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Objective Assessment of Atrophic Acne Scar Depth Using Alginate Imprints and Surface Profilometry: Findings from a Split-Face Intradermal Injection Study

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ABSTRACT

Background: Atrophic acne scars are a common sequela of acne vulgaris and may cause significant cosmetic and psychosocial morbidity. Conventional clinical grading systems are partly subjective and may not adequately detect subtle changes in scar morphology. Surface profilometry offers an objective method for quantifying scar depth. This study evaluated changes in atrophic acne scar depth following intradermal botulinum toxin type A and normal saline injections using alginate facial imprints and surface profilometry.

Aim: To objectively quantify changes in atrophic post-acne facial scar depth following intradermal botulinum toxin type A and normal saline injections using alginate facial imprints and surface profilometry.

Methods: This objective analysis was conducted within a prospective, single-blind, split-face, placebo-controlled study performed at a tertiary dermatology center. Thirty patients aged 18–40 years with atrophic post-acne facial scars were enrolled in the parent study; 15 patients underwent surface profilometric assessment and constituted the analysis set. One side of the face was randomized to receive intradermal botulinum toxin type A and the contralateral side received normal saline. Treatments were administered at baseline and repeated after 4 weeks. Alginate facial imprints were obtained at baseline and 8 weeks. Scar depth was measured using a stylus surface profilometer, and the mean of the 10 most prominent scar elevations on each mould was recorded.

Results: Mean scar depth on the botulinum toxin side decreased from 210.98 µm at baseline to 199.21 µm at 8 weeks, representing a mean reduction of 11.77 µm (5.58%; p=0.001). On the normal saline side, mean scar depth decreased from 186.11 µm to 179.66 µm, corresponding to a reduction of 6.45 µm (3.47%; p=0.001). Although the reduction was numerically greater on the botulinum toxin side, the inter-side difference was not statistically significant. Clinical outcome measures demonstrated mild improvement on both sides. Mean ECCA scores decreased slightly but not significantly, and no significant superiority of botulinum toxin was observed in Goodman–Baron grading, patient satisfaction, or independent observer assessment.

Conclusion: Surface profilometry detected small but measurable reductions in atrophic acne scar depth following intradermal injections on both sides of the face. However, botulinum toxin type A did not demonstrate significant objective or clinical superiority over normal saline. The findings suggest that part of the observed improvement may be attributable to the mechanical effects of intradermal injection rather than a specific pharmacological effect of botulinum toxin.

Keywords*: Acne scars, Atrophic scars, Botulinum toxin type A,Surface profilometry. Alginate imprint; Split-face study; ECCA score; Scar depth.*

INTRODUCTION

Acne vulgaris is a common inflammatory disorder of the pilosebaceous unit and may heal with persistent scarring, particularly when inflammation is severe, prolonged, or inadequately treated. Post-acne scarring is clinically important because it may be permanent, cosmetically disfiguring, and psychologically distressing; earlier clinical evaluation studies have shown that facial scarring may occur in a substantial proportion of patients with acne [1]. Atrophic scars are the most frequent form of post-acne scarring and result from inflammation-induced dermal matrix destruction, altered collagen remodelling, and insufficient tissue repair [2].

Atrophic acne scars are commonly classified into icepick, rolling, and boxcar scars according to their morphology. This classification is clinically relevant because scar depth, width, and dermal tethering differ among subtypes and influence both treatment selection and treatment response [3]. Clinical outcome assessment in acne scarring has traditionally relied on validated grading systems such as the Goodman and Baron qualitative grading system and the ECCA quantitative scale, which allow structured evaluation of scar severity and change over time [4,5].

However, clinical grading systems and two-dimensional photography remain partly subjective and may be influenced by lighting, patient positioning, observer experience, and the complex three-dimensional morphology of scars. In atrophic acne scarring, objective measurement of scar depth and surface irregularity is particularly important because subtle changes may not be adequately captured by global clinical scores. Recent work using three-dimensional skin imaging has emphasized that scar depth and volume are not readily measurable by routine clinical examination, and that objective topographic assessment can provide repeatable quantification of atrophic acne scar severity [6].

Surface profilometry provides an objective method for quantifying skin-surface irregularity by measuring topographic parameters in micrometres. Profilometric techniques, including analysis of skin replicas or surface impressions, have been used to assess skin roughness, scars, wrinkles, and treatment-related textural change. Validation studies have shown that profilometric devices can provide reliable and objective assessment of skin and scar surface roughness, supporting their use as adjuncts to clinical scar evaluation [7].

Botulinum toxin type A has been explored as a potential treatment for scars because of its ability to reduce dynamic muscular tension and its proposed effects on wound healing, fibroblast activity, and collagen remodelling. Its use has been described as a primary or adjunctive intervention in post-acne, postsurgical, and traumatic scarring, although the evidence remains limited and objective scar-depth data are scarce [8].

Therefore, the present study was designed to objectively quantify changes in atrophic post-acne facial scar depth following intradermal botulinum toxin type A and normal saline injections using alginate facial imprints and surface profilometry. Conducted within a split-face placebo-controlled intradermal injection study, this analysis aimed to determine whether botulinum toxin produced measurable scar-depth reduction beyond that observed with normal saline and whether objective profilometric changes were consistent with clinical measures including ECCA score, Goodman–Baron grading, patient self-assessment, and independent observer assessment.

AIM

To objectively quantify the change in atrophic post-acne facial scar depth following intradermal botulinum toxin type A and normal saline injections using alginate facial imprints and surface profilometry.

OBJECTIVES

- To determine the change in mean scar depth from baseline to 8 weeks on the botulinum toxin and normal saline sides using surface profilometry.
- To compare the magnitude of profilometric scar-depth reduction between the botulinum toxin and normal saline sides in a split-face design.
- To examine whether objective profilometric changes were consistent with clinical outcome measures, including ECCA score, Goodman–Baron grading, patient self-assessment and independent observer assessment.

METHODS

Study design and setting

This objective scar-depth analysis was conducted within a prospective, single-blind, split-face, placebo-controlled intradermal injection study. The study was performed in the outpatient Department of Dermatology of a tertiary teaching institute between February 2012 and July 2013 after approval from the Institutional Ethics Committee. Written informed consent was obtained from all participants before enrolment.

Study population

Patients aged 18–40 years with atrophic post-acne facial scars over the cheeks were eligible for inclusion. Patients were excluded if they had active facial acne lesions, a history of keloids, pregnancy or lactation, neuromuscular junction

disorders such as myasthenia gravis, current systemic aminoglycoside therapy, a history of radiation therapy or chemotherapy, haematological disorders, or known sensitivity to botulinum toxin. Thirty patients fulfilling the eligibility criteria were enrolled in the parent clinical cohort. Surface profilometry was performed in 15 patients and constituted the objective analysis set for this manuscript.

Baseline clinical assessment

All participants underwent detailed history-taking and clinical examination. Demographic data, duration of acne and acne scarring, previous treatment history, and relevant medical history were recorded. The face was examined for scar type, number, distribution and severity. Atrophic scars were classified clinically as icepick, rolling or boxcar scars. Scar severity was assessed separately on each side of the face using the Goodman and Baron qualitative grading system and the ECCA quantitative grading system at baseline and at 8 weeks.

Split-face intervention

Each participant served as his or her own control. The side allocated to botulinum toxin type A was selected by lottery method, and the contralateral side received normal saline. Botulinum toxin type A was reconstituted with 2.5 mL normal saline per 100 units. The total dose was selected according to scar severity: 10 units for mild scarring and 15–20 units for moderate-to-severe scarring. The assigned dose was distributed intradermally in and adjacent to the scars. In icepick-predominant areas, injections were placed at approximately 1-cm staggered intervals to cover the scarred cheek area. For larger rolling or boxcar scars, 1 unit was injected into the scar. The injections were administered intradermally at approximately 30 degrees to the skin surface to produce a subepidermal wheal. The contralateral side was injected with an equivalent amount of normal saline in the same manner. Injections were given at baseline and repeated after 4 weeks. Final assessment was performed at 8 weeks.

Facial imprint technique

Facial imprints were obtained from both sides of the face at baseline and again at 8 weeks. Before imprinting, the face was washed with tap water and gently dried. Alginate powder was mixed with water in a standardized proportion of one scoop of alginate powder, equivalent to 8.4 g, with 20 mL of water. The mixture was vigorously mixed to form a uniform paste and applied over the cheek. After approximately 2 minutes, the set alginate mould was marked to identify a reproducible cheek area for analysis. The area was demarcated using four anatomical reference points: two fingers medial to the tragus, one finger lateral to the ala of the nose, two fingers below the eyebrow, and one finger above the angle of the mouth. The marked area was cut from the mould, air-dried for 10 minutes, wrapped in sterile gauze, labelled, and stored for profilometric assessment. The same procedure was repeated on the opposite side.

Surface profilometry

The alginate moulds were analysed using a stylus surface profilometer. Because the mould represented a negative imprint of the skin surface, depressed acne scars on the face appeared as corresponding elevations on the alginate surface. For each side of the face, the 10 most prominent elevations within the marked area were measured, and their mean value was taken as the mean scar depth for that side. Measurements were recorded in micrometres. Profilometric measurements at baseline and 8 weeks were used to determine the absolute and percentage change in scar depth on the botulinum toxin and normal saline sides.

Supportive clinical outcome measures

To examine whether objective changes were consistent with clinical outcomes, profilometry findings were interpreted alongside changes in ECCA score, Goodman and Baron grade, patient self-assessment and independent observer assessment of standardized clinical photographs. Clinical photographs were obtained at baseline and at 8 weeks using a fixed stereotactic photographic device to maintain comparable camera distance and angle.

Statistical analysis

Data were analysed using SPSS version 15. Categorical variables were summarized as frequencies and percentages. Continuous variables were summarized using mean, standard deviation and range, as applicable. Baseline and 8-week values were compared separately for the botulinum toxin and normal saline sides using the Wilcoxon signed-rank test. Inter-side comparisons were performed using paired non-parametric methods appropriate for the split-face design. A p value of <0.05 was considered statistically significant.

RESULTS

Study population and profilometry analysis set

The parent clinical cohort comprised 30 patients with atrophic post-acne facial scars. There were 21 males (70%) and 9 females (30%), giving a male-to-female ratio of 2.33:1. The age ranged from 18 to 36 years, with a mean age of 24 years. Most patients were in the 21–30-year age group (23/30, 76.67%).

The duration of acne scarring ranged from 6 months to 10 years, with a mean duration of 3.867 ± 2.8 years. Twenty patients (66.67%) had a scar duration of 4 years or less. Surface profilometry was performed in 15 patients and constituted the objective scar-depth analysis set.

Table 1. Baseline demographic and disease profile of the clinical cohort

Variable	Value
Total patients	30
Male:female	21:9
Mean age	24 years
Age range	18–36 years
Most common age group	21–30 years, 23/30 (76.67%)
Mean scar duration	3.867 ± 2.8 years
Scar duration range	0.5–10 years
Patients undergoing surface profilometry	15

Baseline scar profile

Icepick scars were the predominant scar type on both sides of the face. The mean number of icepick scars was 113 on the right side and 121 on the left side. Rolling and boxcar scars were less frequent. Baseline ECCA scores were comparable between the two sides, with a mean score of 198.5 on the right side and 200.17 on the left side.

Table 2. Baseline scar morphology and baseline ECCA score

Parameter	Right side	Left side
Mean number of icepick scars	113	121
Mean number of rolling scars	38	37
Mean number of boxcar scars	33	37
Baseline ECCA score, maximum	240	210
Baseline ECCA score, minimum	150	155
Baseline ECCA score, mean	198.5	200.17

Objective scar-depth outcome by surface profilometry

Mean scar depth decreased on both the botulinum toxin and normal saline sides at 8 weeks. On the botulinum toxin side, mean scar depth decreased from 210.98 µm at baseline to 199.21 µm at 8 weeks, corresponding to a mean reduction of 11.77 µm (5.58%). On the normal saline side, mean scar depth decreased from 186.11 µm to 179.66 µm, corresponding to a mean reduction of 6.45 µm (3.47%). The within-side reduction was statistically significant on both sides (p=0.001 for each comparison).

Table 3. Surface profilometry outcomes in the objective analysis set

Study side	Baseline mean scar depth (µm)	8-week mean scar depth (µm)	Mean reduction (µm)	Percentage reduction	p value
Botulinum toxin	210.98	199.21	11.77	5.58%	0.001
Normal saline	186.11	179.66	6.45	3.47%	0.001

The reduction in mean scar depth was numerically greater on the botulinum toxin side; however, the inter-side difference was not statistically significant.

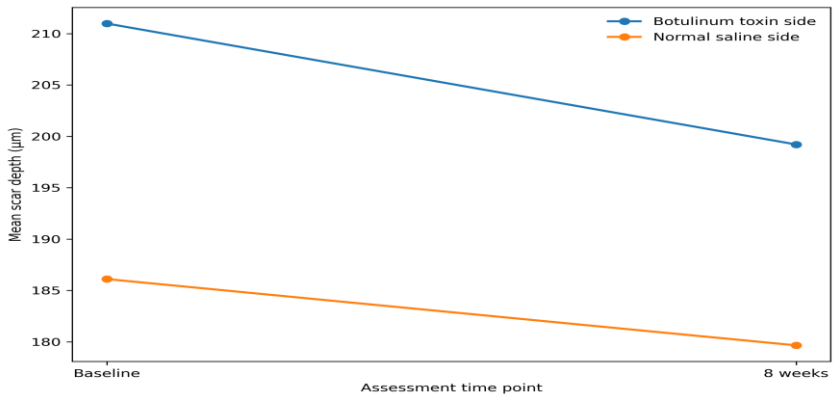

Figure 1. Change in mean scar depth measured by surface profilometry at baseline and 8 weeks in the profilometry analysis set. Both study sides showed statistically significant within-side reduction at 8 weeks (p=0.001 for each comparison).

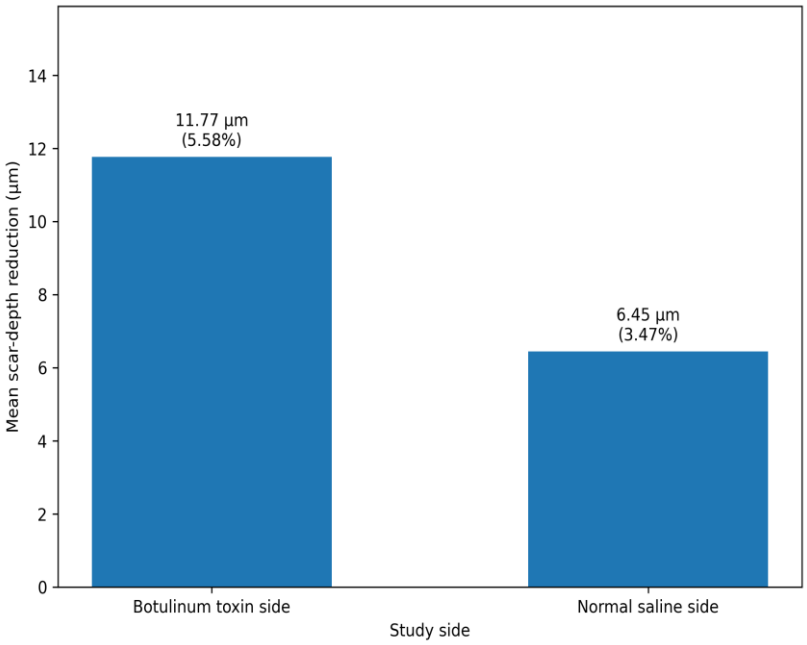

Figure 2. Mean absolute scar-depth reduction from baseline to 8 weeks. The botulinum toxin side showed a reduction of 11.77 µm (5.58%), and the normal saline side showed a reduction of 6.45 µm (3.47%); the inter-side difference was not statistically significant.

Clinical outcome measures in relation to objective findings

Clinical efficacy outcomes showed mild improvement on both sides, broadly paralleling the profilometric findings. The mean ECCA score decreased from 199.5 to 195.33 on the botulinum toxin side and from 199.17 to 196.0 on the normal saline side. These changes were not statistically significant on either side (p=0.063 and p=0.066, respectively).

Table 4. Clinical outcome measures supporting objective assessment

Outcome measure	Botulinum toxin side	Normal saline side	Statistical interpretation
ECCA score	199.5 to 195.33	199.17 to 196.0	Not significant on either side
Goodman–Baron grade	3/24 grade 3–4 patients improved to grade 1–2	5/24 grade 3–4 patients improved to grade 1–2	No treatment-side superiority
Patient self-assessment	24/30 (80%) slightly/somewhat satisfied	22/30 (73.3%) slightly/somewhat satisfied	No significant inter-side difference
Independent observer assessment	Mean score 1.60	Mean score 1.53	p=0.367; not significant

By Goodman–Baron grading, the proportion of patients with grade 3 or 4 scarring decreased from 24/30 to 21/30 on the botulinum toxin side and from 24/30 to 19/30 on the normal saline side. Although within-side improvement was statistically significant on both sides, the normal saline side did not perform inferiorly to the botulinum toxin side. Independent observer assessment similarly demonstrated poor-to-mild improvement on both sides, without a statistically significant inter-side difference (p=0.367).

Summary of the result

Surface profilometry detected a measurable reduction in mean acne scar depth after intradermal injections on both sides of the face. The magnitude of reduction was small and was not accompanied by a statistically significant clinical or objective advantage of botulinum toxin over normal saline. The parallel improvement observed on both sides suggests that part of the measurable scar-depth reduction may be attributable to the mechanical effect of intradermal injection rather than to the pharmacological action of botulinum toxin.

DISCUSSION

In this objective scar-depth analysis, alginate imprint-based surface profilometry detected a small but statistically significant reduction in atrophic acne scar depth on both treatment sides at 8 weeks. Mean scar depth decreased from 210.98 µm to 199.21 µm on the botulinum toxin side, giving an absolute reduction of 11.77 µm or 5.58%, and from 186.11 µm to 179.66 µm on the normal saline side, giving a reduction of 6.45 µm or 3.47%. Although the reduction was

numerically greater with botulinum toxin, the inter-side difference was not statistically significant. Thus, botulinum toxin type A did not demonstrate objective superiority over normal saline in this split-face analysis.

The use of profilometry adds value because conventional scar grading may not fully capture subtle depth changes. Petit et al. validated 3D skin imaging in 31 patients with atrophic acne scars and reported strong correlation between valley void volume and clinical severity, with a correlation coefficient of 0.77 and excellent repeatability, with an intraclass correlation coefficient of 0.98 [9]. Similarly, Tanizaki et al. found that acne scar severity correlated with affected area, scar volume, and maximum depth, with correlation coefficients of 0.736, 0.728, and 0.722, respectively [10]. These findings support the relevance of objective topographic assessment in acne scar studies.

In the present study, profilometry detected statistically significant improvement, whereas ECCA scores showed only small, non-significant reductions and observer assessment showed mainly poor-to-mild improvement. This difference between objective and clinical measures has also been reported by Salameh et al., who found that 3D imaging changes correlated with patient-reported SCARS scores but not with qualitative global scar grading [11]. Bloemen et al. also demonstrated that profilometric assessment of scars can be reliable, with PRIMOS-based roughness measurements showing intraobserver and interobserver intraclass correlation coefficients above 0.85 [12]. Therefore, the present findings suggest that small depth changes may be measurable instrumentally before becoming clinically obvious.

However, the magnitude of improvement was limited when compared with more intensive scar-remodelling procedures. Friedman et al. used 3D optical profiling after five sessions of 1064-nm Q-switched Nd:YAG laser and reported progressive improvement in skin roughness, reaching 39.2% at 6 months [13]. By comparison, the maximum scar-depth reduction in the present study was only 5.58% at 8 weeks on the botulinum toxin side. This difference is expected, as laser procedures induce controlled dermal injury and collagen remodelling, whereas intradermal botulinum toxin injection is less aggressive and was assessed over a shorter follow-up period.

The improvement observed on the saline side is important. Gandhi and Makhecha compared platelet-rich plasma with normal saline injections in acne scars and found significant improvement on both sides without a significant intergroup difference; ultrabiomicroscopy showed scar thickness improvement of 25.35% on the PRP side and 25.65% on the saline side [14]. This supports the possibility that intradermal injection itself may produce a subcision-like mechanical effect, dermal stimulation, and tissue remodelling, independent of the injected agent. The present study's parallel improvement on both sides is consistent with this interpretation.

The findings also contrast with studies combining botulinum toxin with microneedling. Ebrahim et al. reported 70% overall improvement on the botulinum toxin-plus-microneedling side, whereas the saline-plus-microneedling side showed only mild improvement in 50% of patients [15]. The superior response in that study may reflect enhanced botulinum toxin delivery through microneedling-created channels and the collagen-inducing effect of microneedling itself. In contrast, the present study evaluated intradermal botulinum toxin alone, in a cohort with predominantly icepick scars, which are deep and structurally less responsive to diffuse intradermal therapy.

The strengths of this analysis include its split-face design, objective micrometre-level measurement, standardized imprinting method, and comparison with clinical outcome measures. Limitations include the small profilometry sample size, short follow-up of 8 weeks, use of negative alginate replicas rather than direct in-vivo 3D imaging, and possible variability in mould preparation and measurement-site selection. Longer studies using direct 3D imaging and scar-type-specific analysis are needed.

In conclusion, surface profilometry demonstrated a small but measurable reduction in atrophic acne scar depth after intradermal injections. However, botulinum toxin type A did not show significant objective or clinical superiority over normal saline. The findings suggest that intradermal injection itself may contribute to scar-depth reduction, while botulinum toxin, as used in this protocol, is unlikely to provide substantial stand-alone benefit for atrophic post-acne facial scars.

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