Pigments in American tattoo inks and their propensity to elicit allergic contact dermatitis

Walter Liszewski, MD,[a] and Erin M. Warshaw, MD, MS[b,c]
Minneapolis and Bloomington, Minnesota

Background: Tattoos have become increasingly common in the United States. Historically, tattoo inks were comprised of metallic pigments, which have the potential to cause allergic contact dermatitis. Data have been lacking on the current use of these pigments in tattoo ink.

Objective: Identify pigments currently used in tattoo inks manufactured in or sold by wholesalers in the United States and investigate cases of allergic contact dermatitis caused by these pigments.

Methods: Using specific key words, we performed an internet search. Pigment information listed in tattoo product inserts was collated and evaluated.

Results: In total, 1416 unique inks were surveyed. The average bottle of ink contained 3.0 pigments. We identified 44 distinct pigments, of which 10 contained metallic pigments, including iron, barium, zinc, copper, molybdenum, and titanium. The remaining 34 pigments contained carbon, azo, diketopyrrolopyrrole, quinacridone, anthraquinone, dioxazine, or quinophthalone dyes. A literature search revealed that 11 of the 44 (25%) pigments had been suspected to cause contact dermatitis. Five were confirmed by patch testing.

Conclusion: These findings highlight the diversity of pigments currently used in tattoos. Relatively few inks contained metallic pigments to which allergic contact dermatitis has historically been attributed. Patch-test clinicians should be aware of these new pigments. (J Am Acad Dermatol 2019;81:379-85.)

Key words: ACD; allergic contact dermatitis; azo; color; dye; ink; pigment; quinacridone; tattoo.

For centuries and across cultures, tattoos have been used for religious, medicinal, and aesthetic purposes. During the 20th century, tattoos became an increasingly popular form of self-expression. It is currently estimated that ~30% of all Americans have ≥1 tattoo; among Millennials, the rate is nearly 50%.[1]

Historically, black tattoo pigments were derived from carbon, while other colors were produced with inorganic metallic compounds, such as mercury, cobalt, chromium, and cadmium. Many of these metallic compounds are carcinogenic and potent sensitizers.[2]

There is evidence that metallic pigments have been replaced by organic compounds,[3] including azo and quinacridone dyes.[4] Despite the growing presence of organic pigments, dermatology references continue to discuss and ascribe allergic contact dermatitis (ACD) in tattoos to metallic pigments.[5-8]

The purpose of this study was to investigate the listed contents of tattoo inks sold and manufactured

From the Department of Dermatology, University of Minnesota, Minneapolis[a]; Park Nicollet Contact Dermatitis Clinic, Bloomington[b]; and Department of Dermatology, Minneapolis Veterans Affairs Medical Center.[c]
Funding sources: None.
Conflicts of interest: None disclosed.
Disclaimer: This material is supported by the use of facilities at the Minneapolis Veterans Affairs Medical Center. The contents do not represent the views of the US Department of Veterans Affairs or the US government.

Accepted for publication January 30, 2019.
Reprints not available from the authors.
Correspondence to: Walter Liszewski, MD, 516 Delaware St SE, Mail Code 98, Phillips-Wangensteen Bldg, Ste 4-240, Minneapolis, MN 55455. E-mail: wjliszewski@gmail.com.
Published online February 5, 2019.
0190-9622/$36.00

https://doi.org/10.1016/j.jaad.2019.01.078

in the United States and summarize reports of contact dermatitis to identified pigments.

METHODS AND MATERIALS

Searches were performed on June 7 and 8 of 2018 by the primary investigator (Dr Liszewski). The phrases "tattoo ink" and "tattoo inks for sale" were entered in Google Search. The first 100 results (including advertisements) for both search terms were assessed. Inclusion criteria included tattoo inks manufactured in the United States or tattoo inks sold by a US wholesaler. Exclusion criteria included lack of safety data sheets (SDSs), incomplete information on SDS, and pigments made or marketed specifically for permanent makeup. The latter were excluded as the permanent makeup industry has different operating and regulatory procedures from decorative body tattoos, and the pigments used might or might not be different.

For tattoo ink brands that met study criteria, SDSs from the manufacturer were collected, and the pigments used in each of their inks were tabulated. Pigments were organized by both specific pigment name and by color index. The color index is an international system that classifies pigments.[9] For example, orange 13 and disperse orange 13 are different pigments with different color indices (21110 and 26080, respectively).

After the identification of pigments, the primary investigator (Dr Liszewski) performed a literature search for publications of contact dermatitis to these pigments using the words "pigment name" or "CI [color index] number" and "contact dermatitis" in PubMed on June 30, 2018.

CAPSULE SUMMARY

- Historically, tattoo pigments were made with heavy metals, such as mercury, cobalt, and cadmium. These are known to be allergenic.
- Older metallic pigments have been replaced with organic dyes or less allergenic metals, such as zinc and barium. Cases of contact dermatitis to these organic dyes have been reported.

RESULTS

Our search identified 35 tattoo ink companies, 17 of which provided detailed SDSs and met inclusion criteria (Table I). Combined, these 17 manufacturers produced 1416 unique inks (Table II). The average bottle of ink contained 3 pigments, and across all brands, 44 distinct pigments were identified.

Inorganic metallic pigments

Only 10 of the 44 pigments contained inorganic metals, including iron, barium, zinc, copper, molybdenum, and titanium. The metals occurred as iron oxide, titanium dioxide, zinc ferrite, and barium sulfide, while copper and molybdenum were complexed with organic phthalocyanine rings or xanthene dyes, respectively.

Organic pigments

Of the 34 organic pigments, 3 were black pigments made exclusively from carbon. The remaining 31 pigments included azo, diketopyrrolopyrrole, quinacridone, anthraquinone, dioxazine, or quinophthalone dyes (Fig 1). The organic dyes included all of the orange pigments, as well a majority of the red, violet, and yellow pigments.

Pigment diversity

There were only 2 types of each of the following hues: green, blue, and white. In contrast, there was a greater diversity among yellows and reds, which included 11 and 15 unique pigments, respectively. Among these pigments, some were more frequently used than others. Seven pigments were used by >10 brands: Black 6, Blue 15, Green 7, Red 101, Red 122, Violet 23, and White 6. However, 19 pigments were only present in 1 brand of ink. Among all inks, >70% contained White 6.

Reports of contact allergy to pigments

A comprehensive literature search revealed 7 publications involving 19 individuals with suspected ACD to ≥1 of the 44 pigments found in our investigation (Table III).[4,10-15] These cases implicated 11 of the 44 (25%) pigments. Fourteen individuals had confirmatory testing. Clinical suspicion of ACD within tattoos has been reported with 7 of our pigments.

DISCUSSION

This study yielded several important findings. First, despite historical emphasis on metallic pigments, none of the 1416 inks contained mercury, cobalt, cadmium, manganese, or chromium. Second, the 44 identified pigments were primarily composed of a variety of organic dyes, including azo and quinacridone dyes; a few inorganic metallic oxides and carbon were also identified. Last, 11 of these pigments were reported as confirmed or suspected contact allergens.

Abbreviations used:

ACD: allergic contact dermatitis
SDS: safety data sheet

Pigment content

The metallic pigments in examined inks included iron oxide, titanium dioxide, zinc ferrite, barium sulfide, and copper-containing phthalocyanine dyes. Compared with older metallic pigments, such as red mercuric sulfide (cinnabar), green chromic oxide, yellow cadmium sulfide, purple manganese ammonium pyrophosphate, and blue cobalt oxide, these pigments are not known to cause ACD in tattoos.[2] However, we did find cases of ACD to copper-containing phthalocyanine dyes in gloves and paint, and ACD to iron oxide in ceramic enamels. There was also 1 molybdenum-containing xanthene dye. Although molybdenum has not been implicated in ACD from tattoos, it is known to have allergenic potential in implanted medical devices.[17]

The organic pigments encompassed several families of dyes. Azo dyes are defined by a double nitrogen bond (N=N). Theoretically, an individual with an existing sensitivity to azo dyes (or an azo—cross-reactor) could develop ACD to a different azo dye used in a tattoo. There is 1 reported case of an individual who developed ACD to an azo textile dye after sensitization to paraphenylenediamine in a henna tattoo.[18] Carbonyl dyes, including anthraquinone, quinacridone, quinophthalone, and diketopyrrolopyrrole pigments, are defined by the presence of ≥2 carbonyl groups (C=O). Within the carbonyl family, subgroups are distinguished by the presence of various carbon and pyrrole rings. Dioxazine represents a distinct group of dyes, and it is defined by the presence of 2 connected oxazine rings.[19]

Two families of organic molecules in the inks, phthalocyanines and xanthenes, formed pigments by complexing with metals. Phthalocyanine rings are made up of 4 pyrrole rings; they are structurally similar to porphyrins. Phthalocyanine can complex with most metals, although in our dyes, they exclusively complexed with copper. Xanthene dyes contain a central set of benzene rings joined by an oxygen-containing methylene group.[19] In our pigments, xanthene complexed with molybdenum.

Impact of multiple pigments on tattoo removal

We know from a study of 501 tattooed people that 16.2% regret ≥1 of their tattoos, and 21.2% of all tattooed individuals are interested in having a tattoo removed.[20] Unfortunately, multiple pigments in an ink complicates tattoo removal. Tattoos are primarily removed with 2 lasers with different chromophores: neodymium-doped yttrium aluminum garnet (532 nm, 1064 nm) and alexandrite (755 nm). A 532-nm neodymium-doped yttrium aluminum garnet laser can remove red and orange, and only alexandrite can remove green.[21] Depending on the pigments present, both of these lasers might be needed to remove a single ink.

Titanium dioxide is used to alter the intensity of other pigments, and it was present in >70% of the inks. Unfortunately, titanium dioxide complicates tattoo removal. First, it is notoriously difficult to remove by laser.[22] Second, when irradiated by a laser, it undergoes reduction and turns from white to black.[21] This change is often cosmetically unappealing.

Table I. Tattoo ink manufacturers and their number of unique inks and pigments

Manufacturer	Inks, n	Pigments, n	Average pigments per ink
Alla Prima	56	20	2.4
Black Buddha	5	1	1
Bloodline	103	19	2.2
Cheyenne	59	11	2.3
Dynamic	27	14	1.6
Empire	6	2	1
Inksanity	92	20	2.5
Intenze	315	12	3.5
Iron Butterfly	14	10	1.7
Kokkai Sumi	1	1	1
Kuro Sumi	61	13	2.8
Millennium Moms	42	12	2.9
One Black	1	2	2
Quantum	92	13	2.5
Radiant	307	12	3.6
Starbrite	27	17	1.6
World Famous	208	16	2.9
Total	1416	44	3

Importance of geographic location and age of tattoos

This study demonstrates that US tattoo manufacturers have shifted to using organic pigments. It is possible, however, that in many parts of the world, older metallic pigments are still used.[2] Therefore, the geographic location and date of tattoo placement might provide important clinical information.

Patch testing for suspected pigment allergy

Ink manufacturers are not required to disclose pigment content. Thus, even if a specific ink is

Table II. Pigments used in 17 brands of tattoo ink

	Pigment		Frequency		
Name	**Color index**	**Type**	**Brands**	**Inks**	**Contains metal**
Black					
Black 6*	77266	Carbon	12	335	No
Black 7*	77266	Carbon	6	25	No
Black 8	77268	Carbon	1	1	No
Blue					
Blue 15	74160	Phthalocyanine	13	562	Yes (copper)
Blue 87	74200	Phthalocyanine	1	1	Yes (copper)
Green					
Green 7	74260	Phthalocyanine	12	125	Yes (copper)
Green 36	74265	Phthalocyanine	1	12	Yes (copper)
Orange					
Orange 13	21110	Azo	6	367	No
Orange 16	21160	Azo	9	41	No
Orange 73	561170	Diketopyrrolopyrrole	1	7	No
Orange 5	12075	Azo	1	2	No
Orange 34	21115	Azo	1	2	No
Red					
Red 210	12477	Azo	7	350	No
Red 101	77491	Metallic	15	177	Yes (iron)
Red 170	12475	Azo	8	85	No
Red 122	73915	Quinacridone	11	54	No
Red 269	12466	Azo	5	49	No
Red 146	12485	Azo	3	43	No
Red 254	56110	Diketopyrrolopyrrole	1	12	No
Red 22	12315	Azo	3	3	No
Red 177	65300	Anthraquinone	1	2	No
Red 2	12310	Azo	1	1	No
Red 5	12490	Azo	1	1	No
Red 23	12355	Azo	1	1	No
Red 63	15880	Azo	1	1	No
Red 187	12486	Azo	1	1	No
Red 266	12474	Azo	1	1	No
Violet					
Violet 23	51319	Dioxazine	10	62	No
Violet 1	45170:2	Xanthene	2	58	Yes (molybdenum)
Violet 19	73900	Quinacridone	3	10	No
Violet 37	51345	Dioxazine	1	4	No
White					
White 6	77891	Metallic	14	1003	Yes (titanium)
White 21	77120	Metallic	2	80	Yes (barium)
Yellow					
Yellow 65	11740	Azo	3	359	No
Yellow 14	21095	Azo	7	161	No
Yellow 74	11741	Azo	6	70	No
Yellow 42	77492	Metallic	5	36	Yes (iron)
Yellow 83	21108	Azo	5	25	No
Yellow 138	56300	Quinophthalone	1	22	No
Yellow 151	13980	Azo	3	17	No
Yellow 3	11710	Azo	4	10	No
Yellow 97	11767	Azo	1	6	No
Yellow 119	77496	Metallic	1	3	Yes (iron and zinc)
Yellow 194	11785	Azo	1	1	No

*Black 6 and 7 share the same color index number.

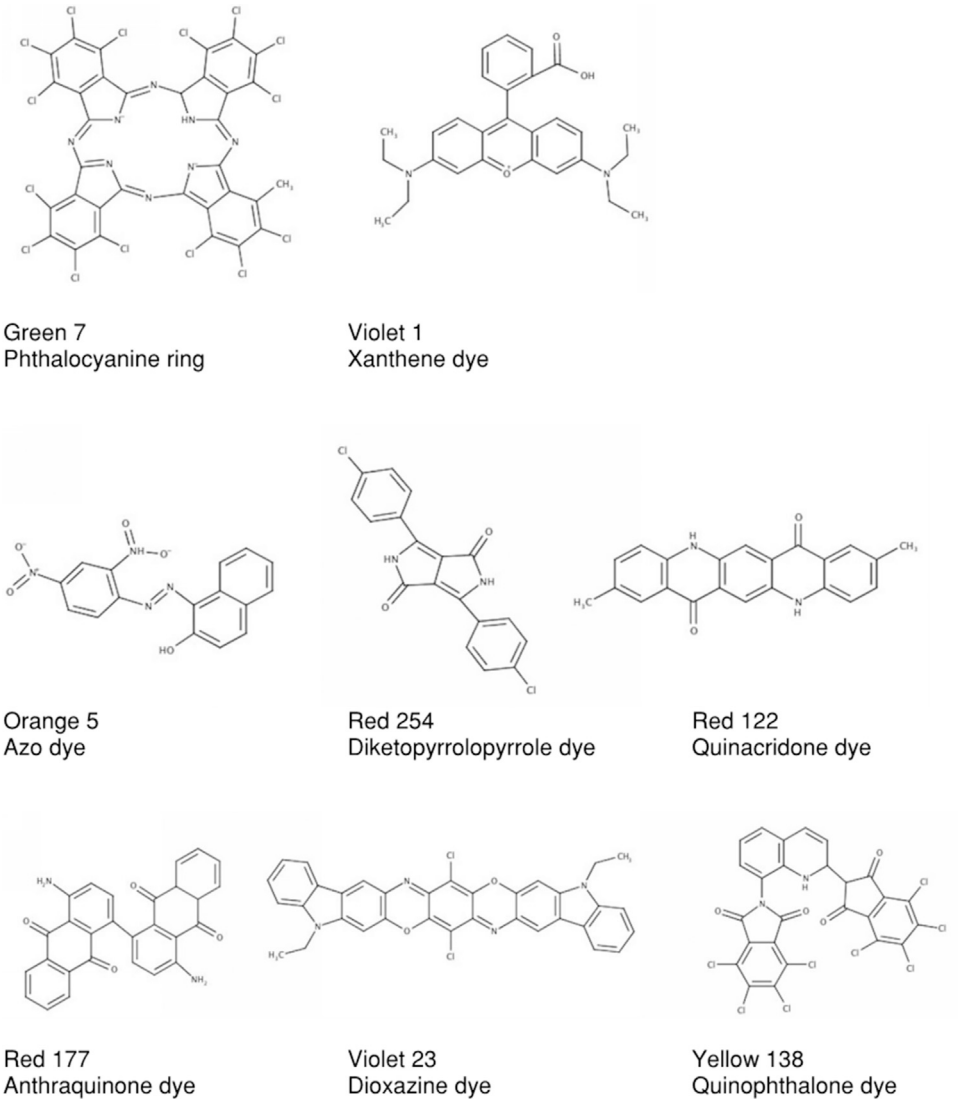

Fig 1. Representative structures of the 8 organic pigment families identified in evaluated inks.

identifiable as the culprit of ACD in a tattoo, detailed information on pigment content might not be available for proprietary reasons.

Most tattoo inks assessed in this study contained multiple pigments. For example, Intenze's Lilac Ink is purple, but it contains 5 pigments: White 6, Yellow 65, Orange 13, Violet 1, and Red 101.[23] This is problematic because if an individual has a reaction to an ink, the allergen could be 1 of multiple pigments.

Once a tattoo is placed, organic pigments, such as the azo dyes, slowly degrade. In some individuals, pigment allergy might not be from the original molecule but rather the breakdown products.[3] This could explain why ACD to pigments sometimes occurs years after tattoo placement.[3,4] It has also been suggested that not all organic tattoo pigments penetrate the skin.[4] These factors could explain false-negative patch tests.[4,16]

Limitations

There are several study limitations. Due to incomplete SDSs, we were unable to investigate 18 brands of inks. It is possible that these inks might have contained additional novel pigments. Even in the brands we were able to assess, we were limited to what the manufacturer disclosed. This limitation highlights a need for greater transparency. Not all suspected cases of pigment ACD had confirmatory patch testing; thus, it is possible that allergic reactions were not due to the pigment but rather a preservative or other ingredient.

Table III. Reports of pigments proven or suspected of causing allergic contact dermatitis

Pigment name	Exposure	Description
Cases with confirmatory testing		
Blue 15	Gloves, paint	3 separate reports: 1) occupational glove allergy in a metal worker, positive patch tests to blue vinyl dots on cotton gloves and Blue 15 (50% and 10% pet, respectively)[10]; 2) occupational glove allergy in a nurse, positive patch tests to blue nitrile glove and Blue 15 (1% pet)[11]; 3) airborne allergy in a painter, positive patch test to Blue 15 pigment power (10% aq)[12]
Red 101	Ceramic enamels	Occupational contact dermatitis in 7 ceramic enamellers and 190 decorators, positive patch test reactions to Red 101 (2% pet)[13]
Orange 34	Plastic gloves	Occupational contact dermatitis in a hospital housekeeper, positive patch-test reactions to orange vinyl glove and Orange 34 (0.5% and 2.0% pet, respectively)[14]
Green 7	Paint	Airborne allergy in a painter, positive patch test to Green 7 (10% aq)[12]
Red 210 Yellow 65 Orange 13	Tattoo	Positive patch test to undiluted red tattoo ink[4]
Red 122	Tattoo	Positive delayed patch test reaction to undiluted red ink[15]
Suspected cases		
Red 63	Tattoo	Clinical findings suggestive of contact dermatitis to pigment, undiluted tattoo ink applied for 2 days under occlusion; no reaction was observed.[4]
Red 122	Tattoo	Clinical findings suggestive of contact dermatitis to pigment, patch testing not performed[4]
Red 170	Tattoo	2 separate reports: 1) clinical findings suggestive of contact dermatitis to pigment, patch testing not performed[4]; 2) clinical findings suggestive of contact dermatitis to pigment, patch and photo-patch testing negative[16]
Violet 19	Tattoo	Clinical findings suggestive of contact dermatitis to pigment, undiluted tattoo ink applied for 2 days under occlusion; no reaction was observed.[4]

aq, Aqueous; *pet*, petrolatum.

Summary

Our findings demonstrate the growing presence of organic pigments in American tattoo ink. Unfortunately, due to multiple pigments in a single ink, lack of awareness among individuals regarding exact inks used in their tattoos, and the breakdown of organic dyes over time, successful identification of allergenic pigments in symptomatic patients is challenging. Continued research on the nature of allergic reactions to tattoo pigments in the 21st century and methods for optimizing patch testing for newer tattoo pigments are needed.

REFERENCES

1. The Harris Poll, Shannon-Missal L. Tattoo takeover: three in ten Americans have tattoos, and most don't sop at just one. Available at: https://theharrispoll.com/tattoos-can-take-any-number-of-forms-from-animals-to-quotes-to-cryptic-symbols-and-appear-in-all-sorts-of-spots-on-our-bodies-some-visible-in-everyday-life-others-not-so-much-but-one-thi/; February 10, 2016.
2. Kaur RR, Kirby W, Maibach H. Cutaneous allergic reactions to tattoo ink. *J Cosmet Dermatol*. 2009;8:295-300.
3. Carlsen KH, Serup J. Patch test study of 90 patients with tattoo reactions: negative outcome of allergy patch test to baseline batteries and culprit inks suggest allergen(s) are generated in the skin through haptenization. *Contact Dermatitis*. 2014;71:255-263.
4. Gaudron S, Ferrier-Le Bouedec MC, Frank F, D'Incan M. Azo pigments and quinacridones induce delayed hypersensitivity in red tattoos. *Contact Dermatitis*. 2015;72:97-105.
5. Bolognia JL, Schaffer JV, Cerroni L, eds. *Dermatology, Fourth edition*. Philadelphia, PA: Elsevier; 2018:1666.
6. Jain S, ed. *Dermatology Illustrated Study Guide and Comprehensive Board Review*. 2nd ed. New York, NY: Spring Publishing; 2017:114.
7. Alikhan A, Hocker TLH, eds. *Review of Dermatology*. Philadelphia, PA: Elsevier; 2017:457-458.
8. James WD, Berger TG, Elston DM, eds. *Andrews' Diseases of the Skin, Twelth edition*. Philadelphia, PA: Elsevier; 2016:908-909.
9. Color Index Leaflet. Available at: https://colour-index.com/assets/files/upl/CI_leaflet.pdf. Accessed July 20, 2018.
10. Reckling C, Engfeldt M, Bruze M. Occupational nitrile glove allergy caused by pigment Blue 15. *Contact Dermatitis*. 2016;75:189-190.
11. Weimann S, Skudik C, John SM. Allergic contact dermatitis caused by the blue pigment VINAMON Blue BX FW — a phthalocyanine blue in a vinyl glove. *J Dtsch Dermatol Ges*. 2010;8:820-822.

12. Raccagni AA, Baldari U, Righini MG. Airborne dermatitis in a painter. *Contact Dermatitis*. 1996;35:119-120.
13. Motolese A, Truzzi M, Giannini A, Seidenari S. Contact dermatitis and contact sensitization among enamellers and decorators in the ceramics industry. *Contact Dermatitis*. 1993; 28:59-62.
14. Kanerva L, Jolanki R, Estlander T. Organic pigment as a cause of plastic glove dermatitis. *Contact Dermatitis*. 1985;13:41-43.
15. Greve B, Chytry R, Raulin C. Contact dermatitis from red tattoo pigment (quinacridone) with secondary spread. *Contact Dermatitis*. 2003;49:265-266.
16. Steinbrecher I, Hemmer W, Jarisch R. Adverse reaction to the azo dye pigment Red 170 in a tattoo. *J Dtsch Dermatol Ges*. 2004;2:1007-1008.
17. Koster R, Vieluf D, Kiehn M, et al. Nickel and molybdenum contact allergies in patients with coronary in-stent stenosis. *Lancet*. 2000;356:1895-1897.
18. Saunders H, O'Brien T, Nixon R. Textile dye allergic contact dermatitis following paraphenylenediamine sensitization from a temporary tattoo. *Australas J Dermatol*. 2014;45: 229-231.
19. Christie RM. *Pigments, Second edition*. Cambridge, United Kingdom: Royal Society of Chemistry; 2015.
20. Liszewski W, Kream E, Helland S, et al. The demographics and rates of tattoo complications, regret, and unsafe tattooing practices: a cross-sectional study. *Dermatol Surg*. 2015;41: 1283-1289.
21. Ho SG, Goh CL. Laser tattoo removal: a clinical update. *J Cutan Aesthet Surg*. 2015;8:9-15.
22. Ross EV, Yashar S, Michaud N, et al. Tattoo darkening and nonresponse after laser treatment: a possible role for titanium dioxide. *Arch Dermatol*. 2001;137:33-37.
23. *19. Lilac [Safety Data Sheet]*. Rochelle Park, NJ: Intenze Ink; 2017.