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Enzymatic Bromelain-Based Debridement With Nexobrid: A New Treatment to Effectively Prevent Traumatic Tattoos After Abrasive Incidents and Explosive Events

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Abstract

Traumatic tattoos, resulting from the accidental impregnation of foreign particles, are common consequences of road traffic accidents and explosions. Unlike conventional tattoos, these occur when high-impact events embed foreign materials into the skin, causing persistent discoloration and cosmetic disfigurement. Preventing the permanent inclusion of these particles through immediate removal is widely considered as the best strategy. Nowadays, the preventing procedures by means of scrubbing remain insufficient and the need for delayed additional methods is one of the main causes of concern. Consequently, we aim to propose a new therapeutic protocol with enzymatic debridement to prevent and treat traumatic tattoos. In this prospective study, we included patients diagnosed with traumatic tattoos referred to our National Burn Center during 9 months (from June 2024 to March 2025). All were treated with enzymatic debridement (Nexobrid) to remove necrotic tissues after initial cleaning of the wound. Pigmented surface was evaluated before and after enzymatic debridement. A total of 15 consecutive patients were successfully treated with enzymatic debridement (Nexobrid) under sedation within the first 24 hours after the initial incident. In total, 92.5% of the surface of pigmented dermis was cleared from pigments after treatment, thus preventing the occurrence of traumatic tattoos. No adverse events were reported during the treatment. Enzymatic debridement presents a comprehensive approach to wound care in cases of traumatic tattoos, offering precision, tissue preservation, and user-friendly application, and to optimize functional and cosmetic outcomes. These advantages position it as an effective alternative to more traditional methods, particularly in settings that require minimal invasiveness and maximal tissue conservation.

Key words: traumatic tattoos; enzymatic debridement; Nexobrid; abrasive trauma; explosive accident.

BACKGROUND

Friction burns, associated with the rising use of motorcycles, e-scooters, and bicycles, but also with traumatic and war injuries, constitute a commonly encountered type of burns. These burns are almost always accompanied by other traumatic injuries as well as traumatic tattooing, which poses a great challenge for plastic surgeons. Traumatic tattoos are created when foreign particles (ie, asphalt, dirt, glass, gravel, metal, etc.) unintentionally penetrate, in an irregular fashion, in the dermis and subcutis, during high-velocity accidents.[1] Two primary mechanisms can cause these tattoos: abrasive incidents, typically seen in road accidents, and explosive events, where gunpowder or metallic particles penetrate the skin. Traumatic tattoos can thus be classified into abrasive and explosive types.

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Low-intensity conflicts and the use of improvised explosive devices have led to an increased frequency of burns and traumatic tattoos in combat zones.[2] As initially described, the abrasive type leaves pigment deposits in the more superficial layers of the skin, whereas the explosive type usually presents with a central focus of deeply embedded detritus and more superficially placed particles radiating outward.[3] These particles can be difficult to remove. Once lodged in the dermis, re-epithelization and healing of the wound on top of these particles may lead to persistent and irregular black or blue skin discoloration.[4,5]

Invasive methods like surgical excision, dermabrasion, and hydrosurgery (Versajet), and noninvasive methods such as chemical peels or laser therapy have also been reported as the standard of care for traumatic tattooing.[1,4,6,7] Historically, acute emergency treatment involves the immediate and thorough removal of all particles, including aggressive mechanical removal (scrubbing) of the wound, alongside care for associated wounds, contusions, and abrasions.[8] The optimal approach is to prevent traumatic tattoo formation by removing foreign particles before the healing process begins.[7] While effective, the main disadvantages of invasive debridement methods are reported to be its invasiveness and that can damage viable skin, requiring specialized personnel and facilities.[9] Noninvasive tattoo removal methods have evolved significantly, from ancient techniques involving salt abrasion to the modern use of Q-switched lasers, which have become the gold standard because of the advantage of their selective pigment absorption and short pulse duration.[10] These techniques, however, have led to increased scarring in the long-term.[1,4,7,8,10]

The actual treatments at the acute phase described above remain insufficient with the necessity of secondary procedures to remove traumatic tattoos. A less invasive and more selective debridement method for prevention and treatment of traumatic tattooing, which will preserve as much viable tissue as possible and lead to less scarring, is lacking. To our knowledge, there is no study in the literature reporting on enzymatic debridement of burns with traumatic tattooing. Enzymatic debridement offers a novel solution to the aforementioned challenges. Nexobrid (NXB, MediWound Ltd, Yavne, Israel), is a bromelain-based product, derived from a pineapple plant stem concentrate of proteolytic enzymes (anacaulase-bcdb, eg, thiol-endopeptidases, phosphatases, glucosidases, peroxidases, cellulases, glycoproteins, carbohydrates, and other nonprotein components). There are numerous reports in the literature on enzymatic debridement of deep partial-thickness and/or full-thickness burns from 1974 up until now.[11,12] NexoBrid has been shown to selectively remove burn eschar and embedded debris without harming viable tissue, minimizing blood loss, and simplifying treatment.[13] This nonsurgical approach reduces the need for excisional debridement and can preserve enough healthy dermis to allow spontaneous epithelialization. Herein, we present our experience with the innovative and effective approach of removing traumatic tattoos through enzymatic debridement and discuss this method compared to the other therapeutic options currently available, ie, invasive methods like surgical excision, dermabrasion and hydrosurgery, and noninvasive methods such as chemical peels or laser therapy.

METHODS

We performed a prospective study in which we included patients diagnosed with traumatic tattoos either from abrasive or explosive mechanisms referred to our National Burn Center during 9 months (from June 2024 to March 2025). Immediate treatment consisted of thorough scrubbing with the use of a surgical sponge and rinsing of the wounds under midazolam and ketamine sedation: a first picture of the lesion was taken after the initial scrubbing. However, a considerable amount of grayish and black pigmentation persisted within the dermis. To prevent traumatic tattoos and treat burn wounds as our standard of care, enzymatic debridement was performed in the first 24 hours using Nexobrid, under sedation. The lesions were covered with a 1- to 3-mm-thick layer of Nexobrid: 2 or 5 g enzymatic powder in 20 ml gel vehicle, according to the extent and anatomical distribution of the friction burns. The surrounding normal skin was covered with sterile Vaseline ointment to contain the product. The area was then covered with a sterile polyurethane occlusive sheet that was sealed for a period of 4 hours. Four hours after application, dressings were removed and the wound was scrubbed again with an abrasive sponge soaked in normal saline and with a blunt wooden tongue depressor until the appearance of a clean, bleeding wound bed. The efficacy of pigments removal was assessed after enzymatic debridement and a second picture was taken. The results of the study were based on the comparison of these 2 pictures. All the patients gave their informed consent to participate.

Clinical tattoo clearance efficacy: a computerized analysis of the clinical tattoo clearance efficacy was performed by comparing pre-and postenzymatic debridement photographs based on the wound surface cleared of exogenous pigments.[14] Assessment of the photographs was based on the presence of any pigment or foreign materials. Pretreatment pictures and posttreatment pictures were uploaded to the open-source software ImageJ, developed by the *National Institutes of Health* (Wayne Rasband). Consistency in photography parameters (zoom, angle of photography, lighting, and limited background noise) was kept to the maximal possible level. The ratio of the pigmented wound area to the total wound surface was quantified pre- and posttreatment using image-based analysis and numerical data generated by the software. Graphical representation and statistical analyses were performed using a paired t-test (GraphPad PRISM 9.4.1 software). Adverse events, such as rash, pruritus, pyrexia, anemia, and vomiting, were recorded during the first 3 days following enzymatic debridement.

RESULTS

A total of 15 consecutive patients (2 children and 13 adults) were treated with enzymatic debridement (Nexobrid) at the bedside for abrasive or explosive burns with exogenous pigments within the dermis, which posed a risk of traumatic tattoos (Table 1). The age range was 4-51 years, with a mean of 22.7 years. A total of 11 patients (73%) in this study were victims of road accidents, either as pedestrians or 2-wheeler drivers. The friction burns were located on the limbs and face, with some patients having burns in multiple areas (Figures 1-4). Four patients (27%) suffered from explosive

Table 1. Characteristics of the Patient Cohort (L = Left, R = Right, Bil = Bilateral, UE = Upper extremity, LE = Lower extremity)

Patient	Sex	Age	Mechanism	Type	Location	Total wound surface (%TBS)	Pigmented surface (%TBS)
1	M	19	Motor vehicle accident	Abrasive	L arm, L knee	2	2
2	M	22	Motor vehicle accident	Abrasive	R elbow and hand, L thigh, L leg	3	3
3	M	8	Pedestrian	Abrasive	Bil UE, knee, face	5	5
4	F	4	Pedestrian	Abrasive	Legs	3	2
5	M	20	Motor vehicle accident	Abrasive	Bil hands, R leg, R knee	3	3
6	F	22	Motor vehicle accident	Abrasive	Bil UE, LE, buttocks	14	10
7	F	18	Motor vehicle accident	Abrasive	Bil UE, legs	5	5
8	M	24	Motor vehicle accident	Abrasive	L gluteus, back, R hand	6	6
9	F	48	Motor vehicle accident	Abrasive	Bil gluteus, R leg	4	4
10	M	51	Motor vehicle accident	Abrasive	Hands, elbows, thighs	6	6
11	M	18	Motor vehicle accident	Abrasive	RUE, LUE, L shoulder, chin, LE	7	7
12	M	34	Rocket sharpnel military	Explosive	L thigh, L hand	3	3
13	F	17	Rocket sharpnel military	Explosive	Bil thighs, L hand, R shoulder	10	5
14	M	19	Improvised explosive devices	Explosive	R thigh	3	3
15	M	17	Improvised explosive devices	Explosive	Bil LE, R forearm	6	6
Results	*10 M 5 F*	*Mean age: 22.7*		*11 abrasive 4 explosive*		*Mean: 5.3%*	*Mean: 4.7%*

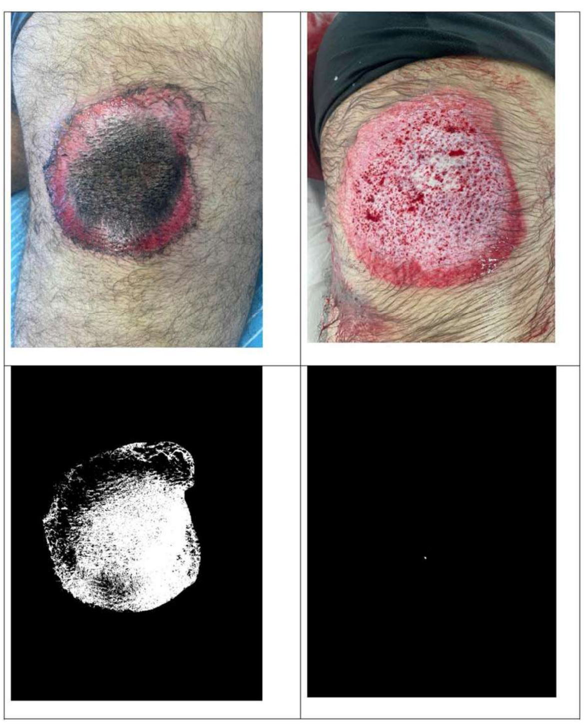

Figure 1. Traumatic Wound of the Knee of a 20-Year-Old Patient Caused by a Motorbike Accident Before (Upper Left) and After (Upper Right) Treatment with Nexobrid, and Pigmented Surface Analysis Before (Lower Left) and After (Lower Right) Treatment With Nexobrid

Figure 2. Traumatic Wound of the Left Knee and Leg of a 4-Year-Old Girl Before (Upper Left) and After (Upper Right) Treatment with Nexobrid, and Pigmented Surface Analysis Before (Lower Left) and After (Lower Right) Treatment with Nexobrid

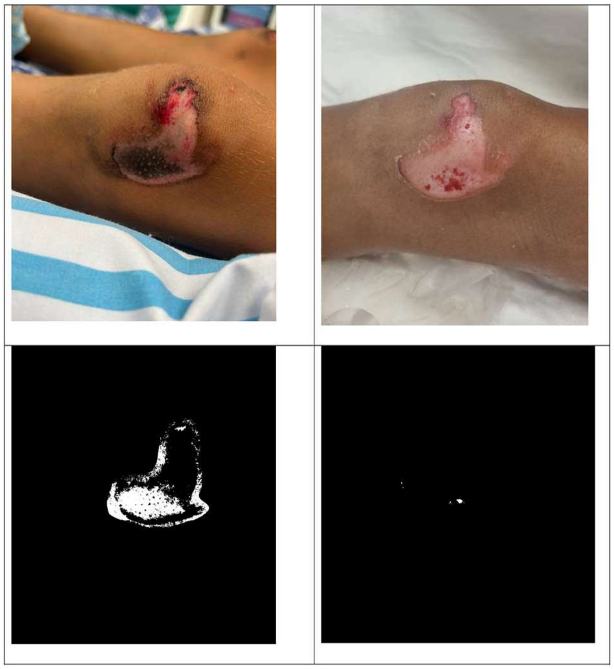

Figure 3. Abrasive Lesion with Traumatic Tattoo of the Left Knee of a Young Pedestrian Patient Hit by a Car, Before (Left) and After (Right) Treatment with Nexobrid, and Pigmented Surface Analysis Before (Lower Left) and After (Lower Right) Treatment with Nexobrid

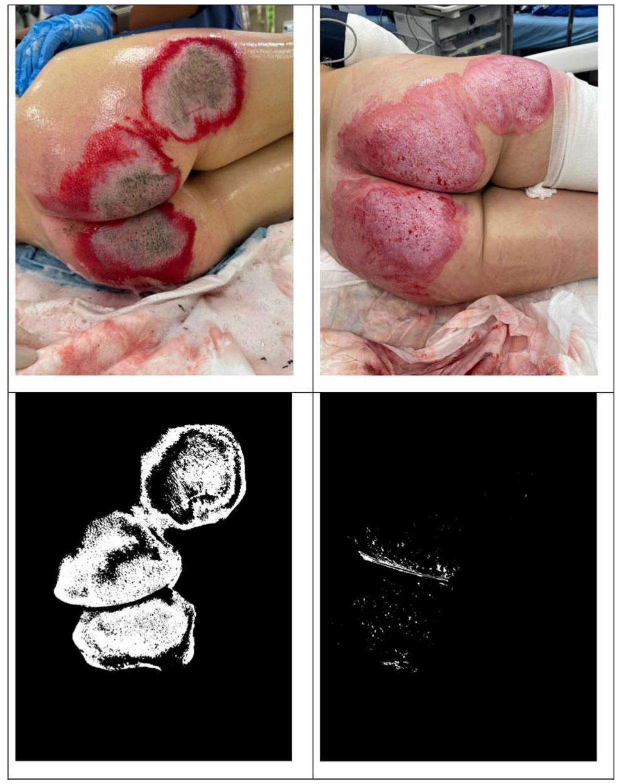

Figure 4. Abrasive Lesion with Traumatic Tattoo of the Buttock and Thigh of a 22-Year-Old Woman Taken in a Motor Vehicle Accident, Before (Left) and After (Right) Treatment with Nexobrid, and Pigmented Surface Analysis Before (Lower Left) and After (Lower Right) Treatment with Nexobrid

trauma (Figure 5). The traumatic lesions covered a mean surface area of 5.3% of the total body surface and the mean pigmented surface was 4.7% TBSA.

The mean surface of burns covered with pigments (Table 2) before application of Nexobrid was 37.5% and decreased to 2.1% after Nexobrid treatment (mean difference −35.4%, 95% CI [−44.8; −25.9], $P < .0001$) (Figure 6). A total of 92.5% of the burned areas were visibly cleared of pigments and foreign particles (95% CI [87.1; 97.9]). When the 2 mechanisms are taken into consideration separately, the mean surface of burns covered with pigments before application of Nexobrid was 41.1% and decreased to 1.71% after Nexobrid treatment in cases of abrasive injuries (mean difference −39.4%, 95% CI [−49.9; −28.9]). In cases of explosive events, the mean surface of burns covered with pigments before application of Nexobrid was 29.1% and decreased to 3.17% after Nexobrid treatment (mean difference −25.9%, 95% CI [−50.3; −1.6]). The treatment effectively removed an average of 96% of pigmented particles from the surface in cases of abrasion wounds and an average of 84% of pigmented particles in cases of explosions of varying depth. No adverse events were reported following the treatment of these patients with Nexobrid.

DISCUSSION

Traumatic tattoos occur when abrasive or explosive incidents embed foreign materials into the skin, causing persistent discoloration and cosmetic disfigurement.[1] The best treatment strategy has been proven to be immediate removal before the healing process begins, thus preventing the permanent inclusion of these particles.[7] We present our experience and propose an innovative approach of removing traumatic tattooing after abrasive or explosive incidents through enzymatic debridement.

The search of the literature yielded no articles reporting on treatment of traumatic tattooing with enzymatic debridement (Nexobrid). A total of 12 studies reported on mechanical debridement of traumatic tattoos by the means of dermabrasion or surgical incisions,[15-26] 3 on microsurgical treatment (surgical treatment under microscope),[27-29] 3 on removal by means of hydrosurgery (Versajet),[1,30,31] 2 on the use of chemical peels and ointments,[32,33] and 20 articles on treatment of traumatic tattooing with lasers,[4,5,7,14,34-49] 3 studies reported no treatment at all or just observation due to patient's request.[50-52] Most of the articles dealt with treatment of posthealing traumatic tattoos, meaning that the patient had to undergo additional invasive or noninvasive procedures once healed.

Secondary treatments posthealing reported included micro incisions,[27-29] dermabrasion methods,[15-20] laser treatments including CO_2, Nd:YAG, QS Ruby, Alexandrite, and PDL.[4,5,7,14,34-49] These methods can lead to undesirable scarring, incomplete removal, and pigmentation disturbances, and can be proven to be costly and time-consuming for patients. Many authors agree that the best strategy is to prevent the permanent inclusion of foreign objects in the skin by removing all visible particles before the healing process begins.[4-6,53]

Table 2. Surface Analysis Based on Each Anatomical Pigmented Zone

Lesions with traumatic tattoos	Anatomical zone/mechanism	% of the lesion covered with pigments after scrubbing	% of lesion covered with pigments after Nexobrid	% of removal after Nexobrid
1	Elbow abrasive	24.04	0.40	−98.33
2	Wrist abrasive	24.14	0.97	−95.97
3	Knee abrasive	61.37	2.89	−95.29
4	Forehead abrasive	16.25	0.15	−99.07
5	Knee abrasive	35.19	0.28	−99.19
6	Leg abrasive	22.90	0.03	−99.88
7	Knee abrasive	26.82	1.48	−94.50
8	Gluteal abrasive	64.96	1.66	−97.45
9	Shoulder abrasive	37.41	0.64	−98.28
10	Leg abrasive	27.16	4.17	−84.65
11	Gluteal abrasive	70.63	0.87	−98.77
12	Forearm abrasive	47.31	0.02	−99.95
13	Wrist abrasive	70.37	8.32	−88.18
14	Back abrasive	47.03	2.06	−95.61
15	Leg explosive	3.09	1.55	−49.93
16	Leg explosive	41.81	0.21	−99.50
17	Leg explosive	62.36	5.71	−90.84
18	Arm explosive	3.90	0.01	−99.76
19	Hip explosive	13.71	2.39	−82.53
20	Hip explosive	49.59	9.15	−81.54
Means		*37.5*	*2.1*	*−92.5*

Immediate treatments emerge as more appropriate methods to prevent traumatic tattoos and avoid the need of secondary procedures. In the acute phase, the treatment that has long been considered the reference standard involves aggressive scrubbing of the affected area with sterile or surgical brushes to remove superficial particles before skin re-epithelialization.[22,23] This immediate care is crucial for preventing permanent pigment embedding.[22,23] Despite its relative effectiveness, aggressive scrubbing can only be performed within a short window (ideally within 6-72 hours), and delayed intervention significantly reduces the ability to remove particles without causing further skin damage. Application of silver sulfadiazine cream on wounds 12 hours before surgical removal of particles was concluded to be highly efficacious for aiding surgical intervention in such cases by softening the necrotic tissues to allow the pigments to be released.[33] Other methods proposed were electrosurgical cautery pads and forceps removal,[21,24] micro-incisions,[28] V-shaped blades,[25] mini-punches,[26] hydrosurgery,[1,30,31] monofilament fiber debriding technology,[54] and chemical peels.[32]

Enzymatic debridement seems to offer several distinct advantages over traditional methods, such as surgical, mechanical, or hydrosurgical techniques, in treating traumatic tattoos. These benefits include precision, preservation of healthy tissue, and ease of use, making enzymatic debridement a highly favorable option in clinical practice. In 2020, a European consensus guidelines update was published, representing further refinement of the recommended indication, application, and postinterventional management for the use of Nexobrid.[55] Nexobrid offers: (1) Precision in tissue removal by selectively removing necrotic tissue without affecting viable tissue. Its enzymes target only the damaged or necrotic tissue, allowing for more accurate removal of debris, preserving as much healthy tissue as possible, and thus leading to faster healing and reduced scarring. This is particularly beneficial when dealing with wounds with uneven depths like abrasive or explosive burns, as the enzymatic process can adapt to the wound's specific topography, ensuring that the debridement is no deeper than necessary.[56] (2) Reduced pain and discomfort, although performed under sedation in the majority of our cases, enhance the overall healing process and patient experience.[57] (3) Speed and ease of use and cost-effectiveness making it an attractive option in traumatic tattoo prevention. Enzymatic agents are an off-the-shelf product that can be applied directly to the wound without the need for surgical intervention or specialized equipment, particularly in settings where resources are limited.[58] (4) Versatility and adaptability, making it applicable across different clinical scenarios, including prevention of traumatic tattoos.

Although the mechanism of action of enzymatic debridement with the use of Nexobrid has been reported, the mechanism of clearance of particles that lead to traumatic tattooing has yet to be cleared. Our hypothesis relies on the fact that Nexobrid can selectively debride traumatized skin layers including degenerated collagen thus removing the aforementioned particles. However, in cases of explosive mechanisms, the particles are projected deeper into the viable tissues and some remain after enzymatic debridement of the necrotic tissues. This is supported by our findings that the treatment removed pigmented particles from abrasions in a greater extent when compared to explosive incidents (96% vs 84%).

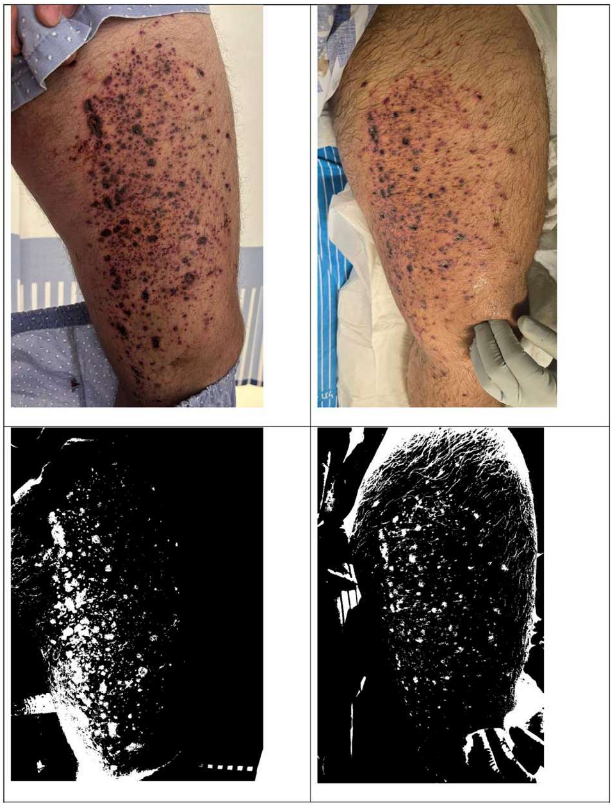

Figure 5. Explosive Lesion with Traumatic Tattoo of the Thigh of a 34-Year-Old Man Suffering from Wounds due to the Explosion of Rocket Shrapnel, Before (Left) and After (Right) Treatment with Nexobrid

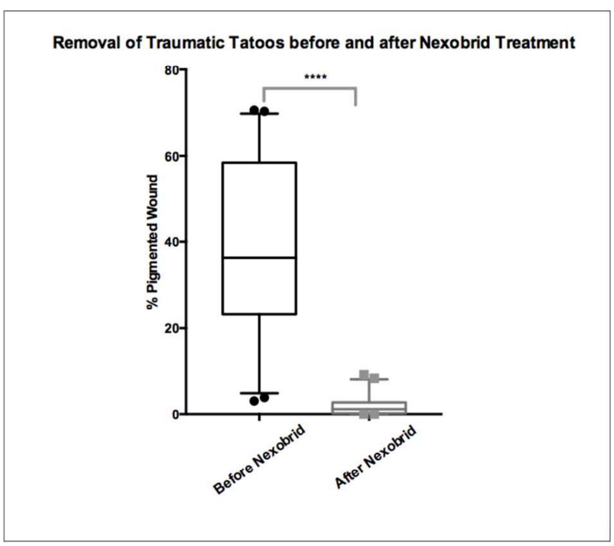

Figure 6. Percentage of the Surface of Pigmented Wound Before and After Treatment with Nexobrid

Differences among particles have yet to be elucidated and described.

Our study has several *limitations*, including the limited number of patients and follow-up period, the young age of the patients' cohort and the lack of histological examination as a further tool to assess clinical effectiveness of the proposed treatment for traumatic tattoos. Regarding the number of patients included, our patient cohort is characterized by different ages, variant mechanisms of trauma and involving variable anatomical areas, offering adequate statistical analysis. Moreover, the mean age of the presented cases was 24 years old, mainly due to the involvement of younger ages in road accidents. A bigger cohort of patients will be needed to assess the efficacy of the proposed treatment in older ages, although in the country that the study has been conducted, motor vehicle accidents and explosion incidents affect mostly younger ages. As far as longer follow-up is concerned, although our patients will be followed clinically for longer periods, pigment removal is assessed and documented in the immediate posttreatment phase and only factors such as scar quality can be assessed in the long-term. What is more, in cases with incomplete pigment removal after Nexobrid, a combination of enzymatic debridement with existing techniques could be performed (ie, enzymatic debridement followed by microscopic removal of pigment) and compared to enzymatic debridement alone and assessed for efficacy. Thoughtfully, a medicoeconomic analysis could be conducted to compare the cost of each different invasive and noninvasive treatment and to be further analyzed, taking the efficacy of each method into account. It seems that, although not evaluated, saving on blood products, number of surgical operations and operating times, length of hospital stay, and time to rehabilitation was more valuable as already reported.[59-61] Nexobrid's value is variable and depends on each country's regulations. Finally, although histological analysis can be a potential future pathway, it appears as a challenging endeavor, especially when treating large TBSA. Pigment removal is primarily assessed clinically macroscopically.

CONCLUSION

Enzymatic debridement presents a comprehensive approach to wound care in cases of traumatic tattoos, which seems to offer precision, tissue preservation, and user-friendly application, to optimize functional and cosmetic outcomes. These advantages position it as an effective alternative to more traditional methods, particularly in settings that require minimal invasiveness and maximal tissue conservation. Therefore, we propose the Nexobrid as a valuable treatment for the initial debridement of pigmented burns to prevent traumatic tattoos. Further research and clinical trials continue to refine its applications and outcomes, solidifying its role in modern wound management practices.

ETHICS STATEMENT

The local ethics committee approved the study as an extension of the validated clinical indication and the patients gave their informed consent to participate.

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