EJR European Journal of Rheumatology

DOI:10.5152/eurjrheum.2025.24099

Original Article

Adhering to European Alliance of Associations for Rheumatology Standards: A Visual Representation of Nailfold Videocapillaroscopy Results for Systemic Sclerosis and Raynaud's Phenomenon

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Abstract

Background: This study aimed to create a simplified visual representation of nailfold videocapillaroscopy (NVC) results based on the European Alliance of Associations for Rheumatology (EULAR) standardization. The goal is to enhance the readability and communication of NVC findings among rheumatologists, other specialists, and patients.

Methods: A diagrammatic representation was created using a free-form concept map to illustrate the capillaroscopic results based on EULAR standardization. Three different color-coded diagrams were proposed: a comprehensive and detailed diagram for research, a simplified version for clinical practice, and a minimalistic one for quick reports.

Results: The proposed visual diagrams effectively summarize capillaroscopic results, facilitating quick assessment. Testing with reference images from EULAR standardization demonstrated the practical application of this visual simplification.

Conclusion: Capillaroscopy has many outputs. A visual diagram helps clarify their significance and easily tracks any changes. In this technical note, 3 different diagrams have been proposed; the first one is a comprehensive and detailed diagram suitable for research proposes, the second is simplified, suitable for clinical daily practice, and the third is minimalistic and convenient for quick reports.

Keywords: Capillaroscopy, nailfold videocapillaroscopy chart, nailfold capillaroscopy standardization, Raynaud's phenomenon, systemic sclerosis

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Cite this article as: Wajih MHA, Ghit MM, Fawzy I, Hamoud H. Adhering to EULAR standards: A visual representation of nailfold videocapillaroscopy results for systemic sclerosis and Raynaud's phenomenon. *Eur J Rheumatol.* 2025;12(4),0099, doi:10.5152/eurjrheum.2025.24099 .

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Received: September 26, 2024
Revision Requested: October 30, 2024
Last Revision Received: November 13, 2024
Accepted: November 15, 2024
Publication Date: December 31 , 2024

Introduction

While capillaroscopy has been studied for more than 350 years, the field has seen significant progress with the development of the standardized nailfold capillaroscopy approach by the European League Against Rheumatism (EULAR) consensus. The nailfold videocapillaroscopy (NVC) is a crucial technique that promotes the early detection of systemic sclerosis (SSc) and other conditions marked by peripheral vascular disorders. It is an essential diagnostic procedure for all patients with Raynaud's phenomenon (RP).[1] The first reports of studies with capillaroscopy date back to 1663. Since then, this technique has kept evolving, and recently the great work of Smith et al,[2] provided "the Eular standardization of NVC assessment," which is a consensus viewpoint from capillaroscopy and microcirculation experts on various aspects including image acquisition and analysis, different capillaroscopic techniques, the characteristics of normal and abnormal capillaroscopic findings, their significance, scoring systems, and the reliability of interpreting images. In this technical note, we want to add a simplification step that represents the results visually, which will include all the essential data in the form of a colored diagram built on the previous Eular standardization works.

Approximately 50% of all diagnostic errors result from incorrect cognitive processing of data; many of these problems can be addressed by enhancing data visualization. Developing and promoting these visualization techniques will have a game-changing impact on current research, communication, training, and clinical practices.[3]

Visualization is the process of representing data using effective visual components, including charts, plots, diagrams, infographics, and animations. These visualizations facilitate the transmission of data-driven knowledge and simplify complex data relationships representation.[4] Diagrams are examples of graphical illustrations used to clarify the relations between the parts they represent. There are several subcategories of the wider term "diagram," which are characterized by the elements they integrate or their overall topic. Two leading subcategories comprise "concept maps" and "mind maps."[5] As far as we are aware, capillaroscopic results reports are not visually represented. We, therefore, propose this "Free-form concept map" diagram, which fits well with the requirements of this topic.

Material and Methods

In this technical note, human participant recruitment or data collection was not involved. The visual diagrams were developed by analyzing previously published capillaroscopy images and data from the EULAR consensus paper by Smith et al.[2] Therefore, ethics committee approval and informed consent were not applicable.

First, we analyzed the table approved by the EULAR standardization of nailfold capillaroscopy consensus published in the article titled "Standardization of nailfold capillaroscopy for the assessment of patients with RP and systemic sclerosis"[2] (Figure 1). The table consists of 4 rows that represent the capillaroscopic characteristics and 7 columns that represent all the possible results generated from different combinations of these capillaroscopic characteristics, which are defined according to the EULAR Study Group on Microcirculation in Rheumatic Diseases as follows:

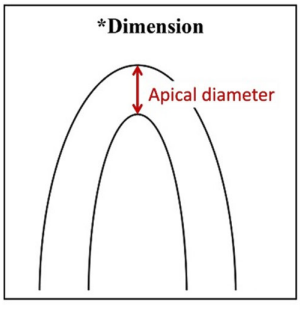
- Capillary dimension: normal (apical limb width ≤20 µm), dilated (20-50 µm), or megacapillaries (≥50 µm).
- Microhemorrhages: the presence of spots with color tends to move from dark red to light yellow in the pericapillary and/or periungual area. They are usually absent in normal NVC.
- Capillary density: defined as the number of capillaries of the distal row adjusted per millimeter of the nailfold. In healthy adults, the normal capillary density ≥7 capillaries/mm.
- Capillary morphology: normal capillaries typically exhibit a "hairpin" shape. Variants, such as single or double cross shapes or tortuous forms (in which the afferent and efferent limbs bend without crossing), are also considered normal, provided the capillary tip remains convex. Any other capillary morphology (such as ramified, bushy capillaries, etc.) is considered abnormal (Figure 1). This structural disorganization can be assessed semi-quantitatively in categorical terms as normal morphology, moderate disorganization, or severe disorganization.[2]

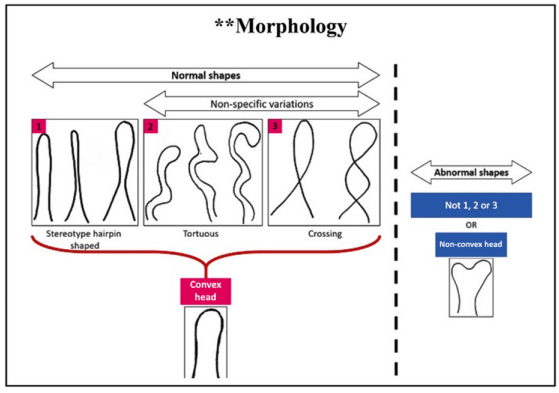
Subsequently, each characteristic is represented by a teardrop shape in the diagram as follows (Figure 2):

- Dimension of capillaries and megacapillaries: thick red teardrop shape.
- Presence of hemorrhage: dotted red teardrop shape.
- Capillary density: thick blue teardrop shape.
- Presence of abnormal morphology: dotted blue teardrop shape.

The name of each shape is noted inside it, and a small box below the name shows its value. The intersections of these 4 teardrop shapes in the diagram give all the possible probabilities of capillaroscopy results, whatever the capillaroscopic characteristics assortment. Each intersection will be allocated to the appropriate area "capillaroscopic pattern" according to

Capillaroscopic characteristics	Category 1					Category 2		
	Non-scleroderma pattern					Scleroderma Pattern		
	Normal	Non-Specific Abnormalities If any of the capillaroscopic characteristics is abnormal, alone or in any combination, as highlighted in yellow				Early	Active	Late
Density (/mm)	≥ 7	↓				≥ 7	Lowered density (4-6)	Further lowered density (≤3)
Dimension (µm)*	Normal		20-50			> 50 (giant)	> 50 (giant)	-
Abnormal morphology**	-			+		-	+	++
Haemorrhages	-				+	+/-	+/-	-





Some notes, considering scleroderma patterns:

i. The early pattern NEVER presents with lowered density (cut-off ≥ 7 capillaries /mm).
ii. The active and late patterns ALWAYS present with lowered density (< 7 capillaries /mm); however, the cut-offs are not absolute.
iii. In the active pattern, the loss of capillaries is **combined** with giant capillaries;
In the late pattern, the loss of capillaries is **combined** with abnormal shapes.
iv. In the late pattern, giant capillaries are NEVER found

Figure 1. EULAR study group on microcirculation in rheumatic diseases standardized capillaroscopy evaluation chart. This figure details the capillaroscopic characteristics and their definitions. From Smith et al (2020), licensed under CC-BY-NC-ND.

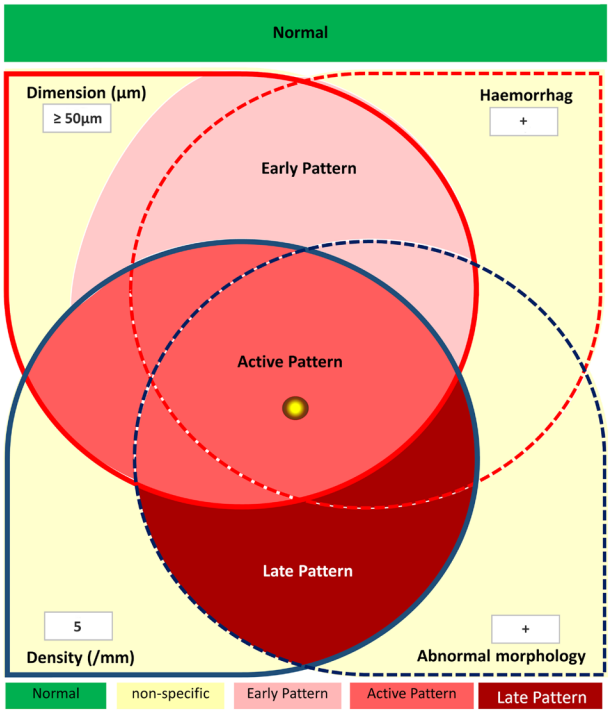


Figure 2. Visual representation of nailfold videocapillaroscopy results built on EULAR standardization, using a comprehensive and detailed diagram suitable for research purposes. Each colored area in the diagram has a color-coded key at the bottom of the diagram that explains its meaning.

the EULAR definitions. The different areas of the diagram are colored to represent all possible outcomes: healthy (green), non-specific abnormalities (yellow), early scleroderma pattern (light red), active scleroderma pattern (red), and late scleroderma pattern (dark red).

Once the values of the 4 capillaroscopic characteristics are obtained, each value is initially registered in the corresponding box. Subsequently, the intersection on the diagram where these values converge is identified. Accordingly, a small dot, "result point (Rp)," will be placed at this intersection which eventually represents the final visual outcome that summarizes in a simplified way, the outcome of the capillaroscopy result. The concept of this diagram is similar to that of the bone densitometry graph, and the final output is comparable to the bone density DXA scan graph, where a dot indicates bone density (Figure 3).

If the capillaroscopy result is free of any abnormality, the person is considered healthy and the Rp will be placed in the green rectangular section on the top of the diagram. Conversely, the Rp will be placed in the diagram's yellow area if only 1 characteristic is present. In this case, the abnormalities are regarded as non-specific and the absence of a scleroderma pattern, except for:

- Megacapillaries with dimension ≥50 µm; if present it is a sufficient criterion for the diagnosis of early pattern.
- Capillary density less than 3 capillary/mm is a strong indicator for scleroderma pattern.[6]

The Rp will be placed in the diagram's light red area in the presence of megacapillaries and hemorrhage, indicating an early scleroderma pattern. The Rp will be placed in the diagram's red area in the presence of megacapillaries, hemorrhage, low capillary density, abnormal morphology, and ±hemorrhage, indicating an active scleroderma pattern. The Rp will be placed in the diagram's dark red area in the presence of low capillary density and abnormal morphology, indicating a late scleroderma pattern.

A more simplified diagram is also proposed, and considering that capillary density is the main and most important capillaroscopic feature in determining patient prognosis, it has been assigned to the Y-axis, while the X-axis represents the overall worsening of the other 3 NVC features, the Rp will be represented by a triangle, each side of it represents one of the other features of the capillaroscopic feature (dimension of capillaries, hemorrhage, and abnormal morphology), and their values will appear in the diagram with only a positive or negative symbol according to its presence or absence in the patient's data (capillary dimension between 20 µm and 50 µm will be presented by a ± symbol), this simple diagram is the most important version and is suitable for clinical everyday practice (Figure 4).

In this simplified diagram, the different parts are re-arranged. The intersessions have been merged and re-shaped to create a more convenient visualization. The exact position of the Rp in the diagram is determined by the value of the capillary density on the Y-axis and by the overall combination of the 3 other NVC features on the X-axis. The Rp will be placed in the correct corresponding area in the diagram in a manner similar to the previous diagram. In the Eular standardization, there were only semi-quantitative estimates of capillary dimension,

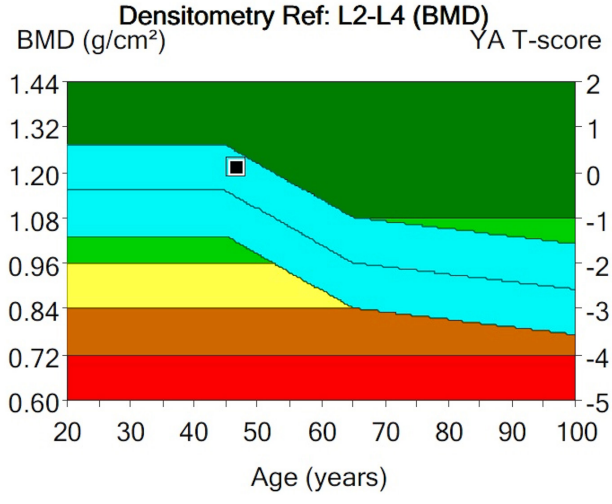


Figure 3. Example of bone densitometry results, with a point indicating the severity of osteoporosis. Source: "Bone Density Results." Chatswood Densitometry, n.d. Web. Accessed July 7 2024. https://www.chatswooddensitometry.com.au/bone-density-results.html.

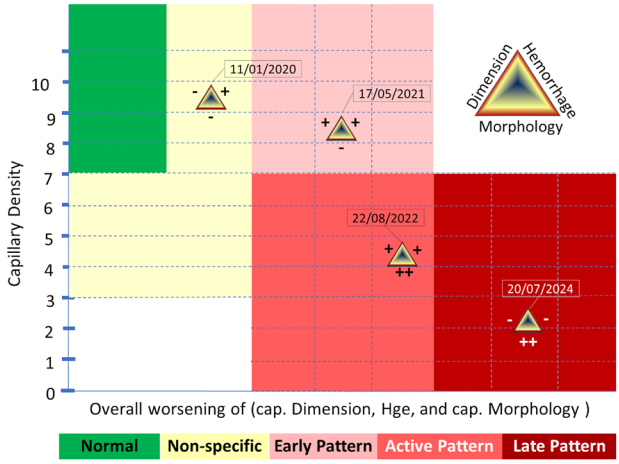


Figure 4. Simplified visual representation of nailfold videocapillaroscopy results built on EULAR standardization. It is the most suitable diagram for daily clinical practice. The exact position of the result point (triangle) in this diagram is determined by the value of the capillary density on the Y-axis and by the overall worsening of the 3 other NVC characteristics on the X-axis (Capillary Dimension, Hemorrhage, and Capillary Morphology), which were estimated semi-quantitatively according to the EULAR standards. Cap, capillary; Hge, hemorrhage. Each colored area in the diagram has a color-coded key at the bottom of the diagram that explains its meaning.

hemorrhage, and capillary morphology, not quantitative ones. Therefore, in this diagram, the Rp on the X-axis is approximate. In the near future, this issue may be addressed by implementing automated software analysis for capillaroscopic images, with fast analysis and accurate quantitative measurements.[7]

Another minimalistic diagram is also provided, made up simply of a rectangular color-coded diagram representing the different patterns that a patient can fall into. The result point (Rp) will be represented by a small square, and each side of it represents one of the capillaroscopic features (dimension of capillaries, hemorrhage, abnormal morphology, and capillary density). The values of each characteristic will appear in the diagram with only a positive or negative symbol according to its presence or absence in the patient's data, except for capillary density, which will represented by its exact numerical value. This minimalistic diagram may be more convenient for rapid NVC reporting and to simplify the explanation for patients (Figure 5).

When the patient has multiple visits with NVC follow-up, each session can be represented by a distinct Rp with the date of the session on it. In every subsequent capillaroscopic assessment, a new point will be added to the same diagram with its respective date. Accordingly, we can follow the NVC changes and track the effectiveness of the disease control (Figure 4).

Results

The best way to test and practically explain this visual simplification is to apply it to the reference images in the same Eular standardization article (Figure 6). In the upper part of Figure 6, the original images represent the exemplary samples of different scleroderma patterns, with a detailed explanation of each one below it. A visual diagram in the row (A) has been added below each image explanation, and then according to each image data, an Rp is placed in its correct position in the diagram to reflect in an inclusive visual manner the final capillaroscopic result. As an example, in image (Figure 6), capillaroscopic characteristics were as follows:

Capillary density: 8 capillaries in 1 linear mm.
Dimension of capillaries: presence of giants with a diameter ≥50 µm.
Morphology: hairpin-shaped capillaries.
Hemorrhages: present.

The data were first added to the diagram in the corresponding boxes, and the abnormal values were determined. In this case, only the dimension and presence of hemorrhage were abnormal. Therefore, the intersection of these 2 characteristics in the diagram is the correct part to add the Rp, which was in this case fell into the light red area, indicating the early scleroderma pattern.

Adding data and placing the Rp can be done manually or automatically when this diagram is incorporated into any automated software.

The same data are also represented more easily in the raw (B) with a further simplification emphasizing the practical viewpoints. An Rp in the form of a triangle was placed according to the CD value on the Y axis, and the values of the 3 other capillaroscopic features on the X-axis. The sides of the triangle represent these features: a (+) sign on the right side indicates the presence of megacapillaries, a (+) sign on the left side indicates the presence of hemorrhage, and a (-) sign at the bottom indicates

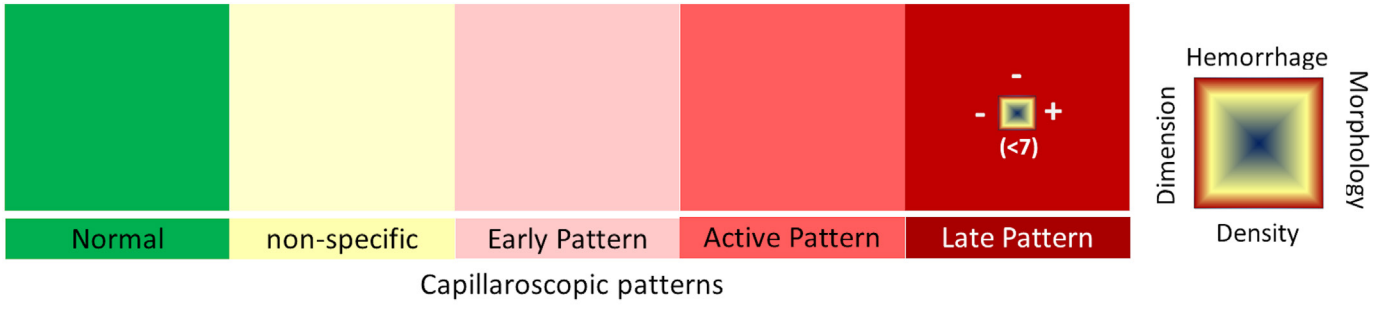


Figure 5. Minimalistic visual representation of nailfold videocapillaroscopy results built on EULAR standardization, convenient for quick reports. Each side of the small square (result point) represents 1 capillaroscopic characteristic: capillary dimension, hemorrhage, abnormal morphology, and capillary density. As illustrated in the box to the left of the diagram, each characteristic will be marked in the diagram with a positive or negative symbol, indicating its presence or absence in the patient's data. However, capillary density will be shown as an exact numerical value, which for a late pattern will be <7 capillaries/mm. Each colored area in the diagram has a color-coded key at the bottom of the diagram that explains its meaning.

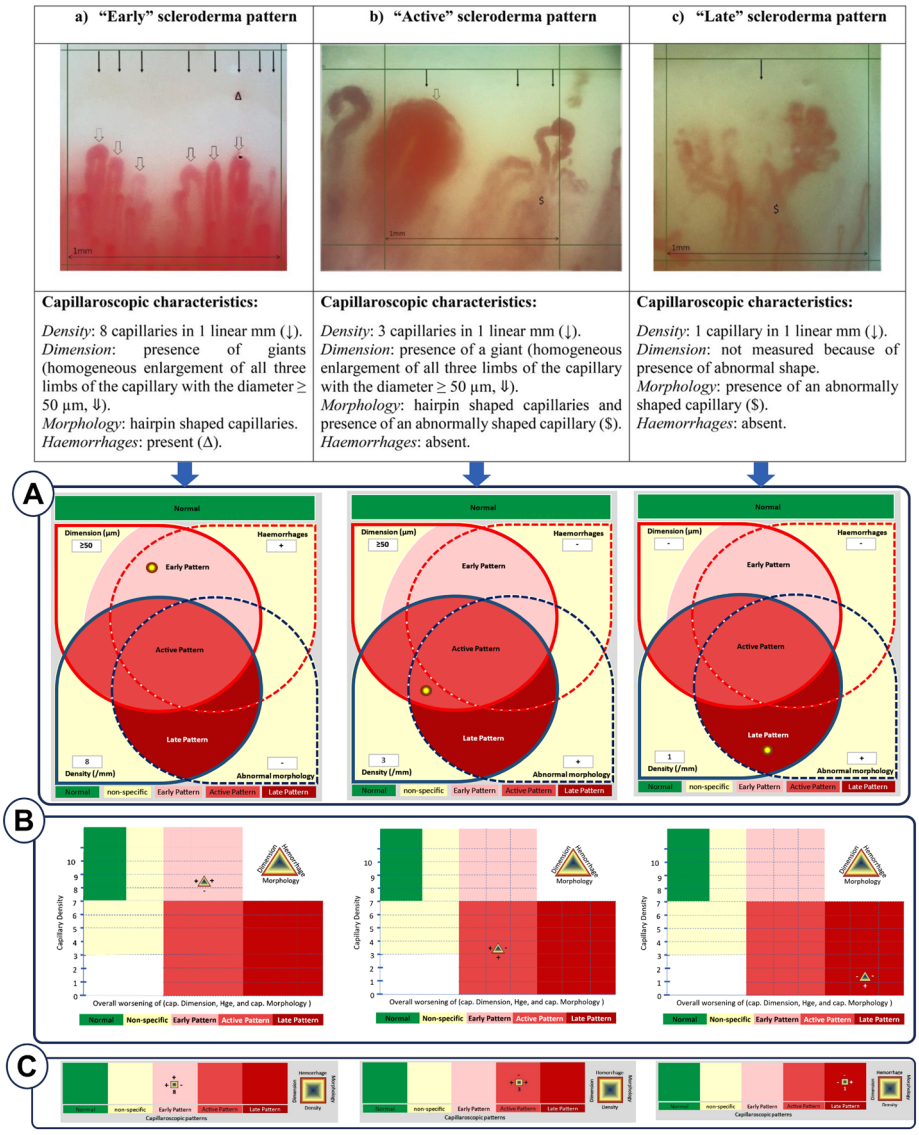


Figure 6. Above are examples of "scleroderma pattern" images from EULAR study group with their capillaroscopic characteristics (Smith et al., 2020), licensed under CC-BY-NC-ND. Below: row (A) the proposed detailed visual presentation for each image, row (B) the more simplified presentation of the same data, and row (C) the minimalist visual presentation. Cap, capillary; Hge, hemorrhage.

the absence of abnormal capillary morphology. According to these values of the Y and X-axes, the Rp was placed in the light red part of the diagram, indicating the early scleroderma pattern.

In the Raw (C), a minimalistic visual diagram represents the same data, allowing for quick interpretation at a glance. The Rp is represented by a small square, and each side of it represents one of the capillaroscopic features; with a (+) sign on the right side indicating the presence of megacapillaries, a (+) sign on the top indicating the presence of hemorrhage, a (–) sign on the left side indicating the absence of abnormal capillary morphology, and a numerical value (8) on the top indicating the number of capillaries. The overall combination of these values represents the early scleroderma pattern.

The same steps can be applied to the rest of the images to obtain a simple and clear visual representation, as shown in Figure 6.

Discussion

Diagrams are frequently used in medical literature to convey complex information clearly and understandably. Visual demonstrations that are well-designed have a special ability to convey complicated information. They can display the data's structure and intricate patterns that are challenging to describe in words.[8] Regarding the capillaroscopy technique, this approach offers several advantages: it simplifies the interpretation of capillaroscopy results, tracks changes over time, and facilitates communication of findings with rheumatologists, other specialists, and even patients for educational purposes.

The significance, utility, and effectiveness of these diagrams can be anticipated by comparing them to the closely similar bone density DXA scan graphs, which have significantly improved report writing and taken it to a new level. Just as DXA scan graphs provide a comprehensive overview of bone health and facilitate the diagnosis and management of osteoporosis, capillaroscopy diagrams can play a crucial role in diagnosing and managing SSc and related conditions.

Furthermore, diagrams can significantly reduce cognitive load by presenting difficult information in a visually appealing way, which improves comprehension and retention. By providing a common visual language, these diagrams bridge communication gaps among medical professionals and enhance the collaborative approach needed for complex patient care. As healthcare becomes increasingly data driven, the role of visualizations like these is likely to expand, providing critical support in decision-making and patient education.

We attempt to contribute through this small step in the ongoing advancement of capillaroscopy. These diagrams need to be refined and adapted by researchers, clinicians, and software developers and integrated into the automated capillaroscopic software reports.

This visual representation has some limitations since it is built on the EULAR Standardization intended for the assessment of patients with RP and SSc; therefore, it does not cover all the capillaroscopic characteristics, such as capillary microcirculation and blood flow velocity. It still needs further validation by experts and researchers at a multi-center level.
Data visual representation facilitates its interpretation. Capillaroscopy has many outputs; visual diagram helps clarify their significance and allow tracking of any changes easily. In this technical note, we have proposed 3 different diagrams: the first one is a comprehensive and detailed diagram suitable for research purpose, the second is simplified, suitable for clinical daily practice, and the third is a minimalistic one, convenient for quick reports.

Data Availability Statement: All data relevant to the study are already presented in the article.

Ethics Committee Approval: N/A.

Informed Consent: N/A.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – M.W., H.H.; Design – M.W., H.H.; Supervision – H.H., M.G.; Resources – M.W., I.F.; Materials – M.W., M.G.; Data Collection and/or Processing – M.W., I.F., M.G.; Analysis and/or Interpretation – M.W., I.F.; Literature Search – M.W., M.G.; Writing – M.W.; Critical Review – H.H., I.F., M.G.

Declaration of Interests: The authors have no conflict of interest to declare.

Funding: The authors declared that this study has received no financial support.

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