androgenetic alopecia when used in conjunction with micronneedling in comparison to conventional minoxidil treatment; they also demonstrated effectiveness of MN and minoxidil combination therapy in patients failing to respond to conventional minoxidil treatment (Dhurat and Mathapati 2015; Dhurat et al. 2013). Jiang et al. (2009) demonstrated effective intrascleral delivery of microparticles via MNs. With possible drug diffusion to surrounding tissues like the choroid, retina, and ciliary body, intrascleral drug delivery via MNs has the potential to treat posterior eye disease such as glaucoma and macular degeneration (Jiang et al. 2009).

In 2020, the first new drug application for a pharmaceutical microneedle patch, Qtrypta, was submitted to the Food and Drug Administration (FDA) by Zosano Pharma. The patch is a titanium microneedle with a coated zolmitriptan for acute migraine treatment.

While most MN vaccination studies focus on delivery of influenza antigen, many other applications exist for MN vaccines. MN delivery of vaccines releases antigenic material into the viable dermis, which has shown stronger immunological reactions when compared to muscle, the delivery target of traditional hypodermic needles (Engelke et al. 2015). A multicenter, randomized, open-label study in 978 healthy adults showed intradermal influenza vaccine delivered by microinjection systems to convey a noninferior humoral response against three influenza strains and two superior humoral responses to both A strains (H1N1, H3N2) (Leroux-Roels et al. 2008). Similar studies on influenza vaccination demonstrated comparable or superior responses when compared to responses from conventional intramuscular vaccination (Kenney et al. 2004; Van Damme et al. 2009). Other studies demonstrated effective levels of neutralizing antibodies in 100% of measles-vaccinated nonhuman primates compared to 75% of subcutaneously vaccinated nonhuman primates (Joyce et al. 2018). In a phase 1, partly blinded, controlled trial, the authors found no significant statistical difference in antibody titers among groups vaccinated with health care–administered intramuscular hypodermic needle influenza vaccine, health care–administered MN influenza vaccination patch, and self-administered MN influenza-vaccination patch, suggesting a possible future for self-administered vaccines (Rouphael et al. 2017). Chiefly, MNs have application in global health vaccination due to the ability for non-climate-controlled distribution and the potential for self-administration. In addition, MNs eliminate sharps, biohazardous waste, painful injections, and potential needle stick injuries present in vaccines administered via hypodermic needles.

Development of optimized hollow MNs has resulted in additional potential applications, including blood and interstitial fluid (ISF) extraction (Kiang et al. 2017; Li et al. 2013). When paired with biosensors and other microsystems, MNs have the potential for glucose and drug monitoring (Kiang et al. 2017). While experiments with MN-integrated biosensors have yielded encouraging results, extensive preclinical and clinical trials are needed before implementation as point-of-care devices for ISF collection, drug concentration assessment, or dosing in real time (Kiang et al. 2017).

Dermal microneedling has proven an effective therapy for atrophic acne scars and skin rejuvenation (Kim et al. 2011). Although the exact mechanism is unknown, MN puncture possibly disrupts older collagen strands and promotes damaged collagen removal (Fabbrocini et al. 2009). In addition, rolling with multiple MNs to promote new collagen and elastin deposition, known as collagen induction therapy, has become a popular practice in treating disfiguring scars and rhytides and rejuvenating skin (Fabbrocini et al. 2009; Aust et al. 2008).

Other methods used to improve the clinical appearance of acne scarring such as laser resurfacing pose potential risks associated with a disrupted skin epidermal barrier. Cho et al. (2012) showed microneedling to lead to improved grade of acne scars and global assessment of large pores in more than 70% of 30 tested patients. Kim et al. (2011) compared the effects of microneedling versus intense pulsed light (IPL) therapy for skin rejuvenation, finding significantly higher levels of collagen in microneedling when evaluated via caliper, microscopic examination, Western blot analysis for type I collagen, and enzyme-linked immunosorbent assay (ELISA) for total collagen content.