Examination of Subungual Hematomas and Subungual Melanocytic Lesions by Using Optical Coherence Tomography and Dermoscopy

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Optical coherence tomography · Dynamic optical coherence tomography · Dermoscopy · Subungual hematoma · Subungual melanoma · Subungual nevus · Onychomycosis · Imaging method · Noninvasive diagnosis

Abstract
Introduction: Examination of subungual pigmented lesions is sometimes a diagnostic challenge for clinicians. Objectives: The study was aimed to investigate characteristic patterns in optical coherence tomography (OCT) of subungual hematomas and determine distinctive features that can differentiate them from subungual melanocytic lesions. Methods: VivoSight® (Michelson Diagnostics, Maidstone, UK) was used to examine 71 subungual hematomas and 11 subungual melanocytic lesions in 69 patients (18 female and 51 male patients). Results: On OCT, bleeding was related to sharply defined black sickle-shaped ($p < 0.001$) or globular regions (not significant [ns]) with a hyperreflective margin ($p = 0.002$), a grey center ($p = 0.013$), hyperreflective lines in the area (ns) or periphery ($p = 0.031$), peripheral fading ($p = 0.029$), and red dots in the area ($p = 0.001$). In the 1 case of melanoma in situ examined, we found curved vessels with irregular sizes and distribution on the dermis of the nailbed, while subungual hematomas and subungual benign nevi presented as clustered red dots and/or regularly distributed curved vessels. Conclusion: Our findings indicate that the use of OCT in addition to dermoscopy provides high-resolution optical imaging information for the diagnosis of subungual hematoma and facilitates the differential diagnosis of subungual hematomas and subungual melanocytic lesions.

Introduction
Subungual hematomas are often incidental findings [1–3]. However, they are, at times, a diagnostic challenge to clinicians, especially when their genesis is unclear [1–3]. The indications of hemorrhage are the history of trauma, typical clinical and dermatoscopy findings of subungual hematomas and lesion outgrowth [1, 3]. Nevertheless, acrolentiginous melanomas also cause localized bleeding [1, 4]. Acrorentiginous melanomas have a poorer prognosis than melanomas of other localizations owing to late diagnosis [4]. The ultima ratio to ensure diagnostic reliability is a nail biopsy, which can cause permanent nail
deformity [1, 3]. Previous studies have reported that dermoscopy helps in distinguishing between subungual hematomas and melanomas [1–4]. However, dermoscopy affords visualization of only the nail surface and not of the deeper anatomical layers of the nail and nailbed. To overcome this obstacle and evaluate deeper structures in nail tissue, we used optical coherence tomography (OCT) and dynamic OCT (DOCT) in addition to dermoscopy.

OCT involves the emission of infrared light into the tissue, which is reflected to generate two-dimensional cross-sectional and horizontal images [5–7]. The axial resolution is determined by the bandwidth of the light source and can therefore only clearly represent superficial tissue [5]. OCT is mostly used to diagnose nonmelanoma skin cancer and its precursors [5, 8, 9]. In addition, DOCT shows the blood flow and morphology of the vessels by repetitive scanning of the lesion [7, 10].

In this study, we used OCT to assess subungual pigmented lesions in a large case series. Furthermore, we determined high-resolution optical patterns of subungual hematomas on OCT and compared subungual hemorrhage and subungual melanocytic lesions to rapidly differentiate between the two types of pigmented lesions.

### Patients and Methods

This prospective study was performed on 69 patients who were treated between May 1, 2020, and April 20, 2021, at the Department of Dermatology, University Hospital Carl Gustav Carus, Technische Universität Dresden, Dresden, Germany. Patients were included if they had a subungual hematoma and/or a subungual melanocytic lesion. Onychomycosis was not an exclusion criterion. Therefore, some of the patients had additional onychomycosis. In most patients, dermoscopy findings (colors, patterns, and changes in nail structure) and medical history (trauma, pain, and lesion outgrowth)
supported the diagnosis. In two patients, punch biopsies of the nailbed were performed to confirm the diagnosis. One punch biopsy was performed 10 months before the inclusion in the study because the pigmented lesion did not grow out. In histopathology, bleeding and onychomycosis were seen. As the pigmentation had not changed, the patient was examined with OCT and included in the study. Twenty-five of the included patients were sent to our hospital with suspected melanoma and a request for diagnosis and/or the performance of a biopsy. The remaining patients were included among our regular patients. The nail changes were examined with OCT and DOCT. We used the VivoSight® (Michelson Diagnostics Ltd., Maidstone, UK) OCT system to examine 82 subungual lesions in 69 patients. The axial resolution was 6 mm, with a depth of 1 mm. For dermoscopy images, we used DermaGraphix® (Canfield Scientific GmbH, Parsippany, NJ, USA) for diagnostics and image acquisition. Furthermore, patient data (age and sex) were collected.

Statistical analysis was performed using SPSS (Version 27, IBM Corporation, Armonk, NY, USA). Tests were two-sided, with a threshold of \( p < 0.05 \) for statistical significance. To explore differences in dermoscopy, OCT, and DOCT findings between patients with subungual hemorrhage and subungual melanocytic lesions, Fisher’s exact test was used (Tables 1, 2). The Mann-Whitney U test was used to determine age differences. We defined the following criteria for subungual hematomas on OCT (Fig. 1):

**Major Criteria**
- Sickle-shaped black or grey areas.
- Globular black or grey areas.

**Minor Criteria**
- Hyperreflective margin of the area.
- Hyperreflective lines in the area.
- Hyperreflective lines surrounding the area.
- Grey center of the area.
- Red dots in the area.
- Peripheral fading of the area.

**Results**

Patients \((n = 69); 51\) male and 18 female patients) with 82 instances of nail discoloration were included in our clinical examination. Subungual hematomas were more common in men, while subungual melanocytic lesions were more common in women (Table 1). However, 3 of the 9 nails with subungual melanocytic lesions were observed in...
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one female patient. Two punch biopsies were performed to confirm the diagnosis in cases of clinically uncertain diagnosis. Pathologic tests performed after biopsy led to a diagnosis of subungual hematoma and subungual melanoma in situ. In the remaining 80 cases of nail discoloration, diagnoses were made based on colors, patterns, and changes in nail structure as noted on dermoscopy and medical history (trauma, pain, and lesion outgrowth). The disease duration ranged from several days to 12 years.

Out of the 82 nails examined, 71 (47 toenails and 24 fingernails) had hematomas and 11 (3 toenails and 8 fingernails) had melanocytic lesions (Table 1). The median ages were 77 and 76 years, respectively, in patients with subungual hematoma and subungual melanocytic lesion (ns).

Visualization of Different Nail Colors and Patterns Using Dermoscopy Helps Differentiate between Subungual Hematomas and Subungual Melanocytic Lesions

Lesions occurred in the proximal third of the nail in 25/71 (35%) of the cases with subungual hematoma (vs. 1/11 [9%] of the cases of subungual melanocytic lesions), in the distal two-thirds in 36/71 (51%) of the cases, and in the entire nail in 10/71 (14%) of the cases (vs. 10/11 [91%] of the cases of subungual melanocytic lesions, p < 0.001).

In cases with subungual hematoma, 6/71 (8%) had one color (vs. 11/11 (100%) in patients with subungual melanocytic lesions). The associations between the colors purple, purplish-black, red, and reddish-black and hematoma were significant (Table 1). All nails with subungual melanocytic were brown, while 23/71 (32%) of the subungual hematomas appeared brown (p < 0.001). The colors black, bluish-white, and greyish-black were only common in patients with subungual hematomas; however, the association was not significant (Table 1). The Hutchinson sign was seen in one patient with subungual melanoma in situ (Fig. 3).

The most common pattern of presentation in hematoma was a homogenous pattern (55/71 [77%] vs. 4/71 [36%] in subungual melanocytic lesions, p = 0.009). On the other hand, a streak pattern was noted in 26/71 (37%) versus 11/11 (100%) cases of subungual melanocytic lesions (p < 0.001) and a globular pattern in 41/71 cases (59%, p < 0.001, Table 1). Of the subungual hematomas, 43/71 (61%) showed more than one pattern (vs. 4/11 [36%] of the melanocytic lesions).

Peripheral fading was seen in 43/71 (61%) of the cases of hemorrhage (vs. 2/11 [18%] of the subungual melanocytic lesions, p = 0.019), and a sharp edge was observed in 44/71 (64%) hematomas (vs. 4/11 [33%] in subungual melanocytic lesions). Periungual hemorrhage was seen in 4/71 (6%) subungual hematomas (Table 1). In cases of subungual hematoma, 9/71 (13%), 11/71 (15%), and 17/71 (24%) showed white longitudinal striae, white jagged edges, and granular leukonychia, respectively (ns, Table 1). Furthermore, 17/71 (24%) subungual hematomas showed onycholysis, 18/71 (24%) had onychodystrophy (vs. 1/11 [9%] subungual melanocytic lesions), and 12/71 (18%) showed visible nail damage. None of the patients with subungual melanocytic lesions showed changes in nail structure or onycholysis (Table 1). However, the association was not significant.

Instantaneous Determination of Subungual Hematomas by Using OCT

Subungual hematomas were associated with sharply defined black or grey areas. These were either globular (21/71 [30%], ns, Fig. 2a–c) or sickle-shaped (59/71 [83%], p < 0.001, Fig. 3a–d) and showed no connection to surrounding areas like a nail bed or vessels. These sickle-shaped or globular areas were, in some cases, grey in the center (27/71 [38%], p = 0.013), had hyperreflective lines (20/71 [28%], ns), or showed hyperreflective margins (36/71 [51%], p = 0.002). Other findings included peripheral fading of the area (23/71 [32%], p = 0.029) and hyper-
reflective lines in the surrounding area (20/71 [31%], \( p = 0.031 \), Table 2).

Among the black or greyish areas, 4% were in the upper third, 25% in the middle third, and 54% in the lower third of the nail, while 17% were subungual (\( p < 0.001 \)). The OCT findings were similar to the findings for recent cases of bleeding (35/71, 49%) of the proximal nail and of hemorrhage of the distal nail that had already grown out (36/71, 51%).

The dermo-epidermal junction (DEJ) was clearly visible in 20/71 (28%) of the patients with subungual hematomas and 7/11 (64%) of the patients with a subungual melanocytic lesion (\( p = 0.035 \)). The nail was thickened in 7/71 (10%) of the subungual hemorrhages and 1/11 (9%) of subungual melanocytic lesions (Table 2). Out of the subungual hematomas, 20/71 (15%) showed hyperreflective lines (vs. 2/11 (18%) in the subungual melanocytic lesions) and 10/71 (14%) showed disturbed architecture (vs. 2/11 (18%) of the subungual melanocytic lesions, Table 2). Moreover, 10/71 (14%) of the nails with subungual hemorrhage had dark bands, 30/71 (42%) had hyperreflective dots (vs. 7/11 [64%] in the subungual melanocytic lesions), and 18/71 (27%) an irregular surface (vs. 1/11 [9%] in patients with subungual melanocytic lesions, Table 2).

Trauma can lead to destruction of the nail and nailbed. Onychomycosis can also lead to changes in the structure of the nail. Therefore, we assessed the OCT findings that correlate with onychomycosis. The association between onychomycosis and disturbed architecture (\( p < 0.001 \)),

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**Fig. 2. a–c** Subungual hematoma: dermoscopy (a), OCT: cross-sectional slide: subungual globular areas (red arrows) (b), OCT: en-face mode: subungual globular areas (arrows) (c).

**Fig. 3. a–d** Subungual hematoma: dermoscopy (a), OCT: subungual sickle-shaped area (red arrows) with a hyperreflective margin (b), DOCT: subungual sickle-shaped area with red dots in the center (white arrows) (c), en-face mode: red dots in the area (orange arrow) (d).
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Morphology and Distribution of Vessels Facilitates the Differentiation of Subungual Pigmented Lesions

In DOCT, dot vessels of the subungual nailbed were visible in 60 (85%) of the cases showing subungual hemorrhage and 9 (81%) of the cases with melanocytic lesions (Table 2). However, the subungual melanoma in situ presented a dense arrangement of branched, serpiginous, and curved vessels with irregular sizes and distribution in the dermis of the nail fold, where the Hutchinson sign was seen. Histologically, the atypia was also mostly in the nail fold. The nail bed of the melanoma in situ showed curved vessels with an irregular distribution and size (Fig. 4a–e). Curved vessels in the nail bed were seen in 1/71 (1%) of the subungual hematomas and 2/11 (18%) of the subungual melanocytic lesions (ns). Thirty-seven of the black areas associated with hematomas showed red dots in DOCT ($p = 0.001$).

Discussion

Subungual hematomas are a common finding, but they can be challenging to diagnose due to the limited high-resolution imaging of the nail in dermoscopy [1, 3]. Indications of subungual bleeding include a history of trauma and outgrowth of the lesion [1, 3]. Nevertheless, about 15% of subungual hematomas do not grow out [1, 11].

Mun et al. [1] presented the characteristic dermoscopy findings of subungual hematomas, which included certain colors, homogeneous patterns, globular or streak patterns, peripheral fading, and periungual hemorrhage [2]. The dermoscopy findings of subungual hematoma observed in our study were congruent with these findings [1, 2]. In the present study, bleeding showed significant associations with colors like purple, purple-black, red, and red-black, as well as homogeneous and globular patterns (Table 1). Metin and Elmas [2] suggested that subungual hematoma inhibits the maturation of corneocytes by exerting pressure on the ventral face of the nail plate and thus causes leukonychia, which we also observed in our patients. Methods to assess discolorations of the nail include evaluation of medical history, dermoscopy, follow-up examinations, and punch biopsy. However, biopsies taken from the nail bed can lead to permanent nail changes [1, 3]. Unnecessary biopsies should, therefore, be avoided [1, 3]. Although dermoscopy provides additional information, the imaging is limited to the surface of the nail. OCT can provide additional information since the cross-section of the nail and nailbed in addition to the horizontal slides can be assessed. By accurately mapping the areas in the cross-sectional and horizontal slides, bleeding that presents as dark areas can be easily followed in the deeper anatomical layers and can be precisely assigned to discolorations on the surface of the nail.
We defined several features that we observed in most of the subungual hematomas. Subungual hemorrhage presented as black sickle-shaped or globular areas. Further characterizations included a greyish center, hyperreflective lines, hyperreflective margin, and peripheral fading of the black areas, as well as hyperreflective lines in the periphery of the areas. Our results suggest that the black or grey areas correlate with clefting in the nail. The hyperreflective margin, white dots and lines, and the red dots in the area might be signs of destruction of the nail and nailbed. However, since clefting attributable to other causes might also present with similar findings to the sickle-shaped or globular areas of subungual hemorrhage, dermoscopy, medical history, and follow-up examination should always be included in the due course.

Aydin et al. [12] showed that nails and subungual epidermis are well presentable with OCT in comparison with high-resolution ultrasound [6]. OCT and DOCT are already used for the diagnosis and follow-up of psoriasis vulgaris with nail involvement and onychomycosis [12–17]. Olsen et al. [15] characterized the typical findings of onychomycosis in OCT, such as dark bands, disturbed architecture of the nail, hyperreflective lines and dots, and irregular surfaces [16]. In the present study, the associations between onycholysis and signs like dark bands, irregular surfaces, disturbed architecture, and hyperreflective lines as clinical signs of onychomycosis were statistically significant. None of these signs were associated with subungual hematomas or melanocytic lesions. Hyperreflective dots may also be seen in nail changes attributable to other causes such as inflammatory nail changes or trauma of the nail [12–17]. Hence, they may not be specific for fungal infection.

The findings in OCT of subungual hematomas that had visibly grown out were similar to those obtained in cases involving recent bleeding on the proximal nail; therefore, the criteria for these cases did not seem to be different. OCT is a noninvasive and instant imaging method that has no known side effects. Thus, follow-up OCT examinations can be performed as needed. In patients with additional nail deformities like onycholysis or onychodystrophy, diagnosis can be difficult since the hematoma may be less clearly definable due to disturbed architecture and artefacts. Such clinical findings can complicate the diagnosis of hemorrhage.

We observed that all subungual hematomas were clearly visible on OCT. A hemorrhage caused by a nail-unit melanoma is an important differential diagnosis [1, 3, 4, 18–20]. Previous studies have shown that dermoscopy is helpful in distinguishing subungual hematomas from nail-unit melanomas [1, 3, 4, 21]. The characteristic findings are longitudinal melanonychia with regular or irregular lines, the Hutchinson sign, and a greyish background [3, 4]. OCT can be helpful in diagnosing melanomas, but shows lower sensitivity than other methods [22–24]. To date, there are no data on the criteria for nail-unit melanomas or subungual nevi in OCT. Subungual melanocytic lesions, when examined with OCT, showed no characteristic findings in comparison with the normal nail and nail bed. However, the vascularization and morphology of vessels of the nail bed can be examined with DOCT [13]. Indications for melanoma in DOCT include a chaotic distribution of vessels in the form of densely clustered red dots in the superficial dermis and thick irregular vessels with a chaotic distribution in the deeper dermis [7, 10, 25–28]. We also found curved vessels and irregularly distributed vessels of different sizes in the deeper dermis in the case of melanoma in situ. In the cases showing subungual hematoma and subungual nevus, vascularization was similar to that of a normal nailbed, and curved vessels, if present, were regularly distributed. Schuh et al. [7] also reported that vascularization in benign nevi was similar to that in normal skin [10]. However, inflammatory nail diseases like psoriasis can also lead to increased vascularization with changes in the morphology of vessels [13]. Furthermore, previous studies reported that DEJ was less clearly visible in melanomas [7, 24, 28]. However, in some of our patients with hematomas and additional nail deformities like onychomycosis or nail trauma, neither the nailbed nor the DEJ were clearly visible due to artefacts. Since only one melanoma in situ was included in the study, it is possible that the DEJ might be less visible in invasive melanomas.

OCT and DOCT provide additional high-resolution imaging information for the diagnosis of subungual pigmented lesions. Additional criteria (such as dermoscopy, medical history of injury, and outgrowth of the lesion in the follow-up examination) should, however, also be included in the diagnosis [1, 2]. The examination with OCT could have the potential to reduce the number of unnecessary biopsies. If the findings are inconclusive, a biopsy should still be performed [1, 3, 4].

Limitations

One limitation of this study is the low number of cases. This was especially pertinent for subungual melanocytic lesions, which were noted in only 11 cases. An increased number of cases might have led to the identification of...
additional characteristics visible under OCT, such as changes in vascularization, DEJ, and structure. Furthermore, we examined only one melanoma in situ. It is likely that invasive melanomas show other signs (like changes in nail structure, vascularization, and DEJ) in OCT than melanomas in situ and benign nevi. Another limitation is that we diagnosed subungual hematomas and melanocytic lesions with dermoscopy and performed biopsy only in 2 cases. Nonetheless, the clinical presentation of all changes and anamnesis (outgrowth, trauma, or stress) were typical and left no doubt. Therefore, a biopsy was not needed for diagnosis.

Conclusion

In summary, OCT can be beneficial in combination with dermoscopy as a useful, noninvasive tool in the differential diagnosis of subungual pigmented lesions and may reduce the number of unnecessary biopsies. The OCT parameters that were associated with subungual hematoma were black or grey, with sickle-shaped or globular areas, hyperreflective margins, a grey center, peripheral fading, and hyperreflective lines in the area and/or the periphery. Subungual melanoma in situ showed curved vessels with irregularity in size and distribution. Larger studies are useful to investigate this further, and more nail-unit melanomas should be examined with OCT so that optical differences can be detected.

Key Message

Optical coherence tomography facilitates the differentiation between subungual hematomas and subungual pigmented lesions.

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