there is a teal header with 'MOSaiC', 'VIDEO GROUPS', and 'ONTOLOGIES'. Below this is a video player showing a surgical procedure. A red arrow points from the text above to a question mark icon in the top right corner of the interface. Below the video player is a timeline with various colored bars representing different phases of the procedure. On the right side, there is an 'Annotations panel' with two entries: 'Distal Fixation' and 'Fixation'. Each entry shows the user, type, start time, duration, and occurrences. The 'Distal Fixation' entry has a start time of 00:07:41.931 and a duration of 00:10:04.825. The 'Fixation' entry has a start time of 00:06:55.814 and a duration of 00:17:53.687. The interface also includes a 'PASTE ANNOTATION (CTRL+V)' button and a 'FALSE POSITIVE' checkbox for each annotation.



- And then click on « Open documentation ».

The screenshot displays the MOSaiC software interface. At the top, there are navigation tabs for 'VIDEO GROUPS' and 'ONTOLOGIES'. The main video player shows a video titled 'mp4 (Entraînement à l'annotation 0)' with a 'DOING' status and a 'Mark as done' button. A help menu is open in the center, listing various sections: 'HELP', 'Documentation', 'Support', and 'Shortcuts'. The 'Open documentation' button in the 'Documentation' section is highlighted with a red circle and a red arrow pointing to it. The 'Shortcuts' section lists various keyboard shortcuts for video control and annotation management. On the right side, there is an 'Annotations panel' showing two annotations: 'Distal Fixation' and 'Fixation', each with details like 'BY', 'TYPE: PHASE', 'START TIME', 'DURATION', 'OCCURRENCES', and a 'FALSE POSITIVE' checkbox.

# Practical remarks for the annotation

- Read carefully the annotation protocol to understand the annotation of the videos studied. **Please note that it is very important to respect this protocol!**
- Use the summary of annotations document to have a support that summarises how to choose the beginning and end of each phase, sub-phase and action to be annotated.
- When annotating, a tip is to annotate in the following order:
  1. phase 1 ("installation"), phase 2 ("approach"), sub-phase 3a ("introduction of the plate"), sub-phase 3b ("distal fixation"), sub-phase 3c ("proximal fixation"), phase 4 ("verification") and phase 5 ("closure") → in this way you can start the annotation of each phase exactly on the image on which you stopped the annotation of the previous phase
  2. phase 3 (« fixation ») → starting at the beginning of sub-phase 3-a and going to the end of sub-phase 3c
  3. actions
- In case of a « bug » in the software, do not hesitate to refresh the page.

- When you have finished annotating the whole video, click on « Mark as done ».

The screenshot displays the MOSaiC video annotation interface. At the top, the header includes 'MOSaiC', 'VIDEO GROUPS', and 'ONTOLOGIES'. The main video player shows a surgical procedure with a 'DOING' status indicator. A red circle highlights the 'Mark as done' button in the top right corner of the video player. Below the video player is a timeline with various colored bars representing different phases: Installation (yellow), Approach (light green), Fixation (red), Introduction of the plate (yellow), Distal fixation (light green), Proximal fixation (dark grey), Verification (teal), and Closure (blue). The right sidebar, labeled 'Annotations panel', shows two annotations: 'Distal Fixation' (green dot) and 'Fixation' (red dot). Each annotation includes details such as 'BY [user]', 'TYPE: PHASE', 'START TIME', 'DURATION', 'OCCURRENCES', and a 'FALSE POSITIVE' checkbox.

If you have any questions, suggestions or remarks,  
please do not hesitate to send me an e-mail!

# Annotation protocol for the recognition of surgical phases on videos of MIPO surgeries

Currently, the gold standard to learn new surgical techniques is to be coached in the operating room by an expert surgeon. However, it has been shown that the use of AI-based tools could:

1. lead to a per-operative assistance thanks to a supervision of the tasks realized by the surgeon, with, if necessary, an emission of warnings
2. offer a postoperative analysis of the surgical procedure in order to signal to the surgeon deviations from the protocol, thus allowing the novice surgeon to improve

Nevertheless, no such technology has yet been dedicated to the minimally invasive plate osteosynthesis (MIPO), which is a surgical technique used to treat distal radius fractures (DRF).

In order to develop a Deep Learning model capable of recognizing the different phases of this surgery, it is necessary to collect videos and to annotate them so that they can be used as training, validation and testing data for the algorithm. For the annotation of the videos, it is therefore necessary to define a detailed protocol of the different phases and steps of the surgery studied, as well as specifying the visual cues that allow the detection of the change of phases.

# 1 Workflow of the surgery

The workflow of the surgery has been divided in five major phases: installation, approach, fixation, verification and closure. Within each of these major phases, several sub-steps can be defined:

## 1. INSTALLATION

- marking of the camera's field of view around a white surgical field
- drawing of the incision
- screwing of the guide on the plate
- application of a Velpeau bandage on the patient's arm for the time of inflating the tourniquet

## 2. APPROACH

- cutaneous incision
- dissection of the subcutaneous tissues
- deep dissection with the rongeur on the distal edge of the pronator quadratus

## 3. FIXATION

- a) **Introduction of the plate:** the plate, with mounted guide, is inserted with the proximal part under the pronator quadratus
- b) **Distal fixation**
  - placement of the most distal and ulnar K-wire (several trials possible)
  - fluoroscopic control
  - placement of the most distal and radial K-wire (several trials possible)
  - fluoroscopic control
  - placement of the two guides for the central screws
  - motor drilling through the two guides for the central screws
  - removal of the two guides for the central screws
  - insertion of the two central screws
  - removal of the two K-wires for the ulnar and radial screws
  - removal of the guide
  - insertion of the two ulnar and radial screws
- c) **Proximal fixation**
  - placement of the two guides for the proximal screws

- reduction of the fracture on plate with the rongeur
- motor drilling through the two proximal drill bit guides
- removal of the guide of the proximal screw which is the most distal
- insertion of the proximal screw which is the most distal
- removal of the guide of the proximal screw which is the most proximal
- placement of the proximal screw which is the most proximal

#### **4. VERIFICATION**

- fluoroscopic control with several views (front, profile and skyline)
- checking of the freedom of the finger flexors
- checking of the mobility of the wrist

#### **5. CLOSURE**

- intradermal suture
- measurement of the scar with the ruler
- placement of the bandage

An important remark to make is that, during the verification phase, corrections to the osteosynthesis can be made if necessary (for example, some screws can be replaced if they are found to be too long).

Finally, the workflow of the surgery (in a "simple" case) can be summarized by the flow chart of the Figure 1.

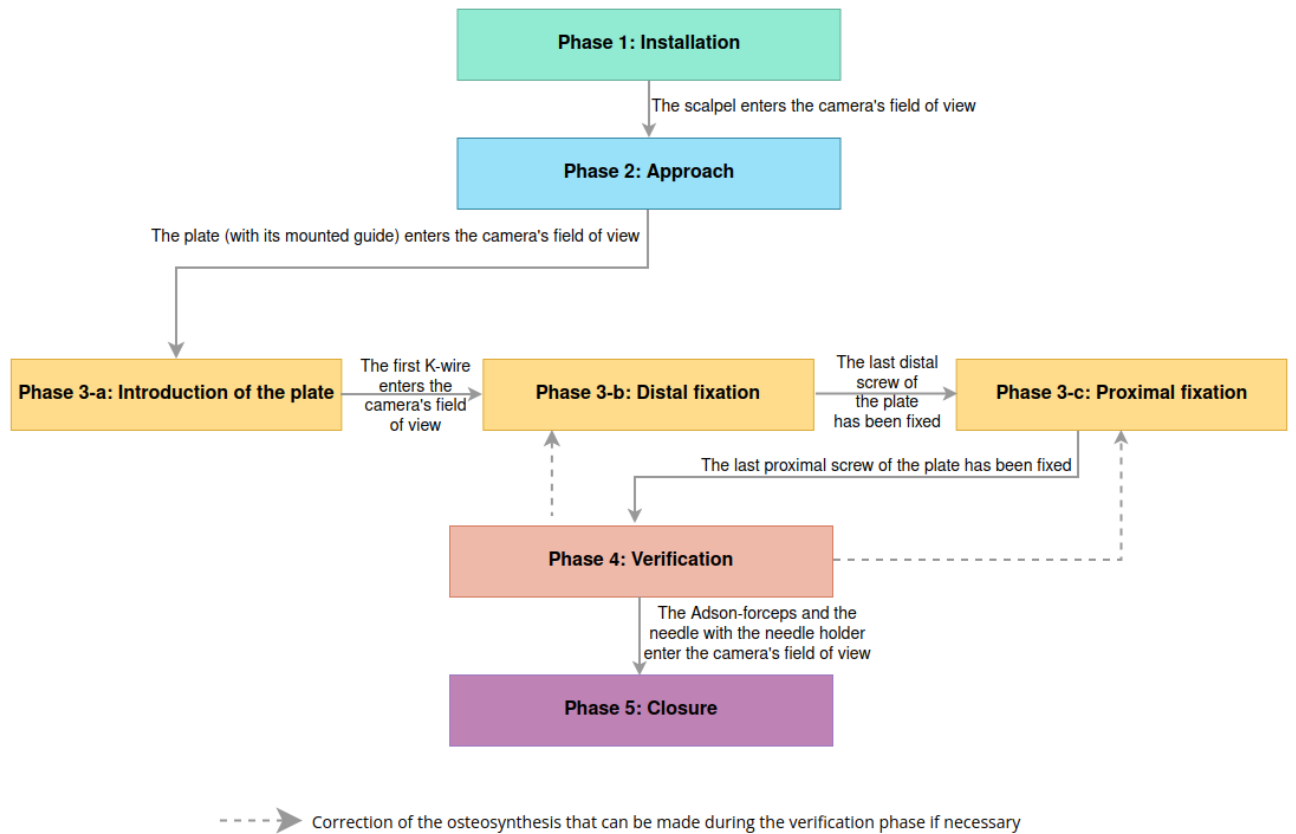


Figure 1: Flow chart of the surgery (in a "simple" case)

However, it might happen that the surgeon needs, after starting the distal (or even proximal) fixation, to remove the plate and reposition it correctly (he will then have to restart the distal and proximal fixation sub-phases from the beginning). It would be interesting to be able to count how many times the surgeon needed to reposition the plate, as a large number of such repositioning could be indicative of a technical error. Thus, in some cases, there will be an additional sub-phase ("modification of the plate positioning") during the fixation phase. The Figure 2 shows an example of a flow chart for such a surgery.



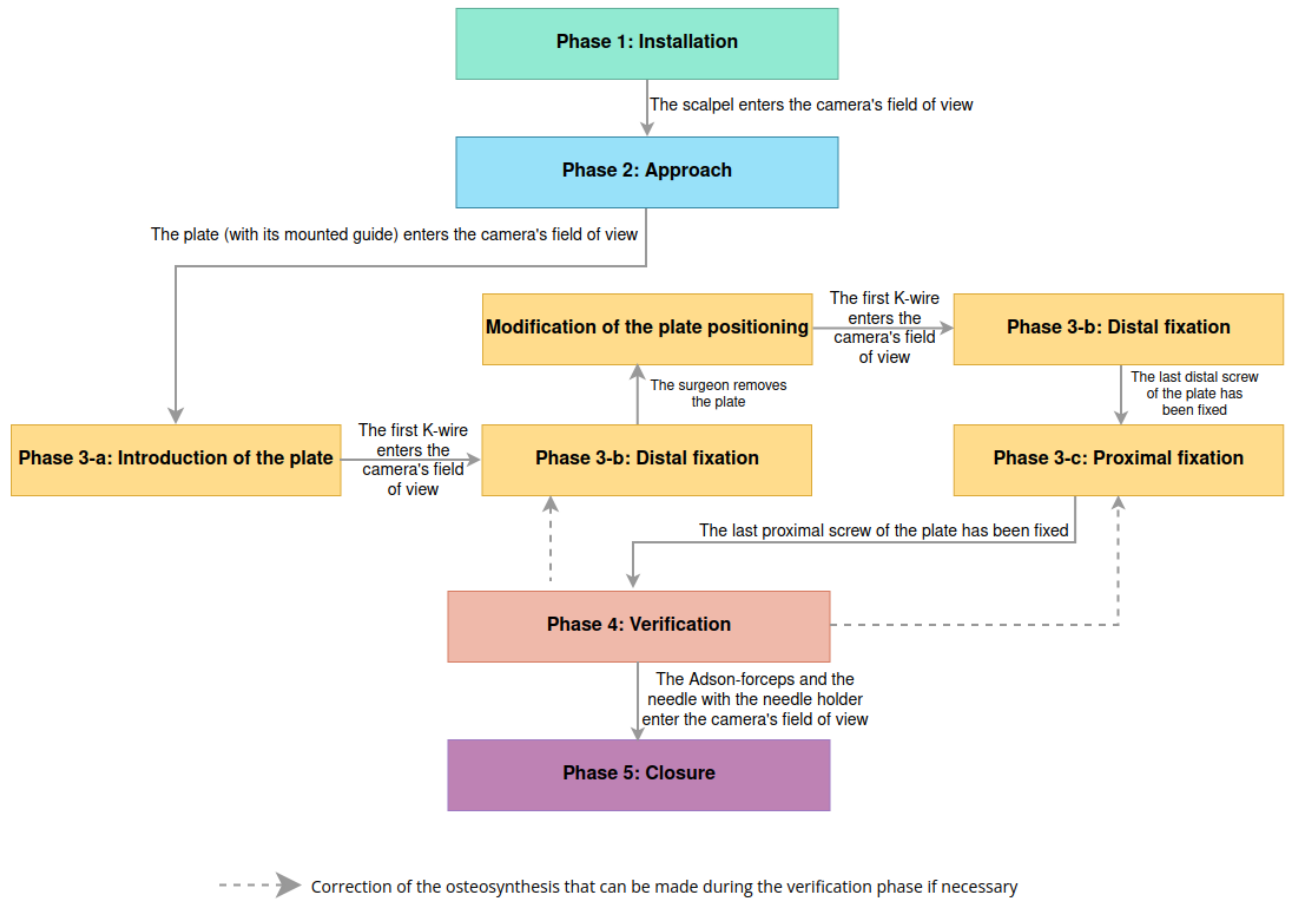


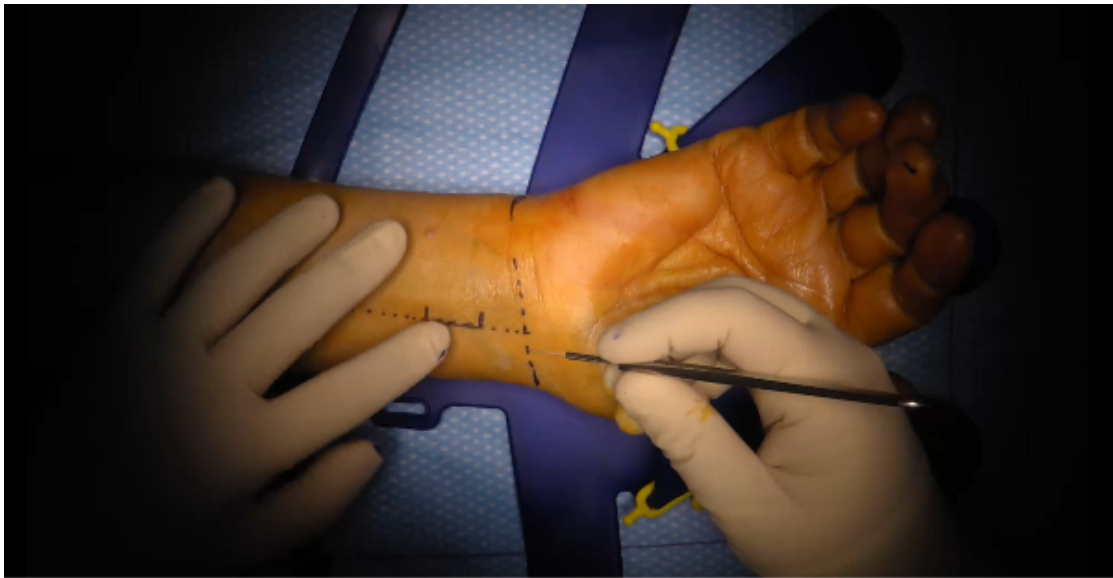
Figure 2: Flow chart of the surgery (in the case where a modification of the plate positioning is necessary)

## 2 Visual cues for the detection of the phase changes

For the annotation of the videos, it is important to know how to detect a change of phase in the surgery. Some cues with visual examples will therefore be given to help detecting these phase changes.

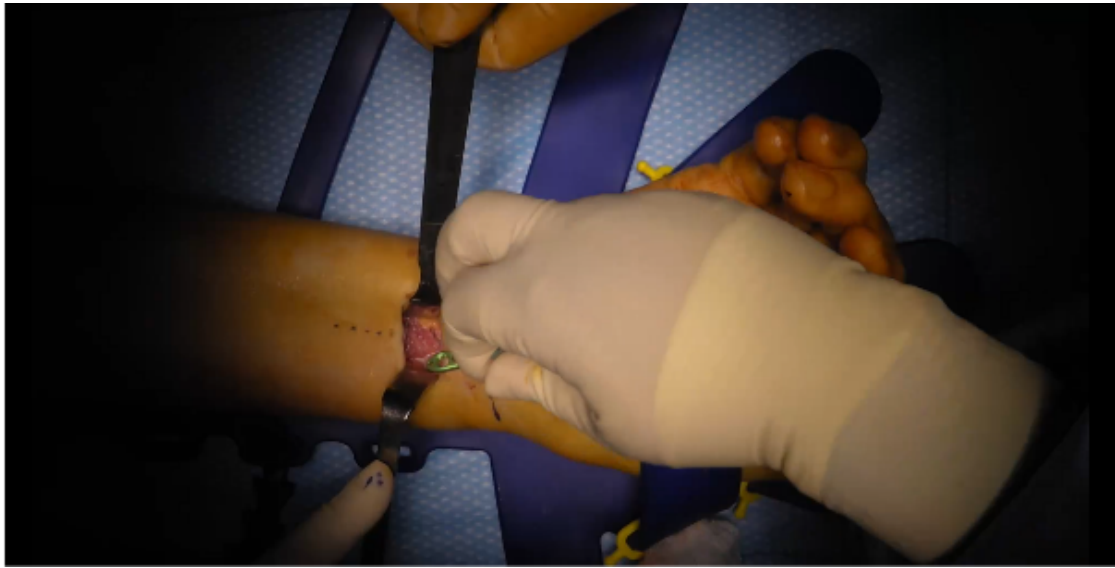
First, it is supposed that the first phase starts automatically with the beginning of the video, and that the last phase ends with the end of the video.

The second phase of approach starts when the scalpel enters the camera's field of view (Figure 3).



*Figure 3: Beginning of the second phase of the surgery (approach)*

The third phase of fixation (with first the sub-phase 3-a corresponding to the introduction of the plate) starts when the plate (with its mounted guide) enters the camera's field of view (Figure 4).



*Figure 4: Beginning of the third phase of the surgery (fixation)*

To better understand how to detect the beginning of this third phase, the Figure 5 shows what can be observed a few seconds after the moment corresponding to the Figure 4. Moreover, the Figure 6 shows what the plate with its mounted guide looks like.

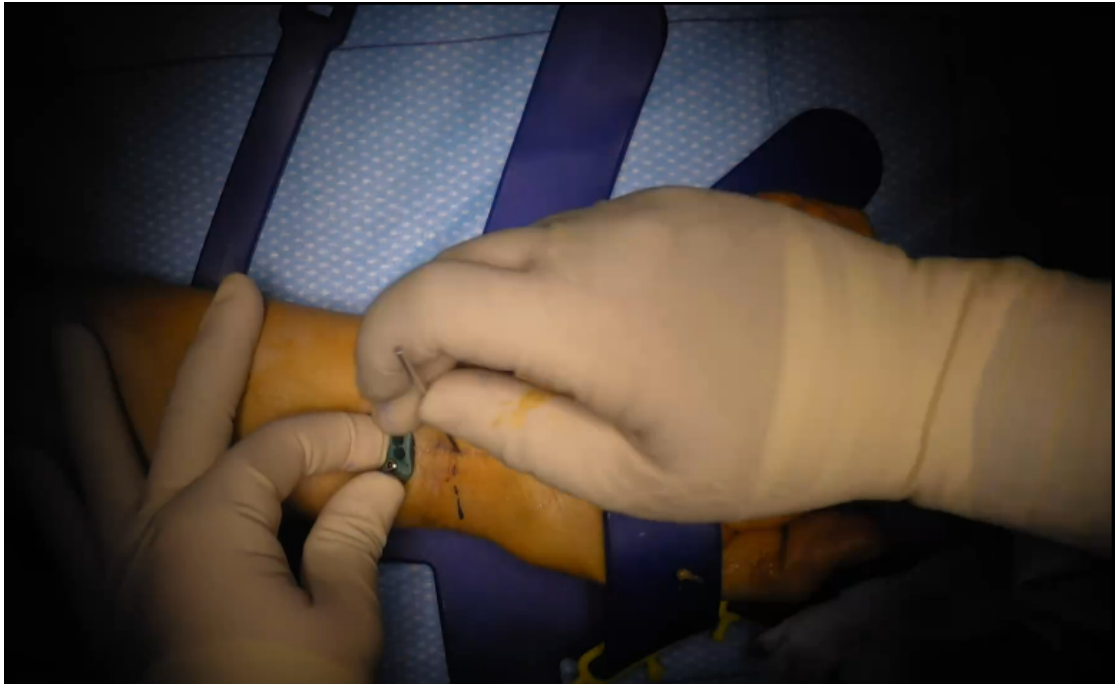


*Figure 5: Start of the third phase of the surgery with the introduction of the plate (sub-phase 3-a)*



*Figure 6: Plate with its mounted guide used for the osteosynthesis*

Once the plate (with its mounted guide) is in place, the sub-phase 3-b (distal fixation) begins. The first K-wire then enters the camera's field of view, as shown with the Figure 7.



*Figure 7: Beginning of the sub-phase 3-b of the surgery (distal fixation)*

Once the last distal screw of the plate has been fixed, the sub-phase 3-b is over and the sub-phase 3-c (proximal fixation) can start (Figure 8).

No surgical tool can help to detect this sub-phase change. As a boundary between sub-phases 3-b and 3-c, we will therefore choose the first image (after the last moment when the surgeon touched the distal screws) where neither surgical

tools (retractors, screwdrivers,...), nor the surgeon's or his assistant's hands can be seen in the camera's field of view (as far as possible).



*Figure 8: Beginning of the sub-phase 3-c of the surgery (proximal fixation)*

As explained earlier, the plate might be removed for proper repositioning after the distal (or proximal) fixation sub-phase has started. This sub-phase of modification of the plate positioning thus begins when the surgeon removes the plate (Figure 9), and it ends when the K-wire enters the camera's field of view.

It should be noted that the surgeon may take several attempts to place the plate the first time (during the plate introduction sub-phase), without this being considered as a modification of the plate positioning. This is because as long as the distal fixation sub-phase has not started, it is still the plate insertion sub-phase. In other words, this sub-phase of modification of the plate positioning can only take place if K-wires and/or screws have already been inserted and removed.



*Figure 9: Beginning of the sub-phase of modification of the plate positioning*

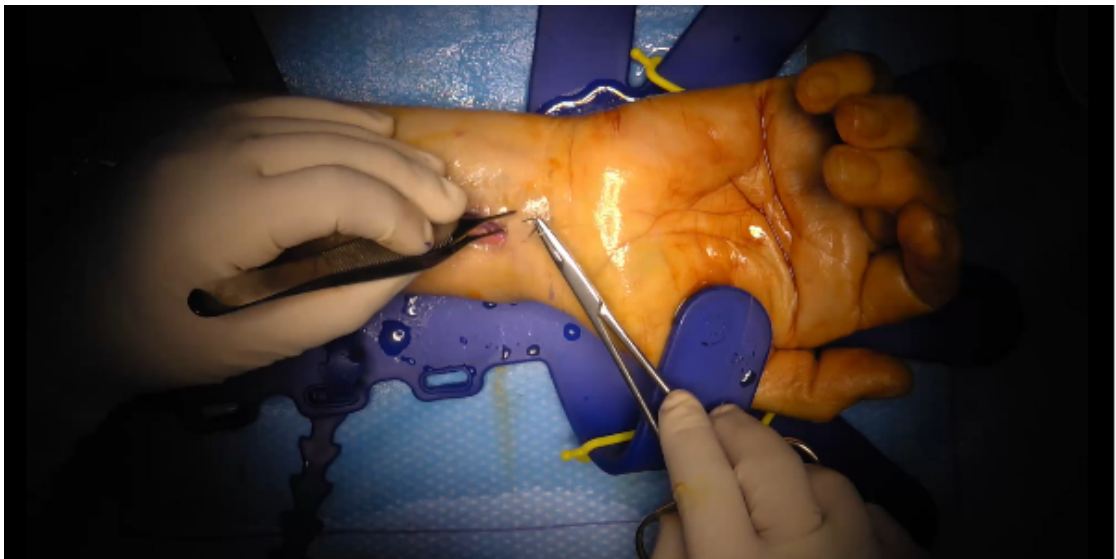
To detect the transition from the sub-phase 3-c to the fourth phase, it is easier to focus on the end of the third phase rather than on the beginning of the fourth phase. The end of the third phase is characterized by the fixation of the two proximal screws of the plate. Therefore, the third phase can be said as finished when the last proximal screw has been put in (Figure 10).

In a similar way to the end of sub-phase 3-b, the first image (after the last moment when the surgeon touched the proximal screws) where neither surgical tools (retractors, screwdrivers,...), nor the surgeon's or his assistant's hands can be seen in the camera's field of view (as far as possible) will be chosen as the limit between sub-phase 3-c and phase 4.



*Figure 10: End of the sub-phase 3-c (proximal fixation) with the screwing of the last proximal screw*

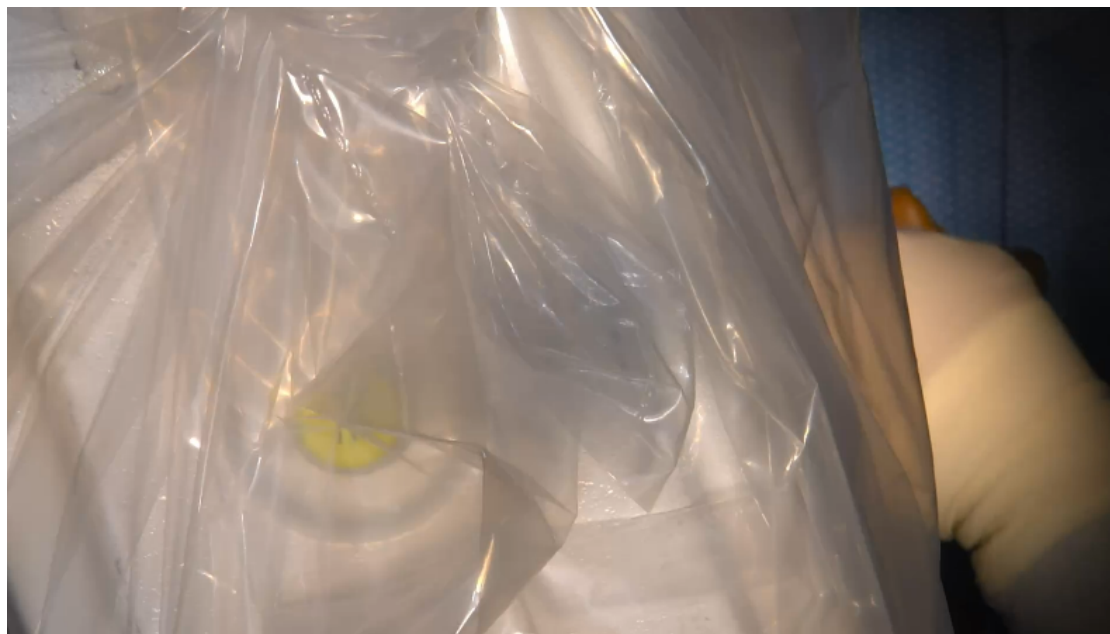
Finally, the last phase (closure) starts when the surgeon is ready to suture the skin, that is when the Adson-forceps and the needle with the needle holder enter the camera's field of view (Figure 11).



*Figure 11: Beginning of the fifth phase of the surgery (closure)*

It should be noted that, during the fixation and verification phases, the cam-

era's field of view will be covered several times by a fluoroscope used to perform a fluoroscopic control. The operating field will therefore no longer be visible but will be replaced by a view similar to the one shown on Figure 12.



*Figure 12: View during a fluoroscopic control*



### 3 Punctual actions

Since the fixation phase consists of several sub-steps composed of different repetitive actions, some of these punctual actions can also be annotated on the videos.

These punctual actions to be annotated are the following:

- fluoroscopic control (Figure 13)
- placement of a K-wire (Figure 14)
- placement of a drill bit guide (Figure 15)
- motor drilling (Figure 16)
- removal of a drill bit guide (Figure 17)
- insertion of a screw (Figure 18)

Those actions will appear several times during the third phase (fixation) and the fourth phase (verification).

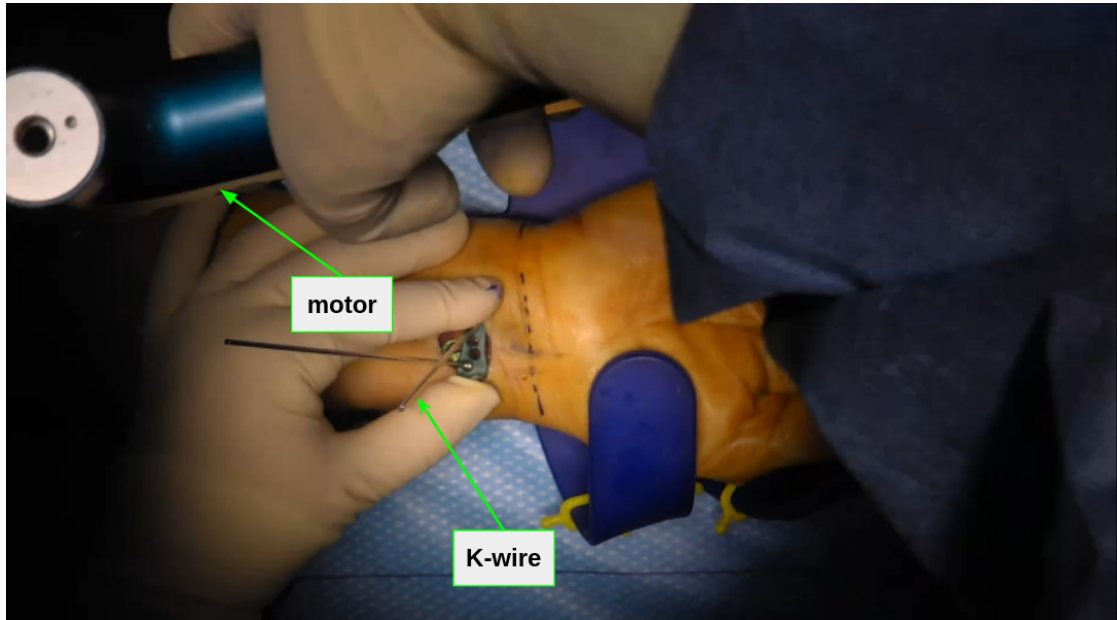
The fluoroscopic control starts when the fluoroscope enters the camera's field of view and ends when the fluoroscope goes out of the camera's field of view.



*Figure 13: Fluoroscopic control*

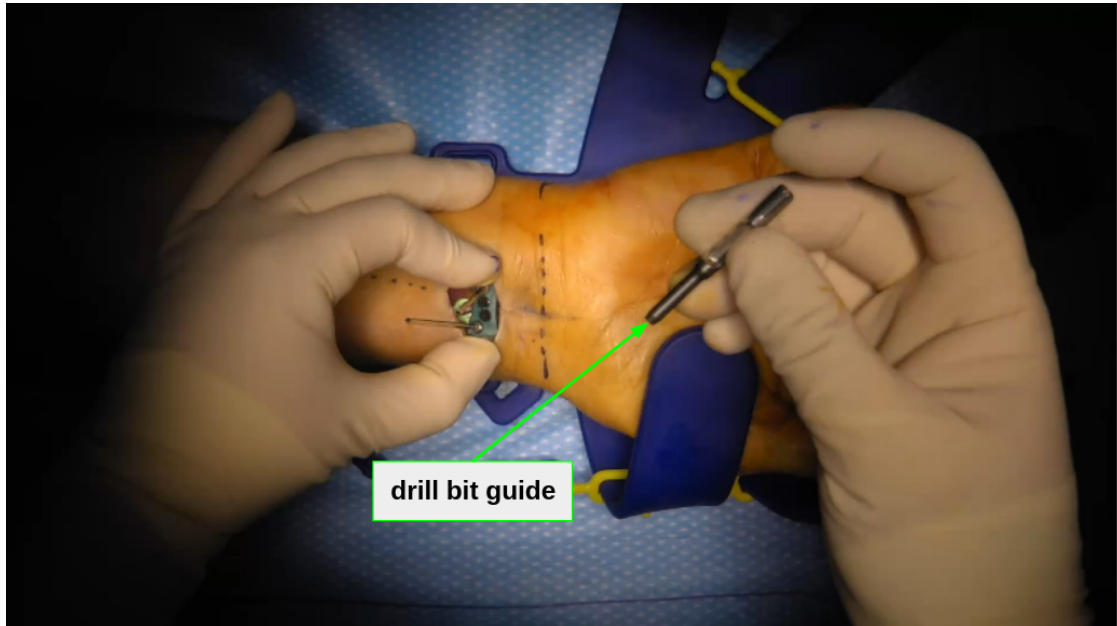
The placement of a K-wire starts when the K-wire enters the camera's field of view. Once the surgeon has placed manually the K-wire, he uses a motor to insert it, as it can be seen on Figure 14. The action of placing a K-wire is therefore over when the motor goes out of the camera's field of view. It is also possible that the

surgeon does not place the K-wire manually, but that this K-wire is directly on the motor when inserted; the K-wire placement action starts, in the same way, when the K-wire enters the camera's field of view and ends when the motor leaves the camera's field of view.



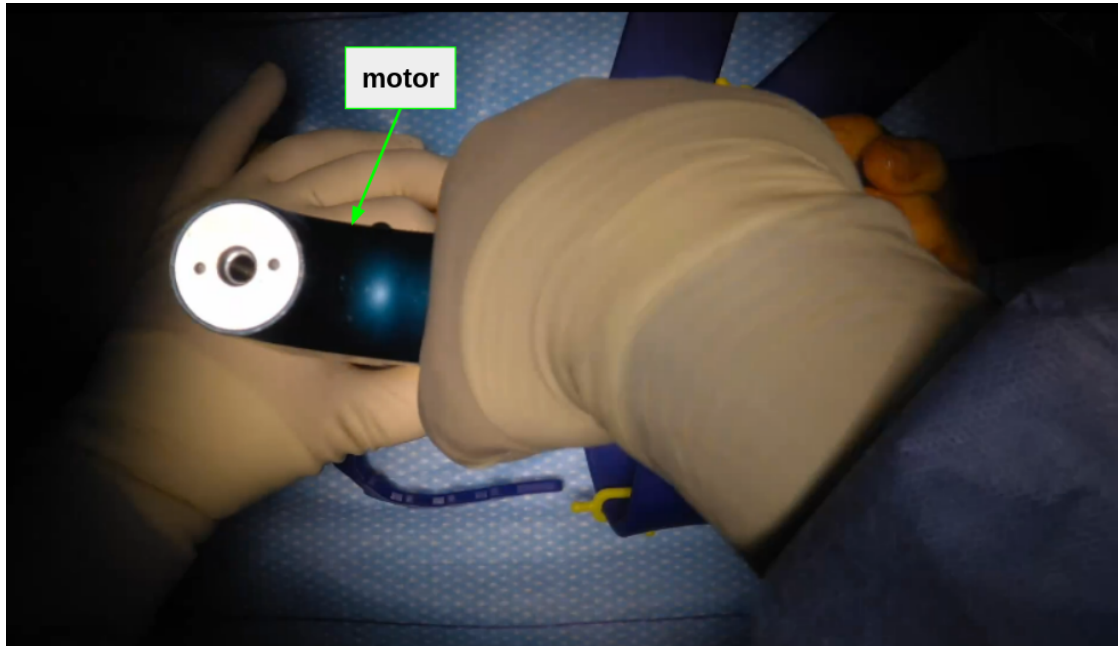
*Figure 14: Placement of a K-wire*

The placement of a drill bit guide begins when the hand of the surgeon holding the drill bit guide enters the camera's field of view and ends when the hand of the surgeon goes back and the drill bit guide can be seen in place.



*Figure 15: Placement of a drill bit guide*

The motor drilling action starts when the motor enters the camera's field of view and ends when the motor goes out of the camera's field of view. It is important to notice that, in general, motor drilling is done through a drill bit guide. However, a surgical error (which would be interesting to detect) is to drill directly through the hole of the plate. It is therefore necessary to annotate each motor drilling action, whether it is performed through a drill bit guide or through a hole in the plate.

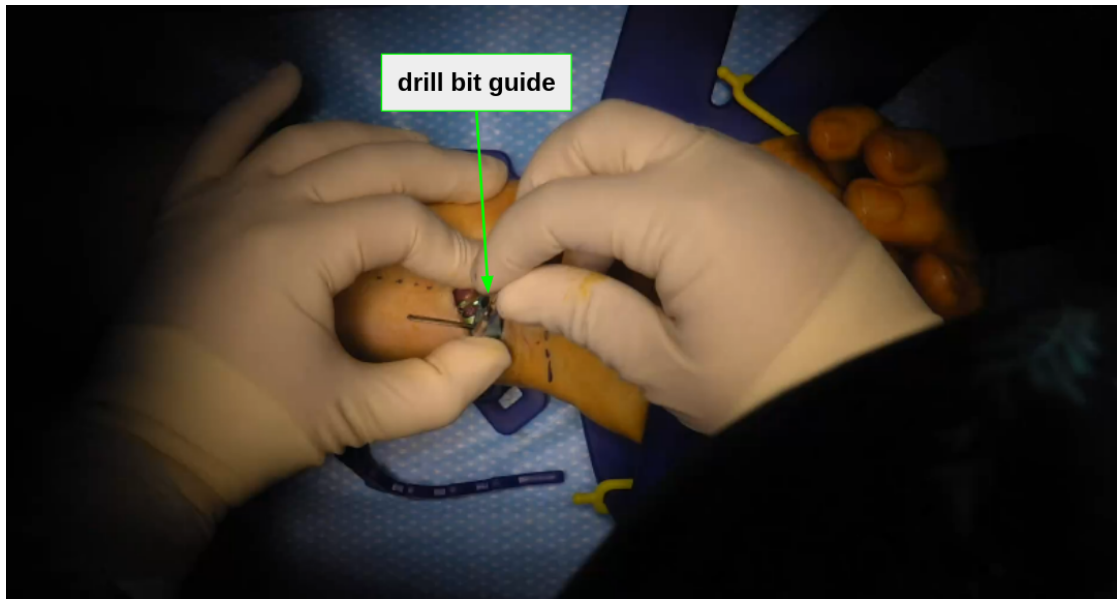


*Figure 16: Motor drilling*

The removal of a drill bit guide begins when the hand of the surgeon enters the camera's field of view and ends when the hand of the surgeon holding the drill bit guide goes back.

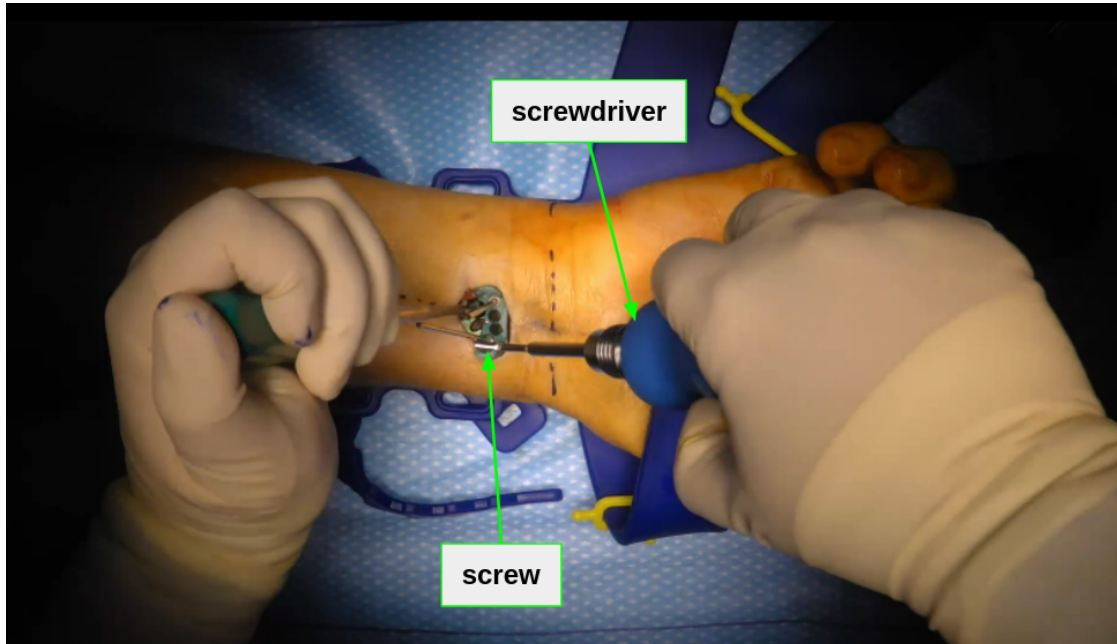
It may happen that the drill bit guide leaves with the motor after a motor drilling. In this case, the action of removing the drill bit guide begins when the motor (with the drill bit guide) starts leaving the hole of the plate and ends when the drill bit guide has left the camera's field of view.

Moreover, when removing a drill bit guide, the surgeon may place the drill bit guide directly into another hole in the plate, without leaving the camera's field of view between these two actions. It is however important to annotate them separately, by ending the annotation of the drill bit guide removal when the surgeon's hand has finished moving backwards and by starting the annotation of the drill bit guide placement at this same moment.



*Figure 17: Removal of a drill bit guide*





























The insertion of a screw starts when the screwdriver (with the screw) enters the camera's field of view and ends when the hand of the surgeon holding the screwdriver goes back and the screw can be seen in place.





*Figure 18: Insertion of a screw*

It is important to notice that an action will be annotated only if it is "fully" performed. For example, sometimes, when the surgeon starts inserting a screw, the screw falls out of the screwdriver. The annotation of this action should therefore not start the first time the screwdriver enters the camera's field of view but only once the surgeon has picked up the fallen screw, put it back on the screwdriver and started his action of inserting the screw again.

**Supplementary Material 3. Summary of the annotations.**

Annotation	Beginning	End
<b>PHASES</b>		
 <b>Installation</b>  phase	Beginning of the video	Beginning of the approach phase
 <b>Approach</b>  phase	Apparition of the scalpel	Beginning of the fixation phase
 <b>Fixation</b>  phase	Beginning of the introduction of the plate sub-phase	Beginning of the verification phase
 <b>Verification</b>  phase	First image, after the last moment when the surgeon touched the proximal screws, where neither surgical instruments nor operator's hands are visible	Beginning of the closure phase
 <b>Closure</b>  phase	Apparition of the Adson-forceps and the needle with the needle holder	End of the video
<b>SUB-PHASES (of the fixation phase)</b>		
 <b>Introduction of the plate</b>  phase	Apparition of the plate	Beginning of the distal fixation sub-phase
 <b>Distal fixation</b>  phase	Apparition of the K-wire	Beginning of the proximal fixation sub-phase
 <b>Proximal fixation</b>  phase	First image, after the last moment when the surgeon touched the distal screws, where neither surgical instruments nor operator's hands are visible	Beginning of the verification phase
 <b>Modification of the plate positioning</b>  phase <i>(not present in all the surgeries)</i>	Plate grabbed to be removed from the wrist	Beginning of the distal fixation sub-phase
<b>ACTIONS</b>		
 <b>Placement of a K-wire</b>  action	Apparition of the K-wire	Disappearance of the motor
 <b>Insertion of a screw</b>  action	Apparition of the screw on the screwdriver	Disappearance of the screwdriver
 <b>Placement of a drill bit guide</b>  action	Apparition of the drill bit guide	Disappearance of the hand or the screwdriver (if used)
 <b>Removal of a drill bit guide</b>  action	Apparition of the hand or the screwdriver handle (if used)	Disappearance of the guide
 <b>Motor drilling</b>  action	Apparition of the motor (motor tip to which the drill bit is attached)	Disappearance of the motor

 <b>Fluoroscopic control</b>  action	Apparition of the plastic of the fluoroscope	Disappearance of the plastic of the fluoroscope
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