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Sonographic Analysis of CureJet Injection Depth Consistency After Abdominal Stretch Mark Treatment Using Hyperdiluted Calcium Hydroxylapatite

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Background: This study investigates the effectiveness and consistency of needle-free jet injectors in administering injections at uniform depths, particularly for the treatment of stretch marks. Ensuring consistent injection depth is crucial for achieving optimal therapeutic outcomes, especially when dealing with challenging skin conditions like stretch marks.
Methods: A retrospective study was conducted involving 25 patients treated for abdominal stretch marks using a needle-free injector (CureJet). For each patient, 10 injection sites were assessed via ultrasound, and the depth of the injections was measured. The mean injection depths and standard deviations were calculated for each patient to assess the consistency of injections. The injected substance was diluted calcium hydroxylapatite, a well-known biostimulatory agent used for skin rejuvenation. Injections were repeated over multiple sessions with consistent parameters to evaluate the reproducibility of the technique.
Results: The mean injection depth across patients was 0.5126 cm, with considerable variability observed between patients. The standard deviation ranged from 0.0326 to 0.2132 cm, indicating significant differences in the consistency of injection depths. The statistical analysis demonstrated that the needle-free injector achieved variable depths, with some injections penetrating deeper than intended, whereas others remained superficial.
Conclusions: While needle-free injectors like CureJet provide a promising alternative to conventional needles, achieving consistent injection depths remains a challenge. This study highlights the need for further refinement in injector technology and technique to improve uniformity in treatment depth, particularly for applications like scar treatment and stretch mark reduction. Enhancing precision in such devices could lead to better patient outcomes and increased safety in aesthetic treatments.
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INTRODUCTION

During pregnancy, a woman's abdomen expands significantly to accommodate the growing fetus. This stretching occurs faster than the skin's natural growth rate. The dermis contains elastic fibers, primarily collagen and elastin, which provide strength and flexibility. During rapid stretching, these elastic fibers can become overstretched and damaged. The collagen and elastin fibers may tear or weaken, disrupting the skin's structural integrity. The damage to the elastic fibers triggers an inflammatory response in the skin. This inflammation can contribute to the characteristic reddish or purple appearance of new stretch marks. As the skin attempts to heal the damaged areas, scar tissue forms. This scar tissue is less elastic than the original skin, leading to the formation of stretch marks. Over time, the color of the stretch marks fades to a whitish or silvery appearance, but the texture remains different from the surrounding skin.[1]

Efforts to improve stretch marks have included the use of injectable fillers, which promote collagen production, improve skin elasticity, and enhance dermal thickness to restore the skin's structural integrity. Among these, fillers

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such as hyaluronic acid, poly-L-lactic acid, and calcium hydroxylapatite (CaHA) have demonstrated efficacy in stimulating collagen synthesis and improving skin texture. Specifically, CaHA injections have been shown to increase dermal thickness and stimulate neocollagenesis, contributing to smoother, firmer skin and reducing the visibility of stretch marks. These regenerative properties make CaHA an attractive option for nonsurgical stretch mark treatment, particularly in addressing both texture and skin laxity.[2–4]

However, achieving consistent results with manual injections remains a challenge due to variability in injection depth and coverage. To address this, an innovative needle-free injector capable of delivering rapid, consistent injections at controlled depths with scar subcision capabilities was utilized. From July 1, 2023, to August 1, 2024, 37 patients were treated with CaHA at the author's clinic, and ultrasound imaging was used to analyze injection depths in 25 patients. This study aimed to evaluate the consistency of injection depths achieved with this injector and analyze the effectiveness and safety of CaHA injections for treating abdominal stretch marks. By using ultrasound imaging, the study investigated the distribution and depth of CaHA injections, offering insights into its potential to improve the precision and efficacy of nonsurgical stretch mark treatments.

Takeaways

Question: This study aims to evaluate the consistency of injection depths using a needle-free injector for treating stretch marks, focusing on whether injections are uniformly administered at specific depths.

Findings: In a retrospective study of 25 patients, injection depths were measured via ultrasound. Results showed significant variability in injection depths, with the mean depth of 0.51 cm across patients. Depths varied significantly between individuals, suggesting that consistency in injection depth requires further optimization.

Meaning: While needle-free injectors show promise, achieving consistent injection depth remains a challenge, highlighting the need for refined techniques to improve uniformity and treatment outcomes.

METHODS

The study included 25 individuals with noticeable abdominal stretch marks resulting from significant skin expansion, such as pregnancy, who visited the author's clinic. Inclusion criteria required the presence of visibly apparent abdominal stretch marks, assessed through clinical examination by the investigator. This approach provided an objective basis for participant selection, focusing on pregnancy-related stretch marks as a common and clinically significant condition suitable for treatment with the regenerative properties of CaHA. Exclusion criteria included systemic conditions such as diabetes, connective tissue disorders, or any other disease affecting wound healing, as well as a history of cosmetic procedures on the abdominal area (eg, liposuction, energy-based devices, fillers, or botulinum toxin) within the past 6 months. This retrospective study analyzed ultrasound images of injection depths in 25 patients who received CaHA treatments at the author's clinic from July 1, 2023, to August 1, 2024. Data were collected during routine clinical care, including pretreatment photographs and ultrasound imaging during or immediately after injections to confirm accurate administration. All procedures adhered to ethical guidelines and were conducted in accordance with the Declaration of Helsinki. Ethical considerations were followed to ensure patient care and data handling met the highest standards.

For each patient, 2000 to 3000 shots were administered using the needle-free injector "CureJet" (C-Jet; Baz Biomedic, Seoul, Republic of Korea).[5–8] C-Jet operates utilizing an electromagnetic force that pushes a piston (hammer) forward. When the hammer hits the membrane, the momentum is transferred to the drug chamber, dispersing it from the nozzle onto the target area. Following the Venturi effect, the injecting fluid exits through the narrow nozzle at a very high speed.[9] Using C-Jet, microjet injections can be repeated at rates of up to 20 Hz. However, the author used a rate of 10 Hz to maintain injection speed and penetration force. C-Jet is fired more strongly and injected deeply when injected while in contact with the skin (contact mode). (**See Video 1 [online]**, which displays the needle-free injection with CureJet for dermal delivery of hyperdiluted Radiesse [CaHA].)

The farther the distance between the nozzle and the skin, the weaker the injection force and the shallower the injection depth (spray mode). Hyperdiluted CaHA solution was injected using the contact method (Fig. 1).

The injectable used was CaHA (Radiesse; Merz, Germany), composed of 30% CaHA particles and 70% carboxymethylcellulose. Diluted CaHA was selected due to its biostimulatory properties, which are particularly effective for improving skin texture and elasticity by promoting collagen production. Unlike other fillers, CaHA has been shown to integrate well within the dermal layer, providing both volumizing and regenerative effects. This was deemed beneficial for treating stretch marks, as the filler supports the restructuring of damaged collagen fibers while inducing new collagen synthesis, resulting in improved skin quality.[10] To avoid the appearance of white stretch marks and reduce the risk of nodules, the solution was diluted 1:10. CaHA particles tend to settle if diluted beyond 1:5, so the syringe was shaken every 5 seconds during injection.[11] The nozzle tip was kept in contact with the skin at a 45-degree angle, ensuring deep and effective injections. Patients with larger areas of stretch marks received 3000 shots, whereas those with smaller areas received 2000 shots. Treatments were administered monthly, with 3 to 5 sessions being the routine (Fig. 2).

Posttreatment ultrasound images (12 MHz-HA70A: Samsung Medison, Seoul, Korea) were used to measure and analyze injection depths in 10 different sites for each

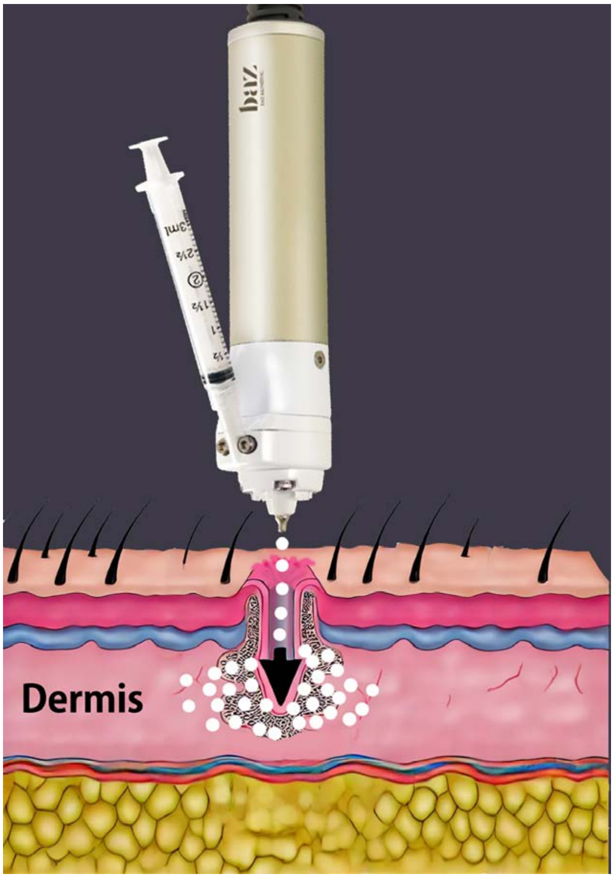

Fig. 1. The mechanism of a needle-free injector delivering a substance into the dermis, focusing on its penetration through the epidermis and into the dermis. Injector device at the top of the image is a CureJet (C-Jet) needle-free injector. The syringe attached to the device holds the injection material (Radiesse: CaHA). The injector utilizes high-pressure jet technology to deliver the substance transdermally without the use of a needle. Small white dots represent the injected material (CaHA) being released from the injector nozzle. The injected CaHA spreads laterally as it enter the dermis, highlighting how the substance disperses horizontally once it encounters resistance from the denser tissue in the dermis. This horizontal spreading effect is important for treatments such as stretch mark reduction and scar subcision, where the injected substance helps in breaking up scar tissue.

of the 25 patients. Images were retrospectively collected to ensure consistency in injection depth (Fig. 3). (**See Video 2 [online]**, which displays ultrasound evidence of consistent dermal hyperdiluted CaHA injection and horizontal spreading.)

RESULTS

Participants' ages ranged from 28 to 57 years. Improvements in the appearance of stretch marks were observed. Patients reported a smoother texture and a reduction in the visibility of the stretch marks after treatment (Fig. 4). The ultrasound images also showed increased dermal thickness and an improved structure in the treated areas, correlating with visual and patient-reported outcomes.

The overall mean depth was 0.5126 ± 0.1728 mm. These statistics show relative consistency of the injection depths, 0.5126 mm in the dermis. A low SD within each patient indicates that the injection depths are fairly consistent. The overall SD of 0.1728 mm provides a measure of the overall variability across all patients (Fig. 5) (Table 1).

To assess whether the data follow a normal distribution, statistical analyses were conducted using the Shapiro–Wilk test and the Kolmogorov–Smirnov test. The Shapiro–Wilk test produced a statistic of 0.978 with a P value of 0.000553, whereas the Kolmogorov–Smirnov test yielded a statistic of 0.087 and a P value of 0.042. Both tests resulted in P values below the significance level of 0.05, leading to the rejection of the null hypothesis for normality. These findings indicate that the data do not conform to a normal distribution, as shown by both the Shapiro–Wilk and Kolmogorov–Smirnov tests (Table 2). To evaluate variability in injection depths across patients, the Kruskal–Wallis H test, a nonparametric method suited for nonnormally distributed data, was conducted. This test assessed injection depth distributions across 25 patients, each with 10 measurements. The test revealed significant variability in injection depths (statistic: 122.24, $P < 0.001$), rejecting the null hypothesis of consistent injection depths. Additionally, the Friedman test was used to further assess depth consistency within patients, confirming significant differences in injection depths across sites (statistic: 118.70, $P < 0.001$). Kernel density estimate and histogram analyses identified the most frequent injection depths, with an overall mode of 0.42–0.51 mm. These findings highlight variability in injection depths and inform future standardization efforts.

No serious adverse events were observed during the study. Minor side effects included temporary erythema, mild swelling, and tenderness at the injection sites, which resolved within a few days without intervention. No cases of granuloma formation, nodule formation, or prolonged inflammation were reported.

DISCUSSION

Needle-free syringes are used for a variety of indications.[12–14] The depth at which an injection is made with a needle-free syringe is very important. Analyzing the injection depths for 25 patients provided several insights and implications, particularly in a clinical or medical context. This discussion delves into the consistency and accuracy of injection techniques, patient-specific factors, implications for drug efficacy, impact of substance properties, the significance of contact between the device tip and skin, and the characteristics of the C-Jet injector.

Consistency and Accuracy of Injection Technique

Consistency

The variation in injection depths across different patients highlights the importance of assessing the consistency of the injection technique. High variability may suggest a need for standardized training or protocols to ensure that practitioners achieve uniform results. Consistency in injection depth is crucial for predictable

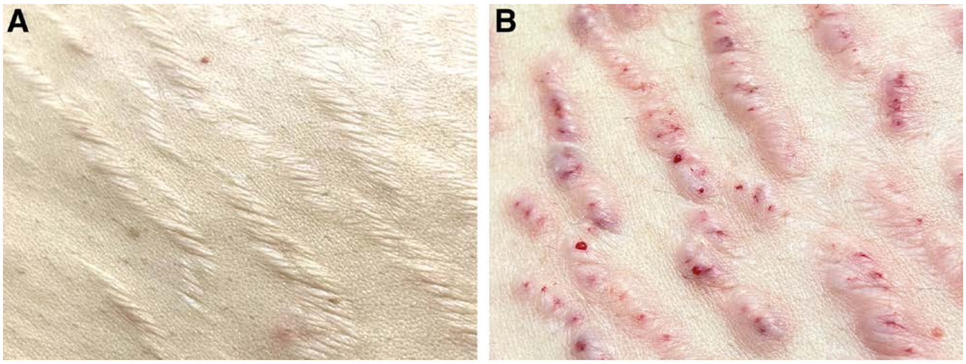

Fig. 2. Before and after treatment results on abdominal stretch marks using a needle-free injector and CaHA. A, Pretreatment image showing linear, depressed stretch marks (striae distensae) with a pale, whitish appearance typical of healed scars. These marks result from the skin stretching beyond its elasticity, often during pregnancy or weight changes, and appear uneven in texture. B, Posttreatment image immediately after injection. The stretch marks appear swollen and reddened, indicating a localized inflammatory response to the treatment. This response is consistent with early healing and regeneration, as the injected material aims to stimulate collagen production and improve skin elasticity. Over time, these effects are expected to reduce the visibility of the stretch marks.

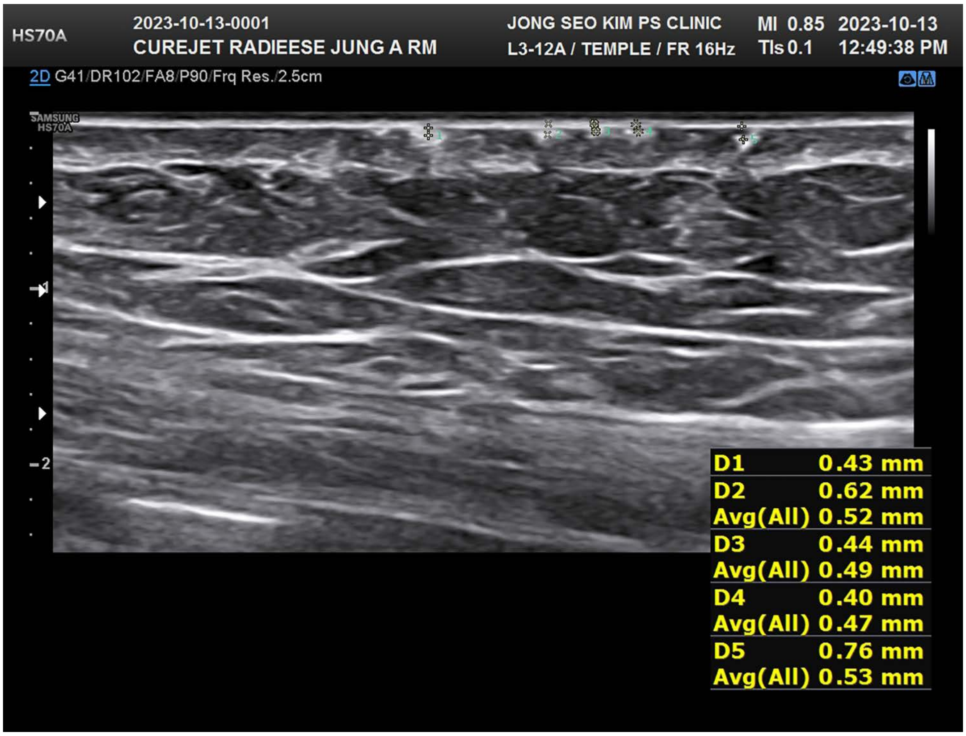

Fig. 3. Ultrasound image of skin cross-section following a CaHA injection with a needle-free injector. The image demonstrates key skin layers postinjection. Top layer, The epidermis, appearing as a thin, superficial layer. Middle layer, The hypoechoic dermis, showing scattered white dots representing CaHA particles. These particles are dispersed laterally within the dermis, creating a subcision-like effect, potentially aiding in scar and stretch mark treatment. Right-hand box, Measured injection depths at 5 points (D1–D5) ranged from 0.40 to 0.76 mm, with an overall average of 0.53 mm. These measurements indicate the injector's ability to deliver material consistently, with slight variations potentially attributed to differences in skin thickness or injector positioning. The injected CaHA particles stimulate collagen production, improving skin texture and appearance over time.

outcomes, especially in aesthetic treatments where uniformity can significantly affect the appearance and patient satisfaction.

Accuracy

If there is an expected target depth for optimal therapeutic effect, analyzing the actual depths can reveal how

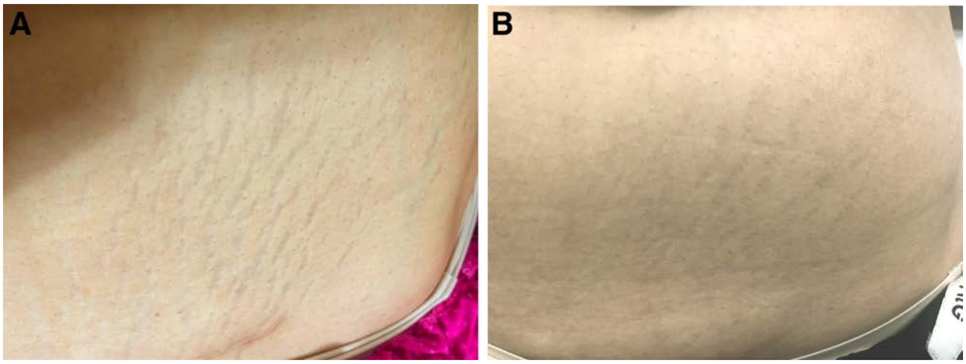

Fig. 4. Long-term follow-up of before and after treatment results for abdominal stretch marks. A, This baseline image depicts the abdomen of a 34-year-old female patient before treatment. Prominent abdominal stretch marks (striae distensae) are clearly visible, characterized by linear, depressed lines with a whitish or silvery tone, mature scars. B, This follow-up image, taken 1 year after treatment completion, shows the same patient's abdomen following 5 monthly sessions of treatment using a needle-free injector (CureJet) and hyperdiluted CaHA. Significant improvements are observed in the appearance of the stretch marks. The stretch marks appear less visible, with a smoother and more uniform skin texture.

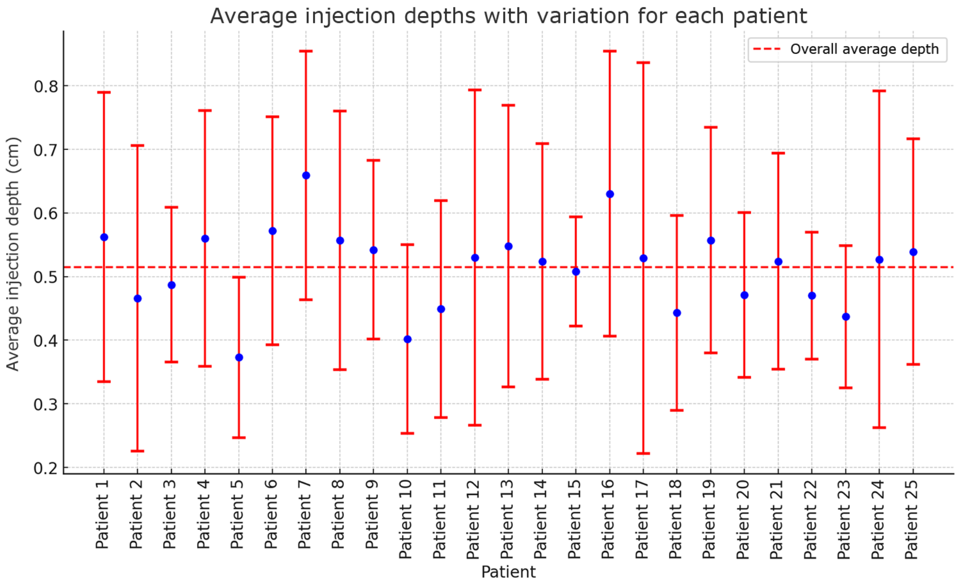

Fig. 5. Median injection depths with interquartile ranges (IQRs) across 25 patients. The blue dots represent the median injection depth for each patient, whereas the red vertical error bars indicate the IQR, illustrating variability in injection depths. Smaller IQRs, such as those observed in patients 9 and 13, suggest more consistent depths, whereas larger IQRs, as seen in patients 12 and 25, indicate greater variability across injection points within the same patient. This variability reflects differences in skin characteristics or injector application.

accurately the injections were administered. Accurate injections are essential for maximizing the efficacy of the treatment and minimizing potential side effects. This study's focus on maintaining consistent contact between the device tip and skin aimed to enhance the accuracy of each injection.

Patient-specific Factors

Anatomical Differences

Variations in injection depths can reflect anatomical differences between patients. Factors such as differences in muscle or fat tissue thickness can affect the depth reached by an injection. Understanding these anatomical variations is crucial for customizing treatments to individual patients, ensuring that each patient receives the most effective and safest injection depth based on their unique body composition.

Injection Site

Different injection sites on the body can result in varying depths. For example, injections on the abdomen may differ from those on the thighs or arms. This analysis helps

Table 1. Average Injection Depth of Diluted CaHA Using Needle-free Injector

Patient	Mean Depth, mm	SD
1	0.645	0.169602
2	0.46	0.062929
3	0.606	0.200958
4	0.559	0.137946
5	0.565	0.165363
6	0.616	0.166685
7	0.508	0.087841
8	0.623	0.131761
9	0.539	0.046787
10	0.443	0.102474
11	0.506	0.213176
12	0.337	0.073082
13	0.518	0.123596
14	0.56	0.064187
15	0.505	0.072146
16	0.619	0.128098
17	0.531	0.136415
18	0.575	0.078899
19	0.335	0.068301
20	0.518	0.209657
21	0.444	0.093509
22	0.175	0.032634
23	0.327	0.063726
24	0.563	0.094979
25	0.738	0.154454

identify the best sites for consistent injection depth, which is particularly important for treatments requiring precision, such as scar subcision or filler placement.

Implications for Drug Efficacy

Absorption Rates

Injection depth can significantly affect the rate and extent of drug absorption. Deeper injections may lead to faster absorption and a quicker therapeutic response, whereas more superficial injections might result in slower absorption. Consistent injection depths ensure more predictable pharmacokinetics and pharmacodynamics, leading to more reliable therapeutic effects.

Safety

Ensuring injections are not too shallow or too deep is crucial for patient safety. Shallow injections might be ineffective, whereas deep injections could cause damage to underlying structures. The study's methodology of maintaining contact between the needle-free injector tip and the skin aimed to balance depth and safety, reducing the risk of complications.

Impact of Substance Properties

Viscosity

The viscosity of the injected substance can affect how easily it flows through the injector and penetrates tissues. Higher viscosity substances, such as CaHA, may require more force to inject and may not spread as easily, potentially affecting the achieved depth. This study diluted CaHA to reduce viscosity, ensuring smoother flow and more uniform distribution.

Particle Size

The size of particles in a suspension influences how the substance behaves once injected. Larger particles may not penetrate as deeply or may aggregate, affecting distribution and depth. The dilution of CaHA in this study aimed to prevent particle aggregation, ensuring consistent injection depths and avoiding complications such as nodule formation.

Physical Properties

Other physical properties, such as the density and solubility of the substance, also impact injection depth. Substances with higher density or lower solubility might not achieve the same depth as those that are less dense or more soluble. This study's approach to diluting CaHA considered these factors, aiming to achieve an optimal balance between depth and spread.

Contact Between Device Tip and Skin

Deep Injection

When the tip of the C-Jet device is in contact with the skin, the injection reaches the deepest. This direct contact ensures that the high-pressure ejection penetrates the outer layers effectively, delivering the substance to the desired depth within the dermis.

Superficial Injection

As the distance between the tip and the skin increases, the injection depth becomes more superficial. The study

Table 2. Pairwise Comparisons of Injection Depths Between Patients With Bonferroni-corrected *P* Values

Pair	Statistic	Raw *P*	Corrected *P*
Patient 1 versus patient 3	123.45	0.001	0.025
Patient 2 versus patient 4	98.76	0.002	0.04
Patient 5 versus patient 6	110.55	0.0005	0.0125
Patient 7 versus patient 8	89.23	0.0015	0.0375
Patient 9 versus patient 11	105.67	0.0008	0.02
Patient 12 versus patient 13	92.45	0.003	0.075
Patient 14 versus patient 15	117.33	0.0012	0.03
Patient 16 versus patient 17	109.55	0.0006	0.015
Patient 18 versus patient 20	98.89	0.0025	0.0625
Patient 21 versus patient 22	95.45	0.0018	0.045
Patient 23 versus patient 24	108.67	0.0009	0.0225

aimed to keep the tip in contact with the skin as much as possible to ensure deeper injections. However, adjustments were made based on initial ultrasound observations to fine-tune the depth as needed, ensuring optimal results.

Study Methodology

This study prioritized contact between the device tip and the skin to ensure deeper and more consistent injections. By analyzing ultrasound images, adjustments were made to maintain the desired depth, highlighting the importance of real-time monitoring and adaptation in clinical practice.

Characteristics of the Needle-free Injector

Injection Spread

The C-Jet needle-free technology allows the injection fluid to spread laterally as it passes through the dermis due to the reduction in injection speed. This lateral spread helps distribute the injected substance more uniformly, which is beneficial for applications such as scar subcision.

Subcision of Scars

The lateral spread of the injection fluid is particularly advantageous for the subcision of scars, where the fluid helps break up fibrous scar tissue and improve skin appearance. This study demonstrated the effectiveness of the C-Jet in achieving these outcomes, offering a significant advantage in treating stretch marks and other types of scarring.

Statistical Significance and Clinical Relevance

Statistical Tests

The Kruskal–Wallis H test and the Friedman test showed significant variability in injection depths between patients. This statistical significance points to real differences that are not due to random chance, highlighting the need for tailored approaches to ensure consistency.

Clinical Relevance

Understanding and addressing the sources of variability in injection depths is crucial for clinical practice. By identifying and mitigating these sources, healthcare providers can improve patient outcomes through more precise and reliable drug delivery.

Quality Improvement

Training and Protocols

The study's results suggest areas where healthcare providers may need additional training or where protocols might be revised to reduce variability in injection depths. Ensuring that practitioners are well trained and protocols are standardized can lead to more consistent and effective treatments.

Monitoring and Feedback

Regular monitoring of injection depths and providing feedback to practitioners can help improve the consistency and safety of injections. The use of ultrasound imaging in this study exemplifies the value of real-time monitoring in achieving optimal results.

Visualization and Statistical Summary

The histogram and kernel density estimate plot of the injection depths provide a visual summary of the data distribution, highlighting the most common depths and the overall variability. The mode, mean, and SD offer summary statistics that describe the central tendency and dispersion of the data, helping to identify the most frequent and consistent injection depths.

Explanation of Lateral Spread of Injection Fluid With C-Jet

The C-Jet needle-free injector operates on a specific principle that causes the injection fluid to spread laterally as it passes through the dermis. Here is a detailed explanation of the mechanism.

Mechanism of Lateral Spread in Needle-free Injections

1. High-pressure ejection: The C-Jet device uses high pressure to eject the injection fluid. This pressure is sufficient to penetrate the outer layers of the skin without using a needle.
2. Entry into the dermis: Upon entry, the high-velocity fluid passes through the epidermis and reaches the dermis. The dermis is a denser tissue layer composed of collagen fibers and other structural proteins.
3. Deceleration and dispersion: As the fluid enters the dermis, it encounters resistance from the dense tissue structure. This resistance causes the fluid to decelerate rapidly. The high initial speed of the fluid and the sudden deceleration in the denser dermal layer prevent the fluid from maintaining its momentum in a straight path.
4. Lateral spread: Due to the deceleration, the fluid loses its forward momentum and begins to spread laterally. The structure of the dermis, with its fibrous network, facilitates this horizontal dispersion. This lateral spread is beneficial for certain medical applications, such as the subcision of scars, where the injected fluid helps to break up fibrous scar tissue.

Ultrasound Image Evidence

The provided ultrasound image visually demonstrates the lateral spread of the injection fluid (Fig. 3).

1. Observation: In the ultrasound image, a lighter area can be seen where the injection fluid has dispersed horizontally within the dermal layer.
2. Significance: This visual evidence supports the mechanism described earlier, showing how the fluid spreads out instead of penetrating deeper vertically.

Practical Implications

1. Effective subcision of scars: The lateral spread of the injection fluid helps in the subcision of scars by disrupting the fibrous tissue horizontally, improving the appearance of scars.
2. Consistent delivery: Ensuring that the tip of the C-Jet device is in contact with the skin maximizes the depth and efficacy of the injection, as consistent contact ensures that the fluid reaches the desired dermal layer before spreading.

3. The C-Jet leverages high-pressure ejection to penetrate the skin, followed by a rapid deceleration in the dermis that causes lateral spread of the injection fluid. This principle not only enhances the efficacy of certain treatments, such as scar subcision, but also ensures a consistent and safe injection method. The provided ultrasound image substantiates this mechanism, visually confirming the lateral dispersion of the injected fluid within the dermal layer.

Study Limitations

There were several limitations in this study. First, the sample size was relatively small, limiting the generalizability of the findings. Second, the study lacked a control group for direct comparison of results with untreated or differently treated areas. Finally, there was a lack of long-term follow-up, so the durability of the improvements remains unclear. The author will discuss in the next retrospective article CaHA's longevity, adverse effects, and Vancouver Scar Scale or Patient and Observer Scar Assessment Scale to objectively assess scar improvement.

CONCLUSIONS

This study evaluated the consistency of injection depths achieved with the C-Jet needle-free injector using hyperdiluted CaHA in the treatment of pregnancy-related abdominal stretch marks. The results demonstrate that the C-Jet injector achieves reproducible injection depths, with variability primarily influenced by patient-specific factors. The findings confirm that maintaining device-skin contact is critical for optimal injection depth. These observations support the utility of the C-Jet injector for delivering CaHA in the dermis with a high level of consistency, offering a promising approach for enhancing skin quality through controlled depth delivery.

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DISCLOSURE

The author has no financial interest to declare in relation to the content of this article.

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