# ANALYSIS OF A NEW TOOL FOR ELECTRODE POSITIONING ON THE SCALP ACCORDING TO THE INTERNATIONAL 10/20 SYSTEM

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## 1.- INTRODUCTION

Non-invasive brain stimulation (NIBS) techniques are currently undergoing significant development and research, emerging as a promising therapeutic option for patients [1]. In clinical practice, NIBS techniques are already being applied in several types of pathology such as major depression, neuropathic pain, stroke treatment, obsessive-compulsive disorder or addictions. The emergence of these techniques, together with the development of quantitative analysis of the electrophysiological signal, has spurred the demand for improved precision in localizing cranial points close to their cortical target. In clinical practice, in the absence of neuronavigation systems, the international system (SI) 10/20 method is the most commonly used to localise cranial points [2].

The manual implementation of the 10/20 method presents inherent limitations. Accuracy may be compromised due to the use of a tape measure for measurements, and the need for multiple mental calculations to compute percentages becomes particularly challenging in high-stress clinical settings, such as a busy intensive care unit. It is also a time-consuming process and sometimes requires quick and accurate marking, such as in the context of intraoperative neurophysiological monitoring [3], where the surgical team stands by while the clinical neurophysiologist places the electrodes on the patient's scalp. In addition, it is necessary to remember the position of the electrodes for each given electrophysiological test, as incorrect electrode placement can result in inaccurate diagnostic. Neuronavigation, on the other hand, is a more accurate method, but a complex, time-consuming and expensive system that is currently no feasible in most electrophysiology laboratories [4].

In order to address these challenges, there is a need for a marking tool that can efficiently and precisely guide the placement of electrodes on the cranial surface, tailored to the specific requirements of each neurophysiological test. This is the aim of the EPlacement, a new device developed by our research team. The innovative device offers a solution to the limitations of conventional marking methods by providing a rapid, user-friendly, cost-effective, and accurate approach for identifying the necessary cranial points in various neurophysiological tests.

This study compares the conventional Tape Measure (TM) method and the new EPlacement method for locating the position of electrodes on the scalp for electrophysiological testing. The comparison is made on the basis of the marking accuracy at different positions of the 10/20 system required in three different neurophysiological tests, Additionally, the study evaluates the time required for each method and gathers feedback from healthcare personnel regarding their opinions on each approach.

## 2.- MATERIALS AND METHODS

### 2.1.- INTERNATIONAL SYSTEM 10/20

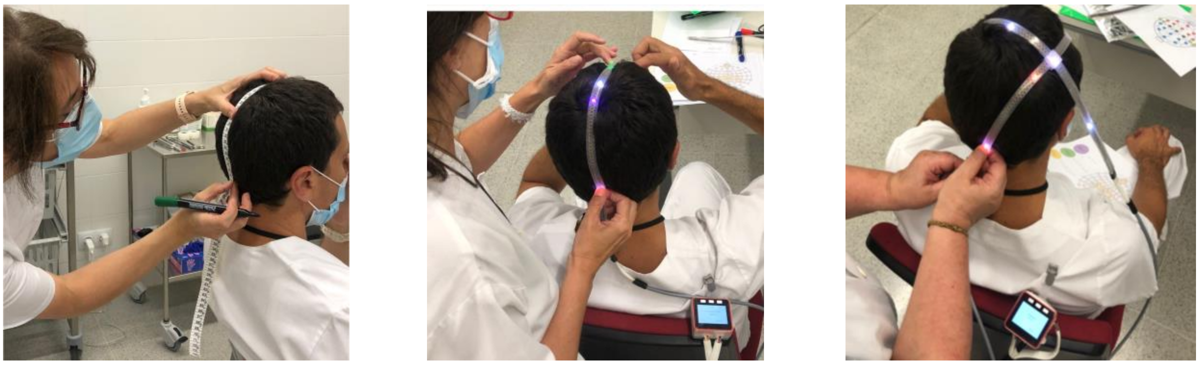
The 10/20 system is a method for determining the location of points on the scalp. The numbers "10" and "20" refer to the distances between adjacent electrodes being 10% or 20% of the total anterior-posterior or right-left distance of the skull. The method relates the location of each point to the underlying area of the cerebral cortex. The nomenclature of each position consists of a letter to identify the underlying brain region, and a laterality identification number. Even numbers correspond to the right hemisphere and odd numbers to the left. The main areas are frontopolar (Fp), frontal (F), central (C), temporal (T), parietal (P) and occipital (O). The "z" (zero) refers to an electrode placed in the cranial midline; thus, the z appears in all central positions: Cz, Fz, Oz, Fpz.

Four anatomical reference points are used to position the electrodes: firstly, the Nasion (Ns), which is the point between the forehead and the nose; secondly, the Inion (In), which is the lowest point of the skull from the back of the head, usually indicated by a prominent cranial protuberance; and the Tragus, the preauricular points anterior to the ear (LPA and RPA). Once these four points are located, the distance between them is measured, as well as the cranial perimeter, and marks are made every 10 and/or 20% of the measured length.

## 2.2.- EPLACEMENT

EPlacement is a tool designed to facilitate accurate electrode placement during electrophysiological studies. It consists of an electronic unit with display, microcontroller and battery; a pressure sensor and a high-density LED illumination system. The electronic unit has a navigation menu that allows the clinician to choose the test to be performed and provides a step-by-step guide for the placement of the electrodes required for each test. This device is currently programmed to guide electrode placement for 11 neurophysiological tests [5] .

The pressure sensor and the illumination system are integrated into the strip and adapt to the shape of the head. The healthcare worker initially adjusts the strip to the head with the cranial references and measures the length of the head using the pressure sensor. The microcontroller performs the necessary calculations to illuminate the LED that indicates the point to be marked on the scalp. The LED strips can produce different levels of brightness and different colours [6]. Two versions of the EPlacement device have been used: one with a single strip (1S-EP) (Figure 1b) and one with two movable strips (2S-EP) (Figure 1c).



a) b) c)

*Fig. 1. Marking procedure in different electrophysiological tests a) Conventional method, b)* 1S-EP. *c)* 2S-EP.

## 2.3.- CLINICAL RESEARCH PLAN

### 2.3.1.- Preliminary considerations

Before carrying out this research, authorisation was received from the Ethics Committee for Research with Medicines (CEIm) of the Institut d'Investigació Sanitària Pere Virgili. The research was carried out by means of a cross-sectional experimental study in which 10 healthcare workers from the Sant Joan de Reus University Hospital carried out a marking on mannequin heads in which the time and accuracy of marking was analysed. Adult volunteers were also marked to answer a survey taking into account the use on human heads. Time and accuracy were not analysed in the volunteers because of the great variability that can exist in hair density and length, as well as cephalic shape.

The markings made on the manikin head correspond to three neurophysiological diagnostic tests, an inverted pattern visual evoked potential (3 electrodes required) (PVEP) [7], somatosensory evoked potentials of the upper and lower extremities (5 electrodes required) (SEP) [8] and intraoperative neurophysiological monitoring (9 electrodes required) (IONM). Marking on the volunteer's head was upper and lower extremity somatosensory evoked potentials (5 electrodes).

The study included 10 clinicians, 5 of whom were experienced in conventional marking and EPlacement (with 1S-EP and 2S-EP subtypes). All of them had performed at least 10 practices with each type of marking (conventional and EPlacement). A 10-minute video, shown just before the marking, explained the EPlacement system to the untrained healthcare personnel. The device itself guides the steps to follow once the test to be performed has been selected. A total of 90 markings were carried out on dummies and 10 markings on volunteers. On the dummies, once each marking was completed, for each position of the 10/20 system, the distances between the experimental points (marked with the EPlacement and TM devices) and the reference positions determined by a 3D printed template were measured.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### 2.3.2.- Description of the study

The study was conducted in two phases. The first phase involved assessing the accuracy and time required for each marking method, namely EPlacement (single and double strip) and tape measure. The health workers performed the markings with each method on three adult manikin heads. To minimize the variability arising from the subjective selection of the anatomical points by each health worker on each dummy, the position of both tragus and Inion were marked. The first and second markings were made with markers that could only be seen under ultraviolet light (blue and pink) so as not to influence the third marking (with tape measure) made with a black marker. Each marking process was timed. Once all markings were completed on the manikins, the points from the first and second markings were highlighted under ultraviolet light, and the difference in millimeters between each point and the reference points, determined by a 3D printed template, was calculated. Additionally, any numerical calculation errors associated with the conventional tape measure method, often resulting from mental calculation errors, were identified.

In the second part of the study, the ease of use and comfort of each method was assessed by means of a survey. Prior to answering the survey, healthcare staff performed a tagging on adult volunteers to assess how the device works on real human heads. Neither time nor accuracy was analysed in this case due to the large variability in head shape and hair length between volunteers. A total of 10 volunteers participated in the SEP marking test, using all three methods. At the end of the marking, they answered the survey.

### 2.3.3.- Methodology for analysing marking errors

#### 2.3.3.1.- Scanning

Thirty-one identical mannequin heads were used to conduct the study. One of them was used for precision structured light scanning (HP 3D Pro S3). Before scanning, the 10/20 positions were marked manually to validate that the points calculated on the 3D scanned model were correct.

#### 2.3.3.2.2.- 3D modelling of the 10/20 system positions

Once the 3D head model of the scanned dummy was obtained (the file resulting from the previous step), the location of the reference points of the 10/20 system was established in order to subsequently calculate the error in the two methods studied (TM and EPlacement). The location of the points was carried out using the Autodesk Fusion 360 software (Figure 2a). With this program, the real locations of the electrodes were determined following the method proposed in the 10/20 system from the Ns-In, LPA-RPA and cranial perimeter measurements obtained by intersecting different planes with the profile of the model.

On the other hand, with the same STL base file, the outer surface was selected and the size of the head was enlarged in the direction normal to the outer surface by 2 mm with the Meshmixer program. The two files were merged and the heads were perfectly centred on each other. The first file had the marked points, which were used as a base, to create holes perpendicular to the surface at the positions of the 10/20 system. Once the holes were made in the template, the file was exported to Prusaslicer for printing (Figure 2b).

#### 2.3.3.3.3.- Printing of the template with the positions of the 10/20 system.

The template was 3D printed with the Original Prusa i3 MK3+ printer (Figure 2c). PLA Prusament Galaxy Black filament material was utilized for the printing process. Openings were incorporated into the template design to enhance flexibility, enabling it to conform to the shape of the manikin head while maintaining the necessary rigidity for accurate positioning reference.

On each dummy, once the markings had been made with both methods, the template was attached (aligning both tragus and Inion) and the reference positions of the 10/20 system were marked using the holes in the template (Figure 2d). Then, using ultraviolet light, the points of the first and second marking (obtained with the two versions of the EPlacement device) were indicated. Finally, for each position of the 10/20 system, the distances between the experimental points (EPlacement and tape measure) and the reference positions (template helmet) were measured. These measurements (EPlacement vs. template and tape measure vs. template) were made with an electronic calliper with a 0.01 mm accuracy. The difference in mm of each point was measured in Euclidean distance and further decomposed on the horizontal axis (LPA-RPA) and on the vertical axis (Ns-In).


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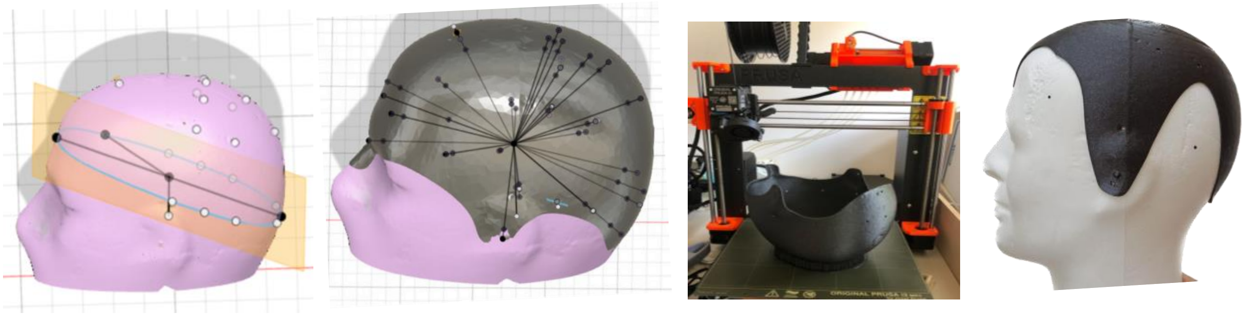


a) b) c) d)

*Fig. 2. 3D printed template. a) 3D modelling of the positions of the 10/20 system. b) Creation of the holes in the template. c) Printing of the template. d) Template attached to the manikin head* [6].

## 3.- RESULTS

### 3.1.- MARKING ACCURACY

The error (ε) was obtained with the Euclidean distance measured with the calliper (EP vs. template and TM vs. template). To analyze the accuracy of the marking, the different electrode positions were divided into two groups: those within the Ns-In and LPA-RPA planes, and those outside of these planes (CP3, CP4, and CPz). This division was made due to the significantly higher error (ε) observed in electrodes that do not align precisely with the Ns-In and LPA-RPA planes. In such cases, sometimes in clinical practice, approximate methods are used or to obtain a position a previous marked point is used (which further contributes to the error). For example, to place the CP3 electrode, in clinical practice the electrode is placed 2 cm below the C3 position (it is in the LPA-RPA plane).

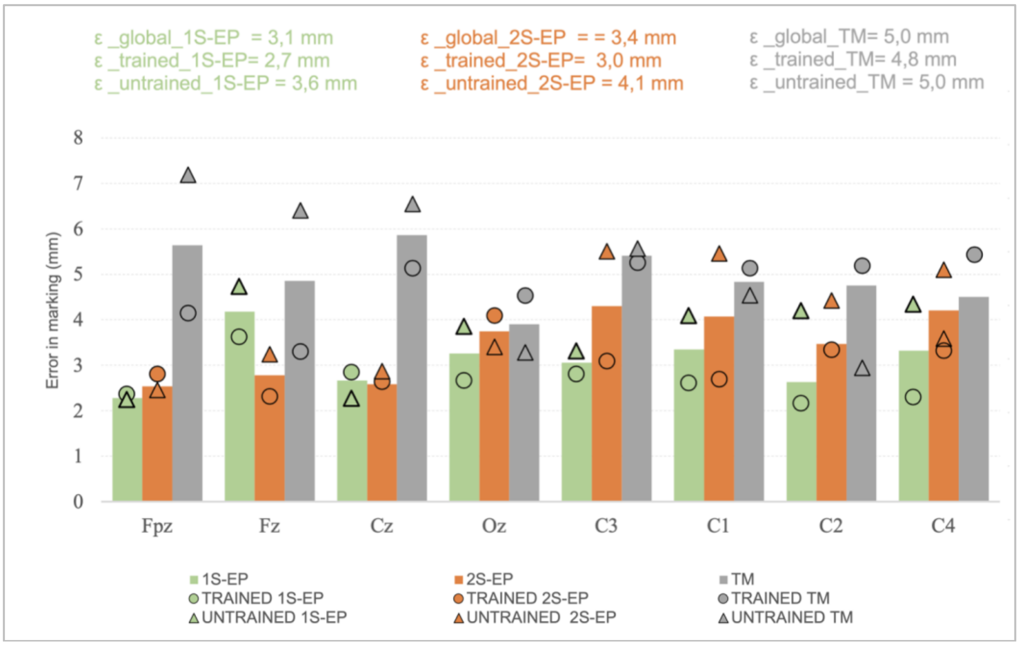
Figure 3 shows a grouped bar chart of the mean distance error per electrode for the three types of marking used, single strip EPlacement (green), two strip EPlacement (orange) and finally the tape measure (grey). Each bar represents the overall mean value of the error at each position, the circle symbol represents trained personnel and the triangle represents untrained personnel.

The results obtained for the positions in the two planes clearly show that the error with tape measure is much higher than that obtained with EPlacement and that the error with EPlacement is similar in both versions (Figure 3a). The mean error with tape measure for trained personnel is 4.8±0.73 mm, with 1S-EP it is 2.7±0.45 mm and with 2S-EP it is 3.0±0.55 mm. On the other hand, for untrained personnel, the mean error with the tape measure is 5.0±1.64 mm, with 1S-EP it is 3.6±0.94 mm and with 2S-EP it is 4.1±1.21 mm.

In the results of the CPz, CP3 and CP4 positions in Figure 3b it can be seen that the trend is the same (the error in tape measure is much higher than that obtained with EPlacement and that the error with EPlacement is similar in both versions) but the error values with tape measure are significantly very high, with an average error with tape measure for trained personnel of 15.3±3.57 mm, with 1S-EP it is 3.9±0.89 mm and with 2S-EP it is 3.2±0.81 mm. For untrained personnel, with a tape measure an error of 17.3±3.96 mm is obtained, compared to 3.8±1.2 mm for an 1S-EP and 4.1±0.22 mm for 2S-EP These three positions are analysed separately from the other positions because in clinical practice they are not positioned according to the international 10/20 system. They are placed 2 cm behind the electrode Cz, C3 and C4 respectively [9].

To identify the direction of the error at each position, the error per electrode has been plotted, taking into account the sign of the coordinates with the origin at Cz and the positive direction of the LPA-RPA axis towards RPA and the positive direction of the Ns-In axis towards Ns. Figure 4 shows that, in the 1S-EP, all positions have a common trend of error towards the right, which may be due to an error in the placement of the strip to the right of the Inion. However, no significant problem is detected in the marking, as the error is less than 1.6 mm. As for the Ns-In axis, errors can be observed in both directions which can be attributed to random errors. The largest error is found at position CP4, with an error of -2.8 mm.

a)




b)

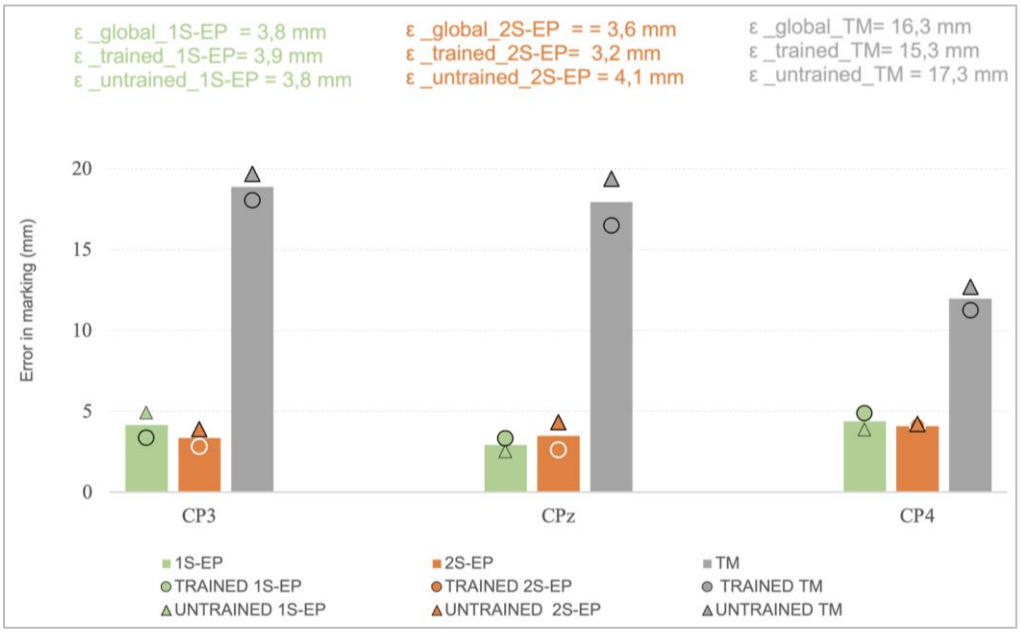



*Fig. 3. Marking error per electrode a) Electrodes Fpz, Cz, C4, C3, Oz, C1, C2, Fz b) Electrodes CP3, CP4 and CPz* [6].



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In 2S-EP, the results are very similar to 1S-EP with most values between -0.3 and 1.2 mm on the LPA-RPA axis and between -2.3 and 1.6 mm on the Ns-In axis. Only the C3 position has a higher error, with an error of 3.3 mm on the LPA-RPA axis.

In the conventional method, a systematic bias towards right-sided markings is observed, which, consistent with previous findings, can be attributed to a misalignment between Inion and the head's symmetry plane. However, the most significant error in the conventional system manifests along the Ns-In axis. Notably, the CP3, CP4, and CPz positions exhibit the highest errors along the Ns-In axis, with values reaching up to 18 mm. In contrast, the remaining positions demonstrate errors of up to 5 mm.

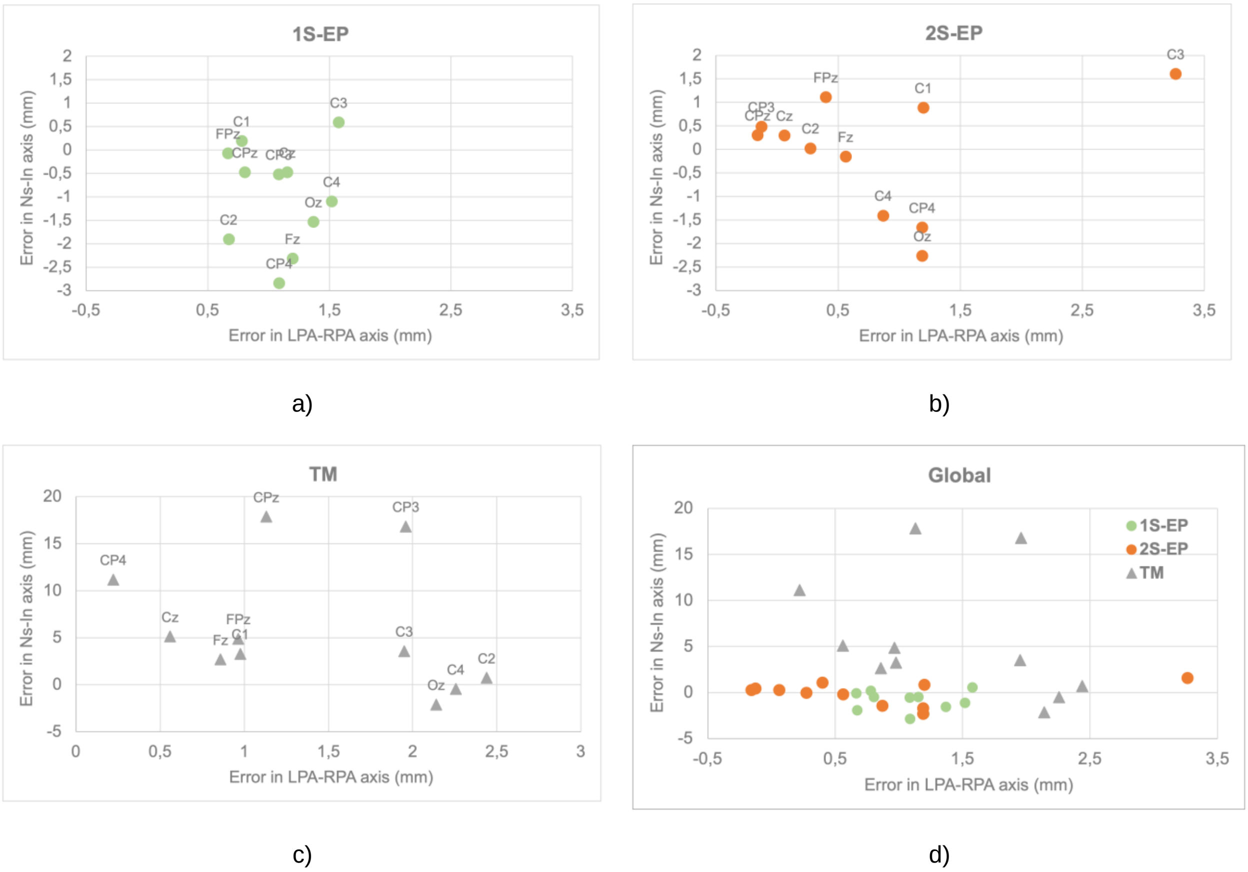



*Fig. 4. Marking error taking into account the sign of the coordinates. a)* 1S-EP*, b)* 2S-EP *c) Tape measure and d) Global*[6].

## 3.2.- TIME SPENT ON MARKING

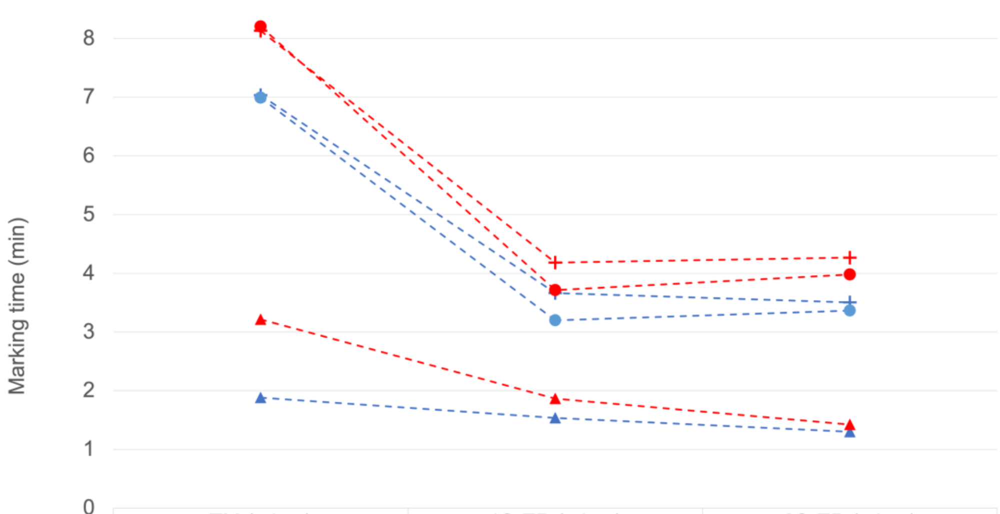
For the analysis of the time used in each type of marking, a timekeeping was carried out. Figure 5 shows the marking time differentiated between trained and untrained healthcare personnel for each test to be performed (PVEP , SEP, IONM). A significant difference is detected between the tape measure and EPlacement (mean of 1S-EP and 2S-EP), with a reduction of 0'28" (25%) in trained PVEP and 1' 35" (49%) in untrained PVEP; 3'27" (49%) in trained SEP and 3'54" (48%) in untrained SEP; 3'07" (49%) in trained IONM and 4' 08" (52%) in untrained IONM. No significant time differences are detected between the one and two-strip versions of EPlacement. The greatest reduction in time is detected in untrained healthcare workers, and the results confirm those obtained in the following section of the survey, as the untrained are the ones who rate the EPlacement the highest for the safety it provides them by informing them step by step of the procedure and the positions to be marked.

In the PVEP with the tape measure between the two groups (trained and untrained staff), there is a difference of 1' 40". It is worth mentioning that the trained personnel performed the marking on a daily basis, and already know the 10/20 system and the positions for each neurophysiological test. From the first test performed, the differences between trained and untrained health workers are reduced, because they have already learned the procedure to be performed.

Secondly, in the SEP the differences are already much more significant between the conventional method and the EPlacement. On the tape measure for this marking, the average time is 7'01'' for trained personnel and 8'07'' for untrained personnel. For the case of EPlacement, the mean time for 1S-EP is 3'39'' for trained and 4'10'' for untrained and for 2S-EP is 3'30'' and 4'16'' respectively. Compared to the conventional method, EPlacement (average of 1S-EP and 2S-EP ) globally (trained and untrained) reduces the time by 40% (60s) in the 3-electrode marking and by 49-50% (217-200s) in the 5 and 9-electrode marking.

Finally, with the IONMs, as they are very similar to the SEP (you have to mark 4 points more), the time is very similar to the previous one, even a little lower. This is probably due to the fact that the markings were done chronologically, first the PVEP , then the SEP and finally the IONM. Therefore, in each test, the agility of the health personnel increased.

Finally, it should be mentioned that between 1S-EP and 2S-EP the results are similar, but it should be taken into account that it has been performed on a mannequin. On the head of a person with hair, this would possibly change, as it is suspected that the 2S-EP would be faster, because it would not be necessary to look for the previous marks in the patient's hair.




| | TM (min:s) | 1S-EP (min:s) | 2S-EP (min:s) |
|---|---|---|---|
| TRAINED PVEP | 01:53,0 | 01:32,3 | 01:18,0 |
| UNTRAINED PVEP | 03:12,9 | 01:52,0 | 01:25,4 |
| TRAINED SEP | 07:02,4 | 03:40,0 | 03:30,3 |
| UNTRAINED SEP | 08:08,2 | 04:11,0 | 04:16,2 |
| TRAINED IONM | 06:59,7 | 03:12,0 | 03:22,0 |
| UNTRAINED IONM | 08:12,7 | 03:43,0 | 03:59,0 |

*Fig. 5. Time of each separate marking in trained (blue) vs untrained (red).*[6].

## 3.3.- OPINION POLL

To assess the satisfaction with the use of EPlacement, each healthcare professional performed a SEP marking on the head of a consenting adult volunteer. No time or precision measurements were taken; the purpose was solely to allow healthcare workers to determine which method was more suitable in a real-world scenario. The opinion survey shows that the healthcare professionals are satisfied with the new method provided with the EPlacement device. The survey has been divided into 2 sections, one for each variant (1S-EP and 2S-EP) of the EPlacement device (Figure 6).

Regarding 1S-EP variant, it can be noted that 80% of the respondents described it as an excellent marking method. Furthermore, 80% say that they are very likely for them to use 1S-EP again, and 70% say that it exceeds their expectations in terms of usefulness. Moreover, when compared to the conventional marking system, 90% of the respondents considered 1S-EP to be the superior choice. Furthermore, 40% mentioned that they are highly likely to recommend 1S-EP to their colleagues. As for the information received about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the use of 1S-EP, half of the respondents indicated that it was good, providing them with a general understanding but leaving some doubts. However, the other 50% responded that the quality of the information was high, precise, and addressed all of their questions.

Similarly, the survey of the 2S-EP version shows that 90% say they are likely or very likely to use 2S-EP again and 80% say it exceeds their expectations of its usefulness. 60% mentioned that they are very likely to recommend 2S-EP to other colleagues. Regarding the information received about the use of 2S-EP, 70% said that it was accurate and 30% were aware of its general characteristics, but had some doubts.

Lastly, only a few participants mentioned aspects they would improve in the 1S-EP. One respondent suggested that it would be beneficial for the device to be more rigid. Another participant stated that marking at the centre of the strip would be preferable, eliminating the need to mark the sides and then reposition the mark in the centre after lifting the strip. Lastly, participants mentioned that a wireless feature would enhance the device by providing better grip and more freedom of movement with their hands.

In conclusion, both versions of the device were perceived as the superior choice compared to the conventional method, as indicated by 90% of the respondents. The survey results clearly demonstrate a strong willingness to incorporate the new device into regular clinical practice.

| | | |
|---|---|---|
| Q1. How would you describe EPlacement 1S-EP as a marking method? | a) Very well | 80% |
| | b) Okay | 10% |
| | c) Neither good nor bad | 0% |
| | d) Functional | 10% |
| | e) Defective | 0% |
| Q2. Are you generally satisfied with EPlacement 1S-EP? | a) Highly satisfied | 30% |
| | b) Very satisfied | 50% |
| | c) Satisfied | 20% |
| | d) Not very satisfied | 0% |
| | e) Completely dissatisfied | 0% |
| Q3: How likely are you to use EPlacement 1S-EP again? | a) Very likely | 80% |
| | b) Likely | 10% |
| | c) Unlikely | 10% |
| | d) Not at all probable | 0% |
| Q4: Do you feel that Eplacement 1S-EP meets your marking needs compared to the traditional method? | a) Exceeds my expectations of usefulness | 70% |
| | b) It solves my needs without providing anything else | 10% |
| | c) It is useful, but there are better options | 10% |
| | d) Does not meet my needs | 10% |
| Q5: Compared to the traditional marking system, how would you rate EPlacement 1S-EP? | a) It is clearly the best option compared to the traditional approach | 90% |
| | b) It is the best option I know of, but I will look for alternatives | 0% |
| | c) It is a good option, but I think there are better options | 10% |
| | d) It will be the option I will choose when the other one is not available | 0% |
| | e) It is the last option because it does not satisfy me at all. | 0% |
| Q6: How likely are you to recommend EPlacement 1S-EP to other colleagues? | a) I will recommend it for sure | 60% |
| | b) It is very likely | 40% |
| | c) It is probable | 0% |
| | d) It is unlikely | 0% |


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| | | |
|---|---|---|
| Q7: What is the quality of the information you received about using EPlacement 1S-EP? | a) High. She was accurate and answered my questions clearly. | 50% |
| | b) Good. It allowed me to know its general characteristics. But I still had doubts | 50% |
| | c) Medium. I was able to know only some characteristics | 0% |
| | d) Low. It does not allow me to know the characteristics | 0% |
| Q8: Do you think that the study conducted allows a valid comparison of EPlacement 1S-EP with the traditional marking method? | a) Yes, it allows an adequate comparison | 80% |
| | b) Allows an approximate comparison | 20% |
| | c) Not entirely adequate | 0% |
| | d) No. It does not allow a correct comparison between both marking methods. | 0% |
| Q9. What aspect of EPlacement 1S-EP would you improve? | | |
| Q10. Other comments or suggestions about 1S-EP | | |
| Q11. How would you describe EPlacement 2S-EP as a dialing method? | a) Very well | 50% |
| | b) Okay | 40% |
| | c) Neither good nor bad | 0% |
| | d) Functional | 10% |
| | e) Defective | 0% |
| Q12. Are you generally satisfied with EPlacement 2S-EP? | a) Highly satisfied | 30% |
| | b) Very satisfied | 50% |
| | c) Satisfied | 20% |
| | d) Not very satisfied | 0% |
| | e) Completely dissatisfied | 0% |
| Q13: How likely are you to use EPlacement 2S-EP again? | a) Very likely | 50% |
| | b) Likely | 40% |
| | c) Unlikely | 10% |
| | d) Not at all probable | 0% |
| Q14: Do you feel that EPlacement 2S-EP meets your marking needs compared to the traditional method? | a) Exceeds my expectations of usefulness | 80% |
| | b) Solves my needs without providing anything else | 10% |
| | c) It is useful, but there are better options | 0% |
| | d) Does not meet my needs | 10% |
| Q15: Compared to the traditional marking system, how would you rate EPlacement 2S-EP? | a) It is clearly the best option in comparison with the traditional method | 90% |
| | b) It is the best option I know of, but I will look for alternatives | 10% |
| | c) It is a good option, but I think there are better options | 0% |
| | d) It will be the option I will choose when the other one is not available | 0% |
| | e) It is the last option because it does not satisfy me at all. | 0% |
| Q16: How likely are you to recommend EPlacement 2S-EP to other colleagues? | a) I will recommend it for sure | 40% |
| | b) It is very likely | 60% |
| | c) It is probable | 0% |
| | d) It is unlikely | 0% |
| Q17: What is the quality of information you have received about using EPlacement 2S-EP? | a) High. She was accurate and answered my questions clearly. | 70% |
| | b) Good. It allowed me to know its general characteristics. But I still had doubts. | 30% |
| | c) Medium. I was able to know only some characteristics | 0% |
| | d) Low. It does not allow me to know the characteristics | 0% |
| Q18: Do you think that the study conducted allows a valid comparison of EPlacement 2S-EP with the traditional marking | a) Yes, it allows an adequate comparison | 80% |
| | b) Allows an approximate comparison | 20% |
| | c) Not entirely adequate | 0% |
| | d) No. It does not allow a correct comparison between both marking methods. | 0% |
| Q19. What aspect of EPlacement 2S-EP would you improve? | | |
| Q20. Other comments or suggestions about 2S-EP | | |

*Fig. 6. Results of the EPlacement device opinion survey, answered after the marking of the different* tests (PVEP, SEP, IONM and SEP in volunteers) [6].

## 4.- CONCLUSIONS

This study demonstrates that the EPlacement device is more accurate and faster compared to the conventional method of cranial point marking as well as it reduces the specific training for electrophysiological tests markings and facilitates the task to the healthcare personnel.

In reference to the error for the different positions of the 10/20 system studied in the three neurophysiological tests carried out, it was found that the error is similar in the positions that are in the Ns-In plane or in the LPA-RPA plane, while the positions that are not in these planes present a greater error with the conventional method due to the use of approximate methods instead of the 10/20 system. On the contrary, with EPlacement this difference is not detected and all positions have a similar error. It is also detected that with the conventional method there is a greater deviation in the Ns-In axis compared to the LPA-RPA axis due to the use of the approximate method in clinical practice instead of the 10/20 system in some positions. In general, an error is also identified due to not positioning the Inion correctly with respect to the plane of symmetry of the head.

The accuracy results yielded comparable outcomes for both trained and untrained personnel. However, notable differences were observed in marking times, with the disparity between trained and untrained individuals being more prominent when using the conventional method. In fact, it is found that with EPlacement the time between trained and untrained is very similar and, therefore, no training is required. Furthermore, it should be noted that EPlacement greatly assists the healthcare staff during the marking procedure. This is due to the automatic calculations it provides, as well as the detailed guidance to indicate the electrode positions required for each test. This decreases the potential for errors in marking because they are not so directly related to the technical knowledge/skills of the staff.

In terms of satisfaction, both versions of the EPlacement device score similarly, with 80% of respondents indicating that they are satisfied or very satisfied with its use and 90% perceiving it as the better option compared to the conventional tape measure method. The staff survey shows a clear willingness to use the new device in routine clinical practice.

It should be noted that these results were obtained by performing the study on mannequins, placed in a comfortable position to make it practical for the healthcare staff. If the study had been carried out on humans, we would expect a greater error in the conventional method, as the measurement of the Ns-In length with tape measure is more difficult and the hair would make it difficult to locate the anterior marks. In addition, given the handicap of the hair, the time would also be increased and, consequently, the differences between the conventional method and EPlacement would be even more significant.

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