The Anatomy behind Adverse Events in Hand Volumizing Procedures: Retrospective Evaluations of 11 Years of Experience

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Background: To retrospectively evaluate the rate of adverse events after hand volumizing procedures using a calcium hydroxylapatite product and to investigate the relationship between injector used (i.e., needle versus cannula) and technique applied (i.e., bolus, tenting, proximal-to-distal fanning, distal-to-proximal single line).

Methods: Two hundred twenty individuals, including 214 women (97.3 percent) aged 52.3 ± 11.4 years, treated bilaterally for hand rejuvenation were investigated between the years 2006 and 2017. Cadaveric dissections (n = 12), fluoroscopic (n = 4), ultrasound (n = 22), and computed tomographic (n = 4) imaging were also performed to guide conclusions.

Results: Thirty-two of 440 hands (7.3 percent) developed adverse events within the first 15 days, with swelling in 11 (5 percent), pain in four (1.8 percent), erythema in three (1.4 percent), and discoloration in one (0.5 percent). Using a needle (versus a cannula) was significantly related to the occurrence of adverse events (OR, 7.57; 95 percent CI, 3.76 to 15.24; $p < 0.001$). The proximal-to-distal fanning technique with access to the dorsal superficial lamina was identified as a safer application technique, with each of the other techniques having a significantly increased odds ratio for adverse events: bolus technique (OR, 26.9; 95 percent CI, 6.87 to 105.2; $p < 0.001$), tenting technique (OR, 24.73; 95 percent CI, 7.48 to 81.76; $p < 0.001$), and single-line technique (OR, 26.68; 95 percent CI, 7.45 to 95.48; $p < 0.001$).

Conclusions: The results of this study support the use of cannula versus needle and the proximal-to-distal fanning technique. The underlying anatomy supports the positioning of the material into the subdermal space, which can be identified less than 1 mm deep to the skin surface, and is termed the dorsal superficial lamina. (*Plast. Reconstr. Surg.* 141: 650e, 2018.)

Between the years 2000 and 2016, the number of soft-tissue filler applications has increased by 298 percent,[1] with most of them being used in the head and neck region. During the last decade, however, other parts of the body have gained increased attention for rejuvenate therapeutic options, with the dorsal hand being one of the most frequently requested.[2,3]

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Signs of the aging hand are dyschromia, lentigines, textural roughness, seborrheic, and actinic keratosis,[4] but also volume loss of the dorsal hand layers, leading to a prominent appearance of the dorsal superficial veins, extensor tendons, and bony contours of the metacarpal and proximal phalangeal bones.[5] Injections of autologous fat,[6–10] hyaluronic acid,[3,11–13] poly-L-lactic acid,[14] or calcium hydroxylapatite[3,11–13,15–19] are being currently performed to effectively restore the loss in volume of the dorsal hand.

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The procedures applying the soft-tissue fillers vary between the use of a needle versus cannula and between various techniques like proximal-to-distal fanning, tenting,[17] bolus injections,[20] or the distal-to-proximal single-line injections.[15,17,21,22] Anatomical dissections provided robust evidence that the material should be applied subdermally to reduce the potential risk for adverse events,[17,23,24] but conflicting results have been presented in regard to the laminae and fasciae between the skin and the metacarpal bones. Whereas Bidic et al.[23] presented a layered model with distinct and separable layers, Lefebvre-Vilardebo et al.[17] reported that no layered arrangement could be identified but instead a sponge-like single fascial layer was present.

The subdermal arrangement, however, is of crucial importance, as here the superficial veins, the sensory nerves, and the extensor tendons are located, and their affection during soft-tissue filler applications could lead to adverse event like swelling, pain, erythema, pruritus, tissue necrosis, and neural damage. In order to avoid adverse events one has to appreciate the underlying anatomy and to respect the subdermal arrangement for safe and optimal aesthetic outcomes.

The aims of the present study are to retrospectively investigate 220 patients treated for cosmetic hand volumizing procedures using a calcium hydroxylapatite product (Radiesse; Merz North America, Raleigh, N.C.) during a period of 11 years and to relate the occurrence of adverse event to the injector used (i.e., needle versus cannula) and the technique applied (i.e., bolus, tenting, proximal-to-distal fanning, distal-to-proximal single line). In addition, cadaveric dissections and ultrasound, fluoroscopic, and computed tomographic imaging were performed to relate the underlying anatomy to the adverse events and to confirm, combine, or reject theories on the dorsal hand anatomy.

PATIENTS AND METHODS

Study Sample

Two hundred twenty individuals, consisting of 214 women (97.3 percent) and six men (2.7 percent), with a mean age 52.3 ± 11.4 years (range, 32 to 82 years), treated for hand rejuvenation at a single center (Clinica Vida, São Paulo, Brazil) were included in this analysis. Individuals were treated between the years 2006 and 2017 for dorsal hand rejuvenation using a commercially available calcium hydroxylapatite product (Radiesse). This type of treatment was selected as the individuals included did not have enough body fat for the harvest of autologous fat or because the individual refused on the baseline examination to undergo any additional surgical intervention for the fat harvest. Two hundred nine individuals (95.0 percent) had no previous treatment for hand rejuvenation, 210 (95.5 percent) had no reported allergies, and 201 (91.4 percent) had no adverse events within 6 months after the treatment (Table 1).

Table 1. Demographic Data of the 220 Individuals Included in the Study

Characteristic	Value (%)
Sex	
Female	214 (97.3)
Male	6 (2.7)
Mean age ± SD, yr	52.1 ± 11.4
Previous treatments	11 (5)
Allergies	10 (4.5)
Rhinitis	7 (3.2)
Nonsteroidal antiinflammatory drugs	3 (1.3)

Injection Procedure

The injection procedure performed was assigned randomly to the patients depending on the location of the volume deficiency (radial versus ulnar, and proximal versus distal) and was decided on a case-by-case basis by the respective practitioner. Both hands of one individual were treated in the same session using the same technique and the same amount of product bilaterally.

The mean applied volume per hand treated was 1.87 ± 0.65 ml (range, 1.5 to 3.0 ml). If 1.5 ml was applied, 0.5 ml of 2% lidocaine with epinephrine was added; and if 3 ml of the calcium hydroxylapatite product was used, 1.0 ml of 2% lidocaine with epinephrine was added, according to the manufacturer's guidelines.

Bolus Technique

Twenty hands (4.5 percent) were treated using the bolus technique. The total volume of the product was applied in a single central location, followed by a manual massage until the product was distributed homogenously throughout the dorsum of the hand and into the areas of interest.

Tenting Technique

Sixty-eight hands (15.5 percent) were treated using the tenting technique. The skin was pinched between two fingers (pollex and index) and lifted in the area of interest. The material was injected in small boluses in the most uplifted portion of the skin in the subdermal plane using a 27-gauge, 13-mm, 0.5-inch needle (Becton Dickinson, Franklin Lakes, N.J.).

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Proximal-to-Distal Fanning Technique

Three hundred twenty hands (72.7 percent) were treated using the proximal-to-distal fanning technique. A single proximal puncture using a 23-gauge, 13-mm, 0.5-inch sharp-tip needle (DermaSculpt Microcannula, London, United Kingdom) was performed at the level of the most distal transverse wrinkle in the line of the third digit. A 22-gauge, 50-mm, 2-inch blunt-tip cannula (DermaSculpt) was introduced into the dorsal superficial lamina and advanced within the subdermal plane into the areas of interest (i.e. into the distal end of the second through fourth intermetacarpal spaces). When reaching the level of the metacarpophalangeal joints the cannula was retracted (i.e., distal-to-proximal movement) and the material was applied simultaneous with the retrograde movement.

Distal-to-Proximal Single-Line Technique

Thirty-two hands (7.3 percent) were treated using the distal-to-proximal single-line technique. The skin puncture was performed using a 23-gauge, 13-mm, 0.5-inch sharp-tip needle (DermaSculpt) between each of the second through fourth metacarpophalangeal joints. A 22-gauge, 50-mm, 2-inch blunt-tip cannula (DermaSculpt) was inserted into the dorsal superficial lamina and advanced proximally in the second through fourth intermetacarpal spaces. When the area of interest was reached, the cannula was retracted (i.e., proximal-to-distal movement) and the material was applied simultaneous with the retrograde movement.

Adverse Events

Adverse events were objectively examined by the practitioner in the consecutive routine visit or if requested by the patient in an additional interim visit. The adverse events occurring in this study included general and local swelling, pain, erythema, or yellowish discoloration. The adverse events were classified by the practitioner based on examination (observer-reported outcome) and together with the patient (patient-reported outcome) into mild, moderate, and severe (Table 2).

Table 2. Frequencies and Types of Adverse Events (*n* = 32) Observed in the 440 Treated Hands of the 220 Individuals Included in This Study

Characteristic	No. (%)
Mild erythema	1 (0.2)
Mild discoloration	1 (0.2)
Severe discoloration	1 (0.2)
Mild swelling general	3 (0.7)
Moderate swelling general	3 (0.7)
Severe swelling local	4 (0.9)
Severe erythema	4 (0.9)
Severe pain	5 (1.1)
Severe swelling general	10 (2.3)
None	408 (92.7)

Anatomical Dissections

Twelve fresh frozen cadaveric hands were objectively dissected at the Department of Medical Education, Albany Medical College, Albany, New York, and at the Department of Anatomy, Ross Medical University, Roseau, Dominica, West Indies. Informed consent was obtained from each body donor while alive, including the permission for the use of medical and scientific purposes. The methodology applied conforms to the laws of the country where this study was conducted. Dissection procedures were based on layer-by-layer dissections with identification of the respective layers and their relevant neurovasculature.

Fluoroscopic Imaging

A subset of four cadaveric hands were injected using radiopaque material by means of the bolus technique, the proximal-to-distal fanning technique, and the distal-to-proximal single-line technique to directly visualize the application procedure as described above. The radiopaque product injected was a mixture of a commercially available calcium hydroxylapatite product (Radiesse) combined with a contrast agent, 320 mg/ml iodixanol (Visipaque; GE Healthcare, Little Chalfont, United Kingdom).

Ultrasound Imaging

Ultrasound imaging using a 15-MHz transducer (MTurbo portable; Fujifilm SonoSite, Inc., Bothell, Wash.) was performed in 22 volunteers to visualize the fascial layers of the dorsum of the hand in untreated individuals. Informed consent was obtained from the volunteers prior to their inclusion in this part of the study. The distance between the skin surface and the dorsal superficial fascia was measured.

Computed Tomographic Imaging

A subset of four hands were used for the computed tomographic part of this study. The hands were previously injected with radiopaque material using various techniques during the fluoroscopic part of this study and consecutively scanned using the following computed tomographic parameters: field of view, 200 mm; slice thickness, 0.6 mm;

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increment, 0.5 mm; voltage, 140 kV; and current, 400 mA/second.

Three-Dimensional Surface Volumetric Analyses

Changes in surface volume were recorded based on structured light imaging technology using the mobile, radiation-free, three-dimensional scanner Eva (Artec 3D, Inc., Luxembourg) with consecutive three-dimensional reconstruction. Differences between preinjection and postinjection surfaces were calculated by the commercially available digital measurement software Mirror (Canfield Scientific, Inc., Fairfield, N.J.) and given as root-mean-square measurement (in millimeters), direct volume subtraction from postinjection to preinjection three-dimensional surface (in millimeters), and as a visual, colored heat map (where blue indicates an increase in volume, red indicates a decrease in volume, and green indicates no change in volume). A surface-volume coefficient was calculated by dividing the difference between preinjection and postinjection surface change by the injected volume. This coefficient provides information on the surface effect of a certain amount of injected volume (i.e., the effectiveness of injected material). A coefficient of 1.0 could be interpreted as very efficient, whereas a coefficient of 0 could be regarded as inefficient (i.e., none of the injected material had an effect on the surface).

Statistical Analyses

The odds of having adverse events in relation to the type of injector (i.e., needle versus cannula), injection technique (i.e., bolus, tenting, and fanning), and direction of injection (i.e., single central, proximal-to-distal, and distal-to-proximal) were calculated per treated hand using Poisson log-linear regression models with adjustment for age. All analyses were performed using IBM SPSS Version 23 (IBM Corp., Armonk, N.Y.), and results were considered statistically significant at a value of $p \leq 0.05$ to guide conclusions.

RESULTS

Clinical

Of the 220 individuals included in this analysis, 19 (8.6 percent) developed an adverse event within the first 15 days. Thirteen of these individuals (5.9 percent) developed bilateral symptoms and six (2.7 percent) developed unilateral symptoms. The right hand was affected in 18 cases and the left hand was affected in 14 cases. In those 32 affected hands (7.3 percent of 440 treated hands), the most frequent adverse event was severe generalized swelling [10 cases (2.3 percent)], followed by severe pain [five cases (1.1 percent)] and severe erythema and severe local swelling [four cases each (0.9 percent)] (Table 2). Whereas swelling and pain symptoms were not treated, erythema (any grade) was treated using topical steroids, and discoloration (any grade) was treated using carbon dioxide fractionated resurfacing. All adverse events resolved within 20 days after the initial injection.

Comparison of Needle versus Cannula

In 88 of the injected hands (20 percent), a needle was used, whereas in 352 of the hands (80 percent), a cannula was used for application of the material. Adverse events occurred in 21 hands treated with a needle (23.9 percent) and in 11 hands (3.1 percent) treated with a cannula. Pain was observed using both injectors (needle versus cannula) [two hands versus three hands (2.3 percent versus 0.9 percent)], whereas swelling (generalized and local), erythema, and discoloration were more frequently observed in hands treated with a needle compared with a cannula [12 hands versus eight hands (13.6 percent versus 2.3 percent), five hands versus zero hands (5.7 percent versus 0 percent), and two hands versus zero hands (2.3 percent versus 0 percent), respectively]. Overall, using a needle significantly increased the odds of having an adverse event (any type) compared with using a cannula (OR, 7.57; 95 percent CI, 3.76 to 15.24; $p < 0.001$).

Comparison of Techniques

The complication rate (independent of the type of adverse event) for the different injection techniques per injected hand were three hands (0.9 percent) for the proximal-to-distal fanning technique, five hands (25 percent) for the bolus technique, 16 hands (23.5 percent) for the tenting technique, and eight hands (25 percent) for the distal-to-proximal single-line technique. The occurrence of adverse events (any type) was significantly increased when the bolus technique (OR, 26.9; 95 percent CI, 6.87 to 105.2), the tenting technique (OR, 24.73; 95 percent CI, 7.48 to 81.76), or the single-line technique (OR, 26.68; 95 percent CI, 7.45 to 95.48; all $p < 0.001$) was applied, compared with using the proximal-to-distal fanning technique.

Three hundred thirty-two hands were injected with a total volume of 1.5 ml, whereas 108 hands

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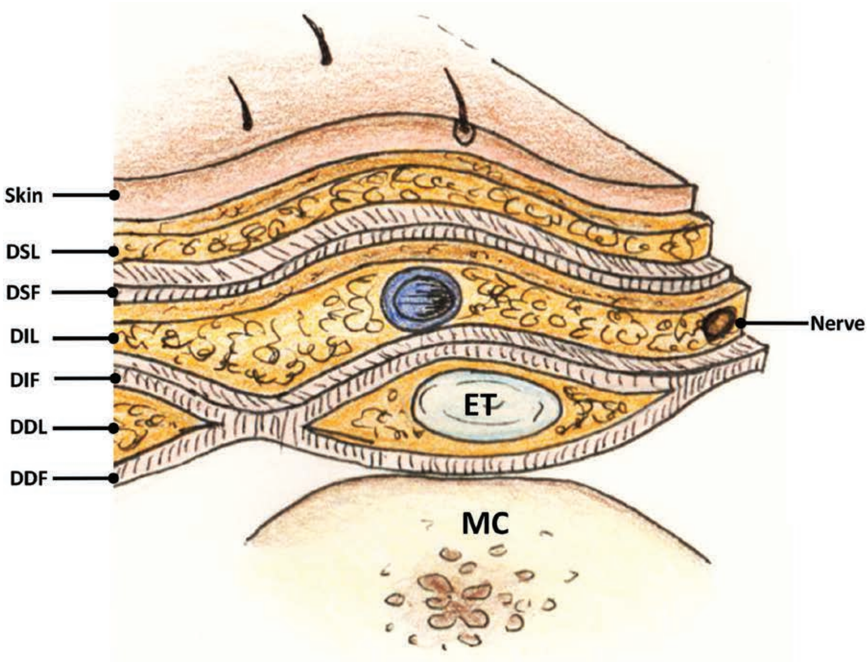
were injected with a total volume of 3 ml. There was a significant relationship between using 1.5 ml versus 3 ml in the occurrence of adverse events: 30 hands versus two hands (9 percent versus 1.9 percent), respectively ($p = 0.01$).

Anatomical Dissections

Twelve fresh frozen cadaveric hands were dissected by performing a layer-by-layer approach. After removal of the skin, a thin layer of fat was identified: the dorsal superficial lamina (Figs. 1



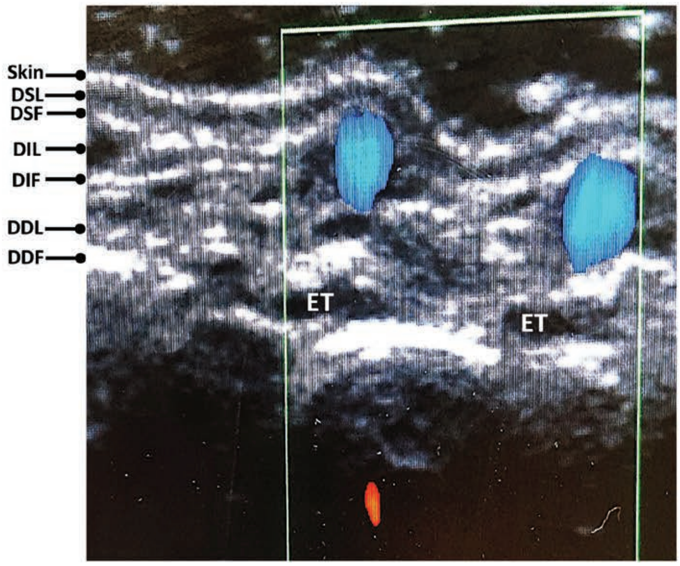


Fig. 1. (*Above*) Schematic drawing of the layered arrangement of the dorsum of the hand. Vein and nerve are present in the dorsal intermediate lamina (*DIL*). Note that the dorsal intermediate fascia and the dorsal deep fascia (*DDF*) form the extensor tendon compartments of the wrist. A dorsal superficial venous branch is colored in *blue*. (*Below*) Ultrasound image of the layered arrangement of the dorsum of the hand using a 15-MHz transducer. Doppler technique is applied to visualize the vein (*blue*) and the artery (*red*). *DSL*, dorsal superficial lamina; *DSF*, dorsal superficial fascia; *DIF*, dorsal intermediate fascia; *DDL*, dorsal deep lamina; *ET*, extensor tendon; *MC*, metacarpal bone.

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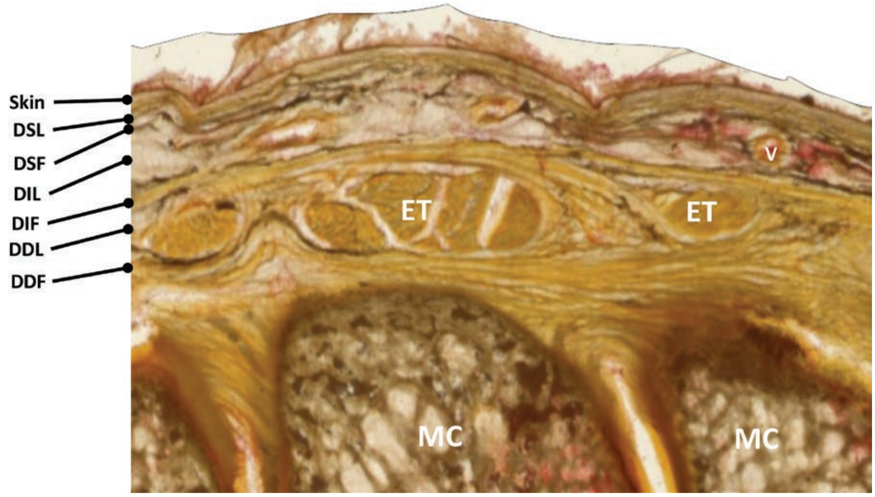

Fig. 2. Plastinated cross-section of the dorsum of the hand. The vein (*V*) is located in the dorsal intermediate lamina. *DSL*, dorsal superficial lamina; *DSF*, dorsal superficial fascia; *DIL*, dorsal intermediate lamina; *DIF*, dorsal intermediate fascia; *DDF*, dorsal deep fascia; *DDL*, dorsal deep lamina; *ET*, extensor tendons; *MC*, metacarpal bones.

and 2). Within this layer, no veins or major sensory nerves were identified. Interestingly, this layer was compartmentalized by longitudinally (proximal-to-distal) oriented septa of various numbers. The number and location seemed to correlate with the metacarpal bones and the underlying neurovascular structures. Injected material between the septa was able to be moved laterally or medially only by strenuous massage, as the observed septa were bounding the respective compartments firmly (Figs. 3 through 5).

The next layer identified was the dorsal superficial fascia, which was measured by means of ultrasound to have a mean distance from the skin surface of 0.98 ± 0.16 mm. Deep to the dorsal superficial fascia and embedded in the dorsal intermediate lamina, the dorsal veins were identified, along with the dorsal sensory branches of the radial and ulnar nerves (Figs. 1 through 4). This lamina was strongly adherent to the underlying dorsal intermediate fascia, which covered the surface of the extensor tendons. This fascia formed fibrous canals together with the dorsal deep fascia for the extensor tendons by means of fibrous septa. Together with the deep dorsal fascia, the dorsal intermediate fascia formed the extensor tendon compartments (Fig. 2).

The dorsal veins were identified deep to the dorsal superficial fascia and embedded in the dorsal intermediate lamina. The veins had connecting branches to the deep veins of the hand (Fig. 6) and gave off small branches to supply the overlying skin. The latter traveled in the fibrous septa connecting the dorsal superficial fascia and the skin. The observed layered arrangement was less clear and less distinct, distal to a line of 1 to 1.5 cm proximal to the metacarpophalangeal joints (i.e., the distal one-third of the dorsum), as here the veins and the nerves were identified to have a deeper course compared with the proximal two-thirds of the wrist, potentially due to alternating course to supply the second through fifth digits.

Anatomical Considerations of the Injection Techniques

The dorsal superficial lamina provided a free gliding space for the proximal-to-distal fanning technique using a cannula. Insertion into deeper layers resulted in the accidental injection of material into the dorsal veins (Figs. 7 and 8). Fluoroscopic analyses revealed that the radiopaque material had a strong retrograde flow when injected with a cannula along the canal by which the cannula was inserted, and this direction of flow occurred before the antegrade flow (Fig. 9). The single-line distal-to-proximal technique provided good accessibility to each of the intermetacarpal spaces, but because of the less clear arrangement of the fascial layers in the distal third of the dorsum of the hand, this technique seemed to be prone to apply the material into deeper planes (Figs. 4, 5, and 10).

The bolus technique was limited in its accessibility for the total dorsum of the hand because of the longitudinal septa connecting the dorsal superficial lamina to the skin and by thus forming compartments within the dorsal superficial lamina.

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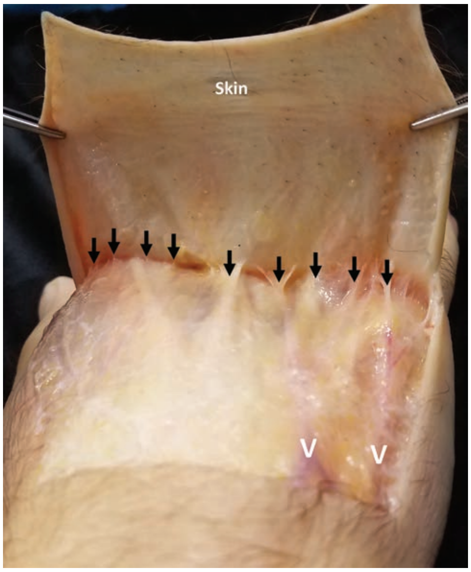

Fig. 3. Cadaveric dissection of the dorsum of the hand. The skin is elevated and the dorsal superficial lamina is exposed. Adhesions between the dorsal superficial fascia and the skin leading to a compartmentalization of the dorsal superficial lamina are indicated by the *black arrows*. The veins (*V*) and sensory nerves are deep to this layer.

These compartments inhibited the lateral distribution of the material (Fig. 3). Due to the strong fibrous connections observed, the lifting of the skin (as performed during the tenting technique

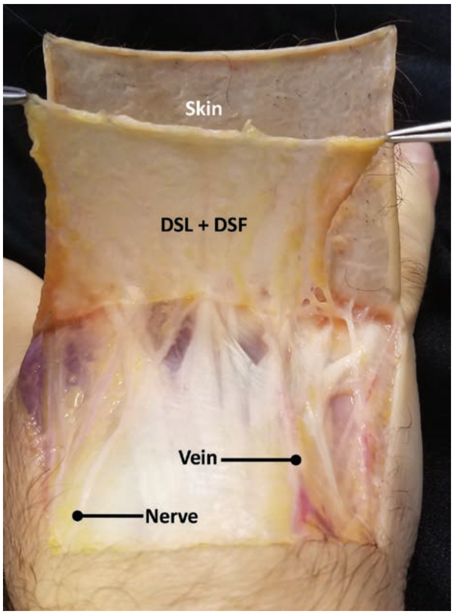

Fig. 4. Cadaveric dissection of the layered arrangement of the dorsum of the hand. The skin and the dorsal superficial lamina (*DSL*) and dorsal superficial fascia (*DSF*) are both elevated. The dorsal intermediate lamina including the veins and the superficial branches of the radial and ulnar nerves are exposed. Note that this layered arrangement was difficult to appreciate in the distal third of the hand.

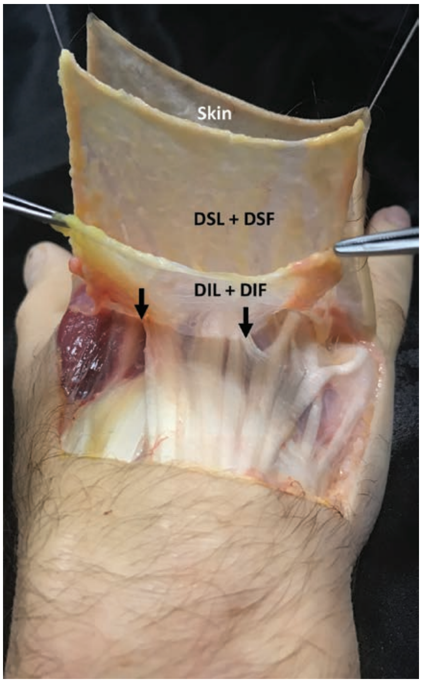

Fig. 5. Cadaveric dissection of the layered arrangement of the dorsum of the hand. The skin, the dorsal superficial lamina (*DSL*) and dorsal superficial fascia (*DSF*), and the dorsal intermediate lamina (*DIL*) and dorsal intermediate fascia (*DIF*) are elevated, exposing the extensor tendons and the dorsal deep fascia. Please note that the veins and sensory nerves are observed in the dorsal intermediate lamina, which is elevated by the pickups. *Black arrows* indicate the fibrous connections between the dorsal intermediate fascia and the dorsal deep fascia, forming the extensor tendon canals.

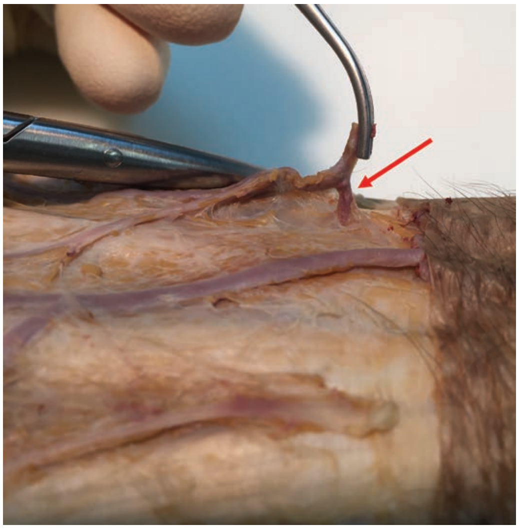

Fig. 6. Cadaveric dissection of the layered arrangement of the dorsum of the hand from the lateral view exposing the dorsal intermediate lamina and the dorsal superficial veins. Elevation of a proximally cut vein exposes a deep perforator (*red arrow*).

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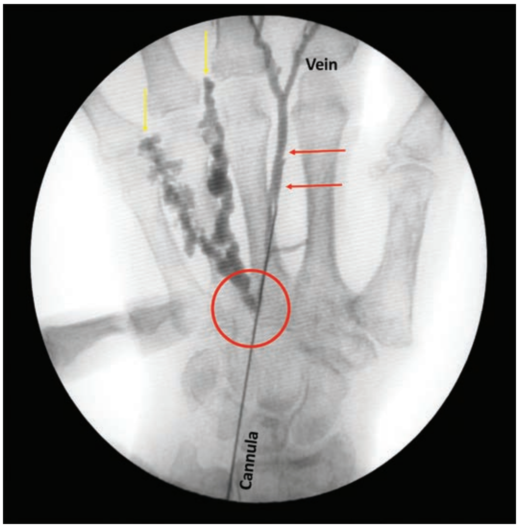

Fig. 7. Fluoroscopic imaging of the hand showing accidental intravascular (venous) application of radiopaque volumizing material using the proximal-to-distal fanning technique with a single cutaneous entry point (*red circle*) and a cannula. *Yellow arrows* indicate the regularly applied radiopaque volumizing material in the third and fourth intermetacarpal spaces. *Red arrows* indicate the accidentally penetrated superficial vein.

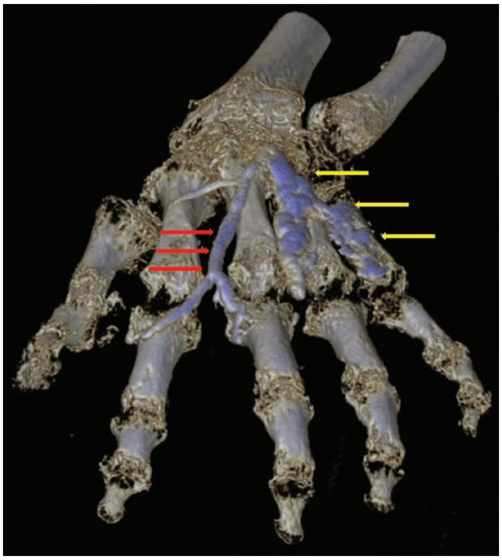

Fig. 8. Three-dimensional reconstruction of a computed tomographic scan of the hand showing accidental intravascular (venous) application of radiopaque volumizing material using the proximal-to-distal fanning technique. *Yellow arrows* indicate the regularly applied radiopaque volumizing material in the third and fourth intermetacarpal spaces. *Red arrows* indicate the accidentally injected superficial vein.

(Fig. 11) resulted in an additional elevation of the underlying fascial and fatty layers, including the dorsal intermediate lamina, the veins, and the nerves.

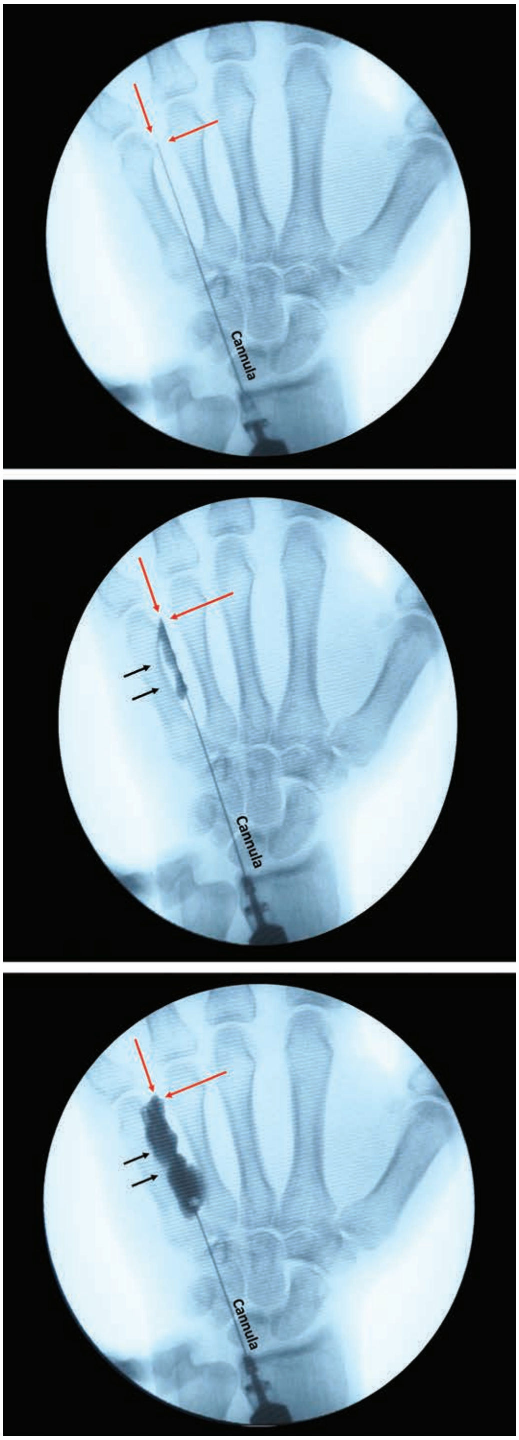

Fig. 9. Fluoroscopic imaging of the application process of radiopaque volumizing material using the proximal-to-distal fanning technique with a cannula. *Black arrows* indicate the retrograde flow of the radiopaque material along the canal previously created by the cannula. *Red arrows* mark the position of the cannula tip.

Three-Dimensional Surface Volumetric Analyses

Performing the proximal-to-distal fanning technique with 1.5-ml injected volume resulted in

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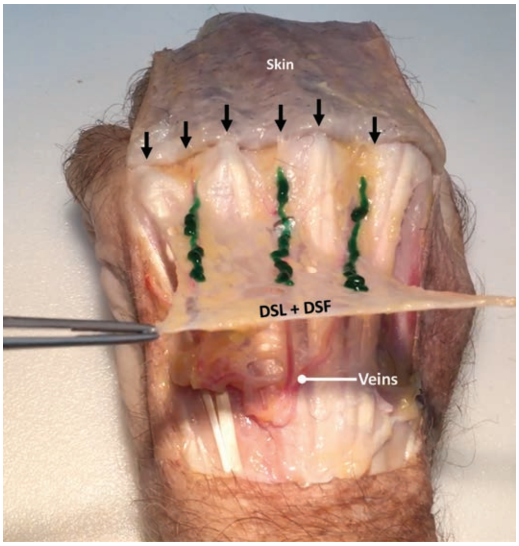

Fig. 10. Cadaveric dissection of the layered arrangement of the dorsum of the hand. The skin is reflected and the dorsal superficial lamina (*DSL*) and the dorsal superficial fascia (*DSF*) are elevated. Green dye was injected using the proximal-to-dorsal fanning technique subdermally. Note that the veins are located deep to the dorsal superficial fascia but superficial to the tendons. Adhesions between the dorsal superficial fascia and the dermis are indicated by the *black arrows*.

a mean skin elevation of 2.94 mm, with a surface-volume coefficient of 0.961 (i.e., loss of injected volume compared to increase in surface volume). For the bolus technique, the skin was on average elevated by 2.83 mm, with a surface-volume coefficient of 0.973; for the tenting technique, the coefficient was 0.726, with a mean elevation of 1.43 mm (Figs. 12 through 15).

DISCUSSION

We investigated retrospectively, over a period of 11 years, the outcome of 440 hands of 220 patients treated for hand rejuvenation using a commercially available calcium hydroxylapatite product. We related the rate of adverse events to the injector used (i.e., needle versus cannula) and to the technique applied (i.e., bolus, tenting, proximal-to-distal fanning, and distal-to-proximal single line). We found that using a needle (compared with a cannula) was significantly related to the occurrence of adverse events (i.e., pain, swelling, erythema, and discoloration) and that not using a cannula significantly increases the odds of having an adverse event (OR, 7.57; 95 percent CI, 3.76 to 15.24; $p < 0.001$). The proximal-to-distal fanning technique was identified to be the safest way of application, as not performing the proximal-to-distal fanning technique was significantly related to the occurrence of adverse events, with each of the other techniques having an odds ratio greater than 20 ($p < 0.001$). Interestingly, the amount of injected product seemed not to influence the occurrence of adverse events, as the lesser amount of injected product (1.5 ml) was significantly related to the occurrence of adverse events compared to the larger amount of injected product (3.0 ml).

Previous studies have reported diverging descriptions of the anatomy of the dorsum of the hand.[17,23] Bidic et al.[23] described distinct layers of the dorsum of the hand starting from superficial: skin, dorsal superficial lamina (lamina is the fatty layer), dorsal superficial fascia, dorsal intermediate lamina, dorsal intermediate fascia, dorsal deep lamina, and dorsal deep fascia. The veins and the sensory nerves were described to be located within the dorsal intermediate lamina and with the tendons located deep to it. In contrast, Lefebvre-Vilardebo et al.[17] described that the fasciae and laminae between the skin and the tendons were inseparable and formed a sponge-like total fascial layer. Within this fascial layer, the veins (and their deep perforators) along with the sensory nerves were identified. Interestingly, they described that in the distal one-third of the dorsum of the hand, the two covering laminae and fascia of the tendons were absent compared to the proximal two-thirds.[17] However, both descriptions concurred that the safest plane for applying volumizing material was subdermally [i.e., deep to the skin, with being in a safe distance (superficially) to the neurovasculature and to the tendons].

Our results have identified a thin fatty layer (i.e., the superficial dorsal lamina) deep to the skin, as reported by Bidic et al.,[23] which had a distance from the skin surface of less than 1 mm (when measured by ultrasound). This plane was identified as being without major veins and sensory nerves, and would thus provide an explanation for why injections in this plane are related to significantly fewer adverse events compared with any other applied technique.

The dorsal superficial lamina, however, was strongly compartmentalized by various longitudinally running septa (Fig. 3). These septa would provide an explanation for why applied bolus injections do not distribute easily across the total dorsum of the hand, but require massaging to reach more ulnar/radial areas of interest. Applying this technique, one has to be aware that in our sample the complication rate for this specific technique was

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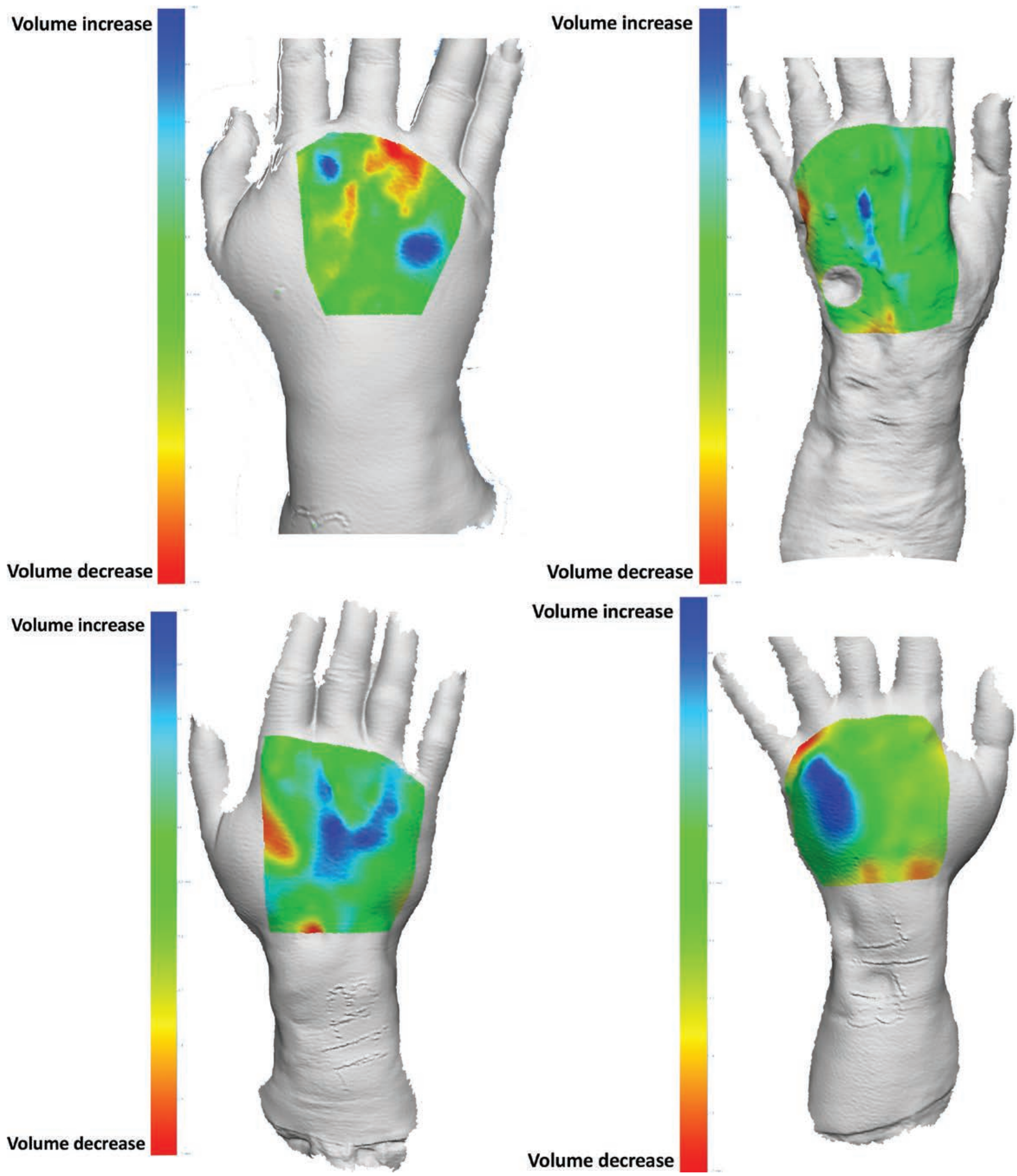

Fig. 11. Three-dimensional heat map of the dorsum of the hand after volumizing injections using the tenting technique (*above*, *left*), the single-line proximal-to-distal technique (*above*, *right*), the proximal-to-distal fanning technique (*below*, *left*), and the bolus technique (*below*, *right*). Changes between before and after the application of the material are represented by different colors: *blue*, increase in volume (compared with before the injection); *red*, decrease in volume; *green*, no change in volume.

25 percent (five of 20), including swelling and pain, which might be attributable to the force applied for massaging, resulting in a disruption of the septa, which provide sheltered passage pathways for lymphatic vessels and the smallest neurovasculature.[25]

Applying the proximal-to-distal fanning technique into the dorsal superficial lamina revealed a reduced rate of complication (0.9 percent) compared with the other investigated techniques (bolus technique, 25 percent; tenting technique, 23.5 percent; and distal-to-proximal single-line technique, 25 percent). One reason could be the fascial separation from the neurovasculature located in the dorsal intermediate lamina by the dorsal superficial fascia (Figs. 1, 2, and 10).

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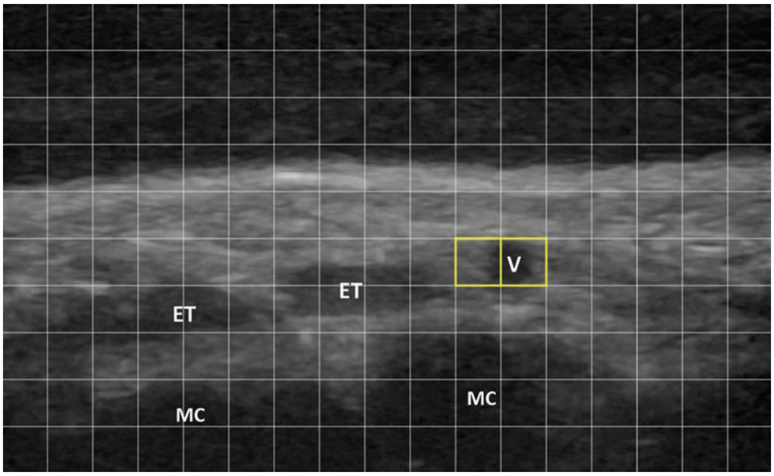

Fig. 12. Ultrasound image of the dorsum of the hand using a 20-MHz transducer. A branch of the dorsal superficial vein (*V*) is shown in the *yellow grid*. *ET*, extensor tendon; *MC*, metacarpal bones.

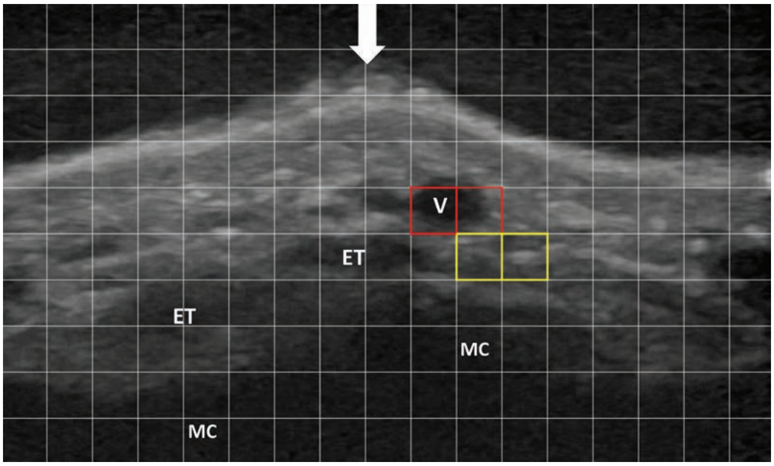

Fig. 13. Ultrasound image of the dorsum of the hand using a 20-MHz transducer. Elevation of the skin and thus simulation of the tenting technique in a healthy untreated volunteer is performed. Location of the elevation is marked by the *white arrow*. The movement of the vein (*V*) can be appreciated by the change of the colored grid from the *yellow* to the *red box*. *ET*, extensor tendon; *MC*, metacarpal bones.

The layered arrangement of the dorsum of the hand was best visible in the proximal two-thirds, whereas in the distal one-third, this arrangement seemed to be less distinct when investigated by anatomical dissections. Interestingly, our results are in line with those of Lefebvre-Vilardebo et al.[17] and would support the theory that, albeit using a cannula, the insertion from distal to proximal would facilitate penetration by the cannula into deeper layers where neurovasculature is present, as here no clear layered arrangement is present and the dorsal superficial lamina cannot be easily accessed.

Another explanation for why the proximal-to-distal fanning technique had a significantly reduced rate of adverse event could be the cannula itself. Our fluoroscopic analyses revealed that the applied material distributed, first, retrograde into the formed insertion canal and, second, antegrade when moving the cannula backward. No change toward deeper layers was observed when confirming the results by means of computed tomographic scanning (Fig. 8). Comparison between injections using the needle versus a cannula revealed a 7.5-fold increased odds of having an adverse event when using the needle

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Fig. 14. Cadaveric dissection of the dorsum of the hand with removal of skin and exposure of the dorsal superficial lamina in a fresh cadaver. Veins are colored in *blue* and are located in the dorsal intermediate lamina (deep to the dorsal superficial lamina and fascia).

Fig. 15. Cadaveric dissection of the dorsum of the hand with removal of skin and exposure of the dorsal superficial lamina in a fresh cadaver. Veins are colored in *blue* and are located in the dorsal intermediate lamina (deep to the dorsal superficial lamina and fascia). Tenting technique is performed, showing that the dorsal superficial veins are also elevated by this procedure.

compared with a cannula. However, using a cannula does not protect against intravascular injection when introducing the cannula into a deeper layer, especially in older patients with fragile vessels (Figs. 6, 7, and 10).

Based on the results of this study, the tenting technique seems to be the most imprecise mode of application, as the tenting procedure elevates all layers, including the veins and the sensory nerves due to the fibrous connection between the layers (Fig. 12). The tendons, however, did not change position during the tenting, whereas the dorsal superficial lamina and fascia and the dorsal intermediate lamina and fascia were uplifted during this procedure (Fig. 13). Therefore, is the volumizing material more prone to be injected into deeper layers, because here no targeted layered arrangement can be appreciated during the procedure (Figs. 12 through 15)?

Our anatomical results were partially in line with the proposed sponge-like fascial layer, as described by Lefebvre-Vilardebo et al.,[17] as we found the dorsal intermediate fascia (according to Bidic et al.[23]) not to be a distinct layer by itself, but to form together with the dorsal deep lamina canals for the extensor tendons. Likewise, our results were in general in line with the layered anatomy described by Bidic et al.,[23] as we were able to support the previously described laminae and fasciae. The anatomy described by Bidic et al. and Lefebvre-Vilardebo et al.[17,23] and our dissections seems to combine both previous anatomical description and seems to be supported by the retrospective analyses of the 440 hands from 220 evaluated patients based on their rate of adverse events.

CONCLUSIONS

The results of this multimodality based study support the use of cannula versus needle and the proximal-to-distal fanning technique as compared to other techniques when treating the dorsum of the hand using volumizing materials. The underlying anatomy supports the positioning of the material into the subdermal space, which can be identified less than 1 mm deep to the skin surface, and is termed the dorsal superficial lamina. This fatty layer is separated from the superficial veins and the sensory nerve branches by the dorsal superficial fascia.

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