# THE UTILITY OF USB MICROSCOPE FOR ASSESSMENT OF RAYNAUD'S PHENOMENON PATIENTS IN RHEUMATOLOGY PRACTICE

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***Abstract. The aim*** *of the study was to assess the utility of USB microscope (DinoLite) for evaluation of patients with primary and secondary Raynaud's phenomenon (RP) in rheumatic diseases, using magnification 200x.* ***Methods:*** *The study represents retrospective analysis of capillaroscopic images of 53 patients with RP – primary and secondary in the context of systemic sclerosis (SSc) or other rheumatic diseases, i.e., undifferentiated connective tissue disease (UCTD), prescleroderma and systemic lupus erythematosus (SLE). Capillaroscopic images are obtained from 8 fingers (II÷V bilaterally) using USB microscope (DinoLite) at magnification 200x. Capillary diameters were measured (arterial, venous and apical loop) as well as the number of capillaries per millimeter and capillary length. The capillaroscopic images were categorized into the following groups, i.e., 1. absence of microangiopathy: i) normal pattern, ii) nonspecific changes; 2. presence of microangiopathy, i.e., "scleroderma/ scleroderma-like" pattern.* ***Results:*** *Images suitable for analysis with good visibility that permit analysis of the major capillaroscopic parameters were available in all patients (100%). Among 53 included patients, 14 patients were with SSc, 12 cases with primary RP, and 27 patients with secondary RP in other connective tissue diseases (22 patients with UCTD, 1 – with prescleroderma and 4 patients with SLE). „Scleroderma" pattern was detected in 11 patients with SSc and in all these cases the capillaroscopic images were classifiable into one of the three distinct validated phases, i.e., "early", "active" and "late". Presence of microvascular changes type "scleroderma-like" pattern was detected also in 17 among 27 patients with other connective tissue diseases. In primary RP patients, capillaroscopy revealed either normal pattern or nonspecific findings, but without features of microangiopathy.* ***Conclusion:*** *Capillaroscopic images of good quality, which could be analyzed and interpreted, are usually obtained using USB microscope. This permits evaluation of the major capillaroscopic parameters including quantitative measurement of the capillary diameters, capillary density and length. Assessment of the degree of microvascular changes, i.e., staging of microangiopathy is also applicable and was possible in all cases with microangiopathy. The available software although less sophisticated vs those of videocapillaroscopes, provides the opportunity for adequate analysis of capillaroscopic parameters. The images obtained via USB microscope using magnification 200x are easily classified into "scleroderma"/"scleroderma-like" pattern, non-specific changes and normal findings using also the software of the device. Thus, USB microscopes using standard, 200x magnification could be suggested as an alternative of videocapillaroscopes in every day rheumatology practice especially in low-budget cases.*

***Key words:*** *USB microscope, nailfold capillaries, Raynaud's phenomenon*

## Introduction

Nailfold capillaroscopy is a non-invasive method for assessment of nailfold capillaries with a strategic role for differential diagnosis of Raynaud's phenomenon (RP) in rheumatology [1]. Presence or absence of microangiopathy at capillaroscopic examination is of key importance during the initial assessment of RP patients in rheumatology practice [2]. Capillaroscopic examination during the follow-up is necessary to assess progression of microvascular pathology or in some cases for evaluation of therapeutic response [3, 4, 5, 6, 7]. In rheumatology, reference pattern of microvascular pathology is "scleroderma" pattern that is characterized with presence of giant capillaries, microhemorrhages, avascular areas and neoangiogenic, bushy capillaries [8, 9, 10]. "Scleroderma" type capillaroscopic pattern is accepted as a diagnostic criterion in the 2013 EULAR (European League Against Rheumatism)/ACR (American College of Rheumatology) classification criteria for systemic sclerosis (SSc) [11].

Analogous microvascular changes that are called "scleroderma-like" capillaroscopic picture could be found in diseases different from SSc such as dermatomyositis, overlap syndromes, undifferentiated connective tissue disease (UCTD) as well as

in systemic lupus erythematosus (SLE) and rheumatoid arthritis, including without presence of overlap with SSc [9, 12, 13, 14, 15, 16, 17, 18].

Videocapillaroscopy is the gold standard for evaluation of nailfold capillaries and the major tool used for differentiation of primary and secondary RP in rheumatology practice. However, nowadays, there are also accessible alternatives such as USB microscopes, which offer the opportunity to apply capillaroscopic examination at a significantly lower price [19]. Digital USB microscopes are compact portable devices, whose optical system is located in the contact probe, which is connected via a USB cable to a computer. USB microscopes provide variable magnifications. They are registered as medical devices and are available for performing dermatoscopy, capillaroscopy (e.g. DinoLite 200Pro–magnification from 20x to 200x; as well as variants with higher magnifications up to 500x; DinoLite, the Netherlands). The switch to the higher magnifications is done through zoom function and focus. The presence of polarization further increases the image quality. Control of magnification and polarization is carried out by rotating movements of respective mechanisms on the contact probe. In the adjacent area there is also a sensor, through which capillaroscopic pictures are taken when touched. There is a possibility of connecting a pedal switch for taking pictures. The software of USB microscopes is not specialized. In contrast to the specialized software of videocapillaroscopes, here in the software of the USB microscopes, the stored images are not arranged in folders on the respective fingers on which they were made, and there is no possibility to automatically enclose a frame for measuring capillary density. It is necessary to manually mark a field with a length of 1 mm (Fig. 1, 2, 3). Despite these limitations, USB microscopes offer good opportunities for diagnostic purposes in terms of image quality, quantitative analysis and are significantly cheaper as compared to videocapillaroscopes [2, 19, 20, 21]. The number of published studies that assess capillaries in the nailfold area using USB microscopes in healthy subjects and in patients with rheumatic diseases is increasing [19, 20, 21, 22, 23, 24, 25].

## The aim of the study

The aim of the current study was to assess the utility of USB capillaroscope (DinoLite) for evaluation of patients with primary and secondary RP in rheumatic diseases, using magnification 200x.

## Patients and methods

The study represents retrospective analysis of capillaroscopic images of 53 patients with RP – primary and secondary in the context of SSc [11] or other rheumatic diseases, i.e., UCTD [26], prescleroderma [27] and SLE [28]. The accepted classification criteria of the scientific societies were used for the diagnoses SSc [11] and SLE [28]. The diagnosis UCTD was established according to the authors' criteria of Mosca et al. [26], and the criteria of Le Roy and Medsger for prescleroderma were used [27]. The criteria of Maverakis et al. (2014) were used for the diagnosis primary RP [29]. All the patients had signed an informed consent for participation in the study. Capillaroscopic images are obtained from 8 fingers (II÷V bilaterally) using USB microscope (DinoLite) at magnification 200x. Capillary diameters were measured (arterial, venous and apical loop) as well as the number of capillaries per millimeter and capillary length. The capillaroscopic images were categorized into the following groups, i.e., 1. absence of microangiopathy: i) normal pattern, ii) nonspecific changes (dilated capillaries with arterial diameter > 0.015 mm, venous > 0.020 mm; hemorrhages; presence of elongated or increased number of tortuous capillaries); 2. presence of microangiopathy, i.e., "scleroderma"/"scleroderma-like" pattern.

Definitions of major capillaroscopic parameters were used as suggested by Schmidt et al. (1997). Capillary diameter higher than 50 μm (0.050 millimeter/mm) is the known definition for giant capillary loop. Capillaries with arterial diameter > 0.015 mm (15 μm) and venous > 0.020 mm (20 μm), but below 0.050 mm (50 μm) are defined as dilated. Normal capillary density varies between 7 and 16 capillaries per mm. Devascularization is present when it is lower than 7 per mm. Capillaries with atypical morphology (bushy and branching) are determined as neoangiogenic [30]. Capillaries longer than 300 μm were considered elongated [31].

The "Fast Track algorithm" suggested by EULAR Study Group on Microcirculation in Rheumatic Diseases was used. The algorithm suggests quick differentiation between "scleroderma" and "non-scleroderma" pattern. In the presence of giant capillaries the capillaroscopic changes are defined as "scleroderma" pattern. If capillary density is ≥ 7 capillaries/mm and giant capillaries are absent, capillaroscopic findings are defined as a "non-scleroderma pattern. In cases of advanced capillary loss with capillary density ≤ 3 capillaries/mm and in the presence of capillaries with atypical morphology, it is recom-

mended to check for “late” scleroderma pattern [32]. Presence of giant capillaries with capillary diameter > 0.050 mm was considered as a sufficient criterion for classifying the image as “scleroderma”/”scleroderma-like” pattern [33]. For “scleroderma” type images in SSc patients staging of Cutolo et al. (2000) was used, i.e., “early”, ”active”, ”late” phase. “Early” phase is characterized with presence of few giant capillaries, microhemorrhages, preserved capillary density and distribution. In the “active” phase, giant capillaries and microhemorrhages are frequent and are associated with moderate devascularization and capillary derangement. Neoangiogenic capillaries are few or absent in the “active” stage. In the “late” phase devascularization and capillary derangement are severe. Neoangiogenic ramified capillaries are characteristic finding. Microhemorrhages are absent and giant capillaries are single or absent [34].

## Results

53 patients with RP were included in the study including 12 patients with primary and 41 patients with secondary RP, i.e., 14 patients with SSc, 22 patients with UCTD, 1 patient with prescleroderma and 4 SLE cases. Demographic data of the patients are presented in Table 1.

***Table 1. Demographic data of the patients***

| Patient group | Age and gender |
|---|---|
| Primary RP<br>n = 12 | Females<br>mean age 41.5 ± 16.73 years |
| SSc<br>n = 14 | 13 females, 1 male patient<br>mean age 49.42 ± 17.16 years |
| UCTD<br>n = 22 | 20 females, 2 male patients<br>mean age 39 ± 15 years |
| Prescleroderma<br>n = 1 | Female<br>age 48 years |
| SLE<br>n = 4 | Females<br>mean age 35 ± 2 years |

Interpretable images, i.e., images suitable for analysis with good visibility that permit analysis of the major capillaroscopic parameters (including quantitative measurement of capillary density, diameters and length) were available in all patients (100%). In all cases with microangiopathy (“scleroderma”/”scleroderma-like” pattern), determination of the degree of microangiopathy, i.e., staging of the capillaroscopic images was possible.

„Scleroderma“ pattern was detected in 11 patients with SSc and in all these cases the capillaroscopic images were classifiable into one of the three distinct phases i.e., “early” (n = 2), ”active” (n = 5) and ”late” phase (n = 4) (Fig. 3, 4, 5, 6). Considering capillary inhomogeneity at different fingers, the most advanced capillaroscopic changes that were registered are documented as a final conclusion [35].

Presence of microvascular changes (“scleroderma-like” pattern) was detected also in 15/22 patients with UCTD (all of them were classified as an “early” phase), in 1 patient with prescleroderma (“early” phase) and in 1 case with SLE (“active” phase). In primary RP patients, capillaroscopy revealed either normal pattern (n = 2) or non-specific findings (n = 10) but without features of microangiopathy.

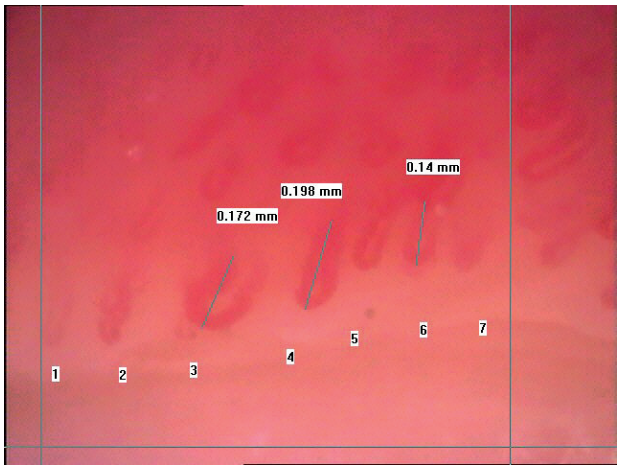



***Fig. 1. 1 mm grid marked with the software of videocapillaroscope. Measurement of mean capillary density per 1 mm and capillary length is demonstrated. Numbers in the image are generated from the software of the videocapillaroscope (Videocap 3.0, magnification 200x)***

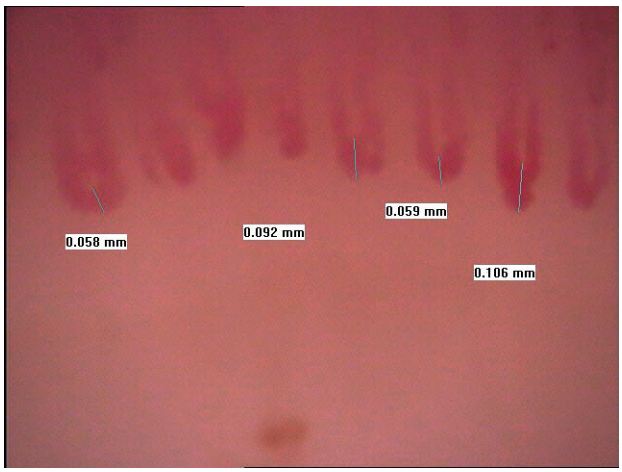



***Fig. 2. Measurement of apical capillary loops of giant capillaries in a patient with SSc, on a capillaroscopy image obtained via videocapillaroscope (Videocap 3.0, magnification 200x)***

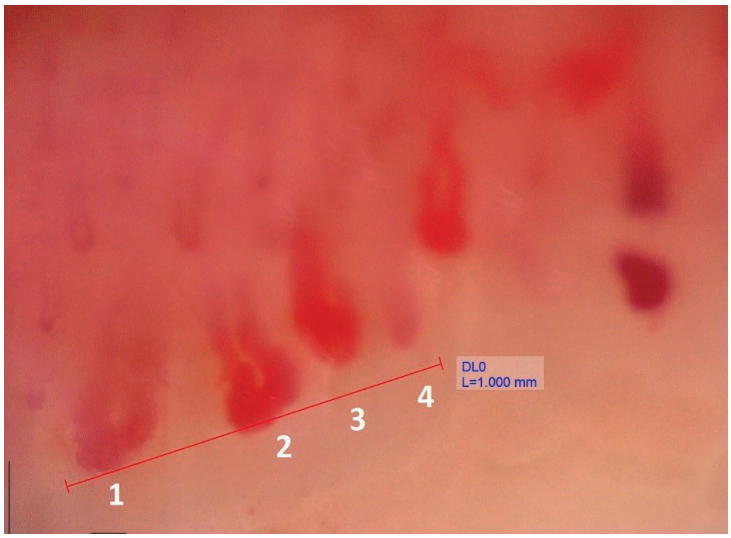



*Fig. 3. Counting the number of capillaries per 1 mm on capillaroscopic image obtained via USB microscope (4 capillaries/mm; capillaries № 1, 2, 3 are giant). The image demonstrates "scleroderma" type pattern, "active" phase in a female patient with limited cutaneous form of SSc. Numbers in the current image are inserted for demonstration and are not generated from the software of the device (USB microscope DinoLite, magnification 200x)*

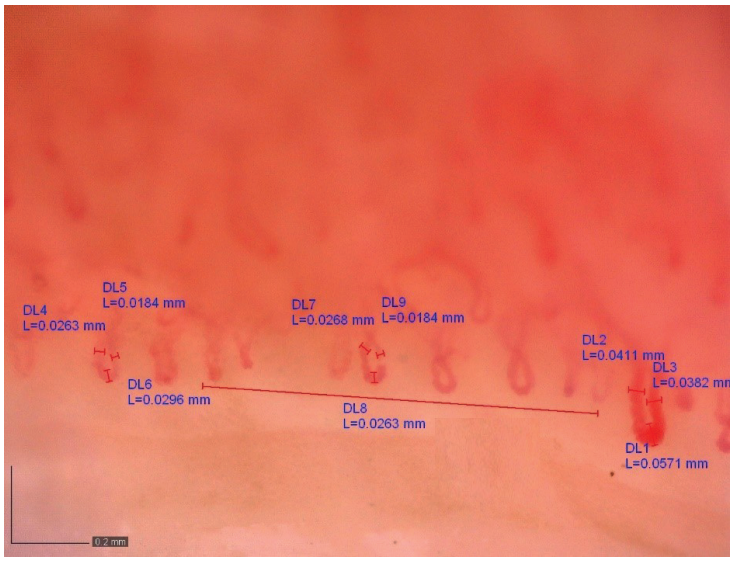



*Fig. 4. "Scleroderma" pattern, "early" phase in a female patient with SSc, limited cutaneous involvement. Presence of a single giant capillary with apical loop 0.0571 mm is demonstrated. Capillary density is preserved (8 capillaries/mm); (USB microscope DinoLite, magnification 200x)*

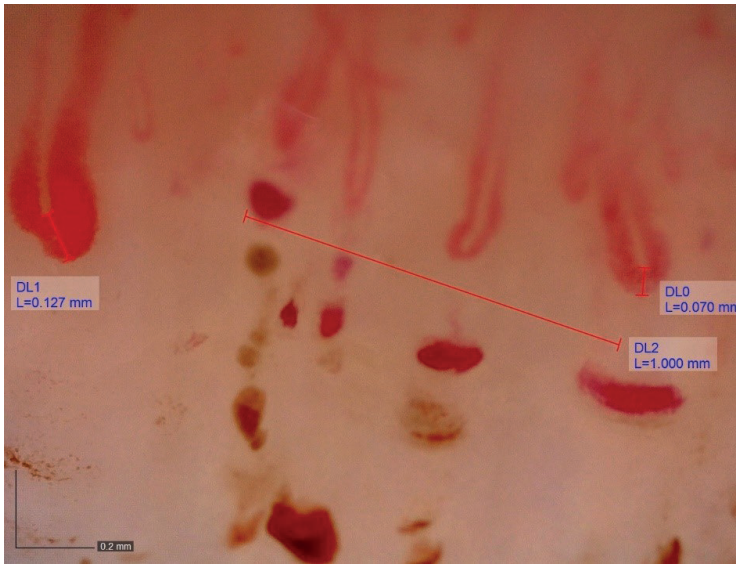



*Fig. 5. "Scleroderma" pattern, "active" phase in a female patient with SSc, limited cutaneous involvement. The image shows presence of giant capillaries (measurement of apical loop of two giant capillaries is demonstrated), microhemorrhages (extracapillary deposits), devascularization (a distance of 1 mm is marked; 4 capillaries per mm are present); (USB microscope DinoLite, magnification 200x)*

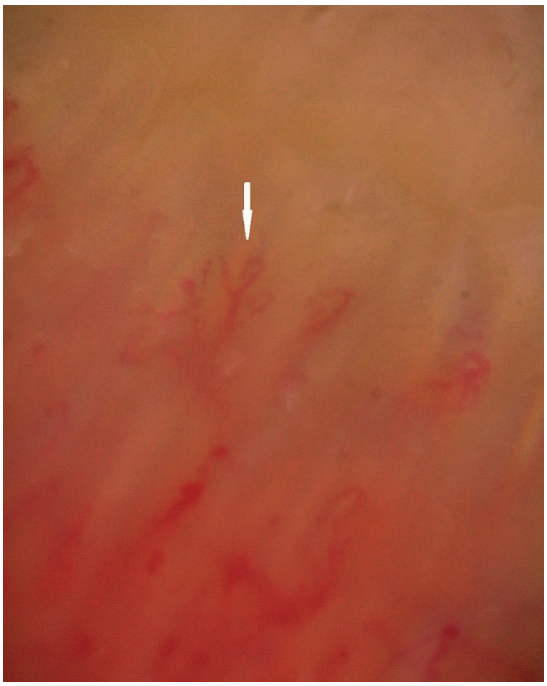


***Fig. 6. "Scleroderma" pattern, "late" phase in a female patient with SSc, limited cutaneous involvement. Advanced devascularization, neoangiogenesis (arrow), absence of giant capillaries and microhaemorrhages are demonstrated (USB microscope DinoLite, magnification 200x)***

## Discussion

Using USB microscopy, capillaroscopic images of good quality were obtained and quantitative analysis was possible in all cases (100%). This provided the opportunity for detection and staging of „scleroderma" type microangiopathy in SSc and other rheumatic diseases as well as definition of other categories, i.e., normal pattern and nonspecific findings. Our results correspond with those of other authors who also observe that USB microscopy provides interpretable images with good quality in healthy subjects, in SSc patients and in cases with other rheumatic diseases [21, 23, 25]. Thus, it could be currently suggested as a useful and cheap diagnostic tool.

Berks et al. (2021) have performed a study to compare USB microscopy with videocapillaroscopy in SSc patients and healthy subjects. The generated panoramic capillary mosaic images across the nailbed were analyzed using software for fully automated measurements of microvessel structure including capillary width and density. The authors have found that capillary width measurements could discriminate SSc patients and healthy controls using both USB microscopy and videocapillaroscopy. Although capillaries on images obtained with USB microscope were visible, in some frames they were obscured. The software of the experts' group was adapted on videocapillaroscopy images, and despite the good quality of the images from the USB microscope, the pictures were with different characteristics and some of the vessels registered on videicapillaroscopy images were not detected on those obtained via USB microscope that lead to difference in capillary density measurement. Of note, where capillaries were detected, measurements of capillary morphology were possible. Data about direct comparison between the results obtained by videocapillaroscopy and USB microscopy are limited but suggest comparable results regarding diagnosis of microangiopathy in rheumatology based on the assessment of capillary width with automated software [20].

In our study we have used software of the USB microscope for analysis of the capillaroscopic images. Manual counting of capillaries might be more precise approach for determination of capillary density because capillaries with less well-defined contour could be noticed.

In the European survey SUNSHINE performed by Ingegnoli et al. (2017) among experts in the field of capillaroscopy, four nailfold capillaroscopy methods were assessed, i.e., videocapillaroscopy, dermatoscopy, stereomicroscopy, digital USB microscopy. USB microscopy, dermatoscopy and stereomicroscopy were rated as appropriate or very appropriate by more than 88% of respondents vs 95% for videocapillaroscopy [36]. In an on-line survey among 104 UK-based rheumatologists, 33% respondents reported using nailfold capillaroscopy only at their own center, 32% referred the patients to other centers, 9% practiced both approaches and 27% did not use capillaroscopy. 58% of the 43 specialists who use capillaroscopy on site performed the capillaroscopic examination with either a dermatoscope (30%, n = 13) or USB microscope (28%, n = 12) and 21% (n = 9) used a videocapillaroscope [37].

In a recent literature review, Ma et al. (2023) have analyzed the current data on other devices used to perform capillaroscopic examination compared to videocapillaroscopy. 9 studies were included in the review, i.e., five studies compared videocapillaroscopy to dermatoscopy, two were about comparison to wide-field stereomicroscopy, one to smartphone attached device and one to USB microscopy. Interesting are the results about comparison of dermatoscopy to videocapillaroscopy that showed a higher percentage of capillaroscopic pictures that were interpretable when obtained by videocapillaroscope (63-77% vs. 100%). Among interpretable images the proportion of those that were classifiable for detection of abnormality was also higher for videocapillaroscopic technique (70%

vs. 84%). Determination of the degree of microvascular changes was possible also significantly more frequently for images obtained via videocapillaroscope (gradable images) i.e., 70% vs. 79.3% in three of the analyzed studies. It has been found that dermatoscopy had a lower sensitivity (60.2% vs. 81.6%) but higher specificity (92.5% vs. 84.6%) compared to videocapillaroscopy. Inability to visualize and interpret the findings in some cases is probably due to the low magnifications used in dermatoscopy [38]. Higher specificity of dermatoscopy is probably related to lower magnifications that permit visualization of larger areas of the nailfold.

Considering the localized and focal microvascular changes in some cases (at single finger and in focal areas of the nailfold), using of higher magnification i.e., 200x without detailed examination of the whole length of nailfold and all fingers might lead to misdiagnosis [35, 39].

Radic et al. (2020) have evaluated the role of dermatoscopy as a screening tool in RP patients in rheumatology in comparison to videocapillaroscopy. Two different hand-held non-contact polarised dermatoscopes were used with magnification 10-16x. Among 100 dermatoscopic images 37 were non-interpretable. All dermatoscopic images that demonstrated normal picture and “scleroderma” pattern were confirmed on videocapillaroscopic analysis. Images that were read as “scleroderma” pattern by videocapillaroscopy have been classified as “non-specific” or “scleroderma” type by dermatoscopy. Despite the high rate of non-interpretable images and the need to re-check the non-specific findings with videocapillaroscopy, the authors suggest dermatoscopy as a useful screening tool in RP patients [40].

In contrast to the above-mentioned limitations, USB microscopes with standard 200x magnification provide images with acceptable quality, opportunities for quantitative assessment of capillaroscopic parameters and staging of microvascular changes.

## Conclusion

Good capillaroscopic images, which could be analyzed and interpreted, are usually obtained using USB microscope with standard magnification 200x. This permits evaluation of the major capillaroscopic parameters including quantitative measurement of the capillary diameters, capillary density and length. Assessment of the degree of microvascular changes, i.e., staging of microangiopathy is also applicable and was possible in all cases with microangiopathy in the current study. The available software although less sophisticated vs those of videocapillaroscopes, gives the opportunity for measurement of major capillaroscopic parameters. The images obtained via USB microscope using magnification 200x are easily classified into “scleroderma”/“scleroderma-like” pattern, nonspecific changes and normal picture. Thus, USB microscopes using standard 200x magnification could be suggested as an alternative of videocapillaroscopes in every day rheumatology practice especially in low-budget cases. Measurements of capillary density, capillary diameters and length provide quantitative data that make these devices also appropriate for scientific research.

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*Постъпила за печат: 5.02.2024 г.*

*Submitted: 5.02.2024*

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