



REVIEW ARTICLE ON BIODEGRADABLE MICRONEEDLE PATCHES FOR PAINLESS VACCINATION AND CHRONIC DISEASES.

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Abstract

Microneedle patches are a groundbreaking development in drug delivery. Traditional hypodermic injections often cause pain, trigger needle phobia, and carry a risk of infection. Biodegradable microneedles offer a new solution by merging the benefits of transdermal delivery with patient comfort and safety for the environment. This manuscript examines their design, fabrication methods, and materials used. It also discusses their increasing significance in vaccination and managing chronic diseases. This review highlights both current progress and future possibilities in this rapidly growing field.

Keywords

Microneedles, biodegradable polymers, Transdermal drug delivery, Painless vaccination, Chronic diseases.

Introduction

Microneedles have emerged as a technology that can painlessly penetrate the stratum corneum, the outermost layer of skin, to deliver drugs directly into the bloodstream. Among the various types, biodegradable microneedles are the most promising because they dissolve after use. This process releases drugs in a controlled way while reducing biomedical waste.

Biodegradable Vaccination is a new type of vaccine that uses safe, natural materials to deliver antigens and other immune-boosting agents to the body. The vaccine is enclosed in a micro or nanoparticle delivery system, which breaks down harmlessly over time. This technology provides a controlled, steady-release method, which can remove the need for repeated booster shots.

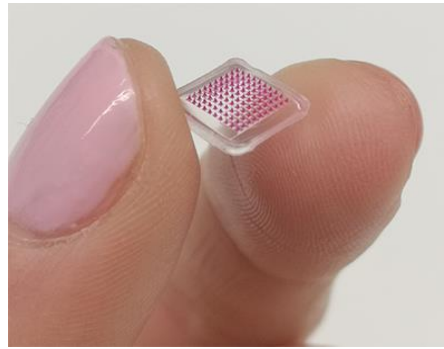


Figure 1: Microneedles

Fabrication techniques of Biodegradable Microneedles

Usually, 3D printing, photolithography, or micro-molding are used to create biodegradable microneedles. Because they are biocompatible and biodegradable, polymers like hyaluronic acid, polylactic acid (PLA), polyglycolic acid (PVP), and chitosan are frequently used. Common fabrication methods for producing biodegradable microneedles include droplet-born air blowing, micro molding, 3D printing, and drawing lithography. The ideal method is determined by the size, shape, and material of the needles as well as whether they will be solid, hollow, or dissolving.

Micro-molding

One of the most popular techniques, it works well with a variety of biodegradable materials such as hydrogels and polymers.

3D printing (Additive manufacturing)

With this technique, intricate microneedle geometries can be quickly and precisely customized from a digital design file.

Drawing Lithography

Under controlled circumstances, this method forms a viscous polymer into the shape of a microneedle. When creating high-aspect-ratio (tall and slender) needles without the use of a mold, it is especially helpful.

Droplet-born air blowing (DAB)

A mold-free, quick, and gentle method for making dissolving microneedles that can maintain the effectiveness of medications that are sensitive to temperature.

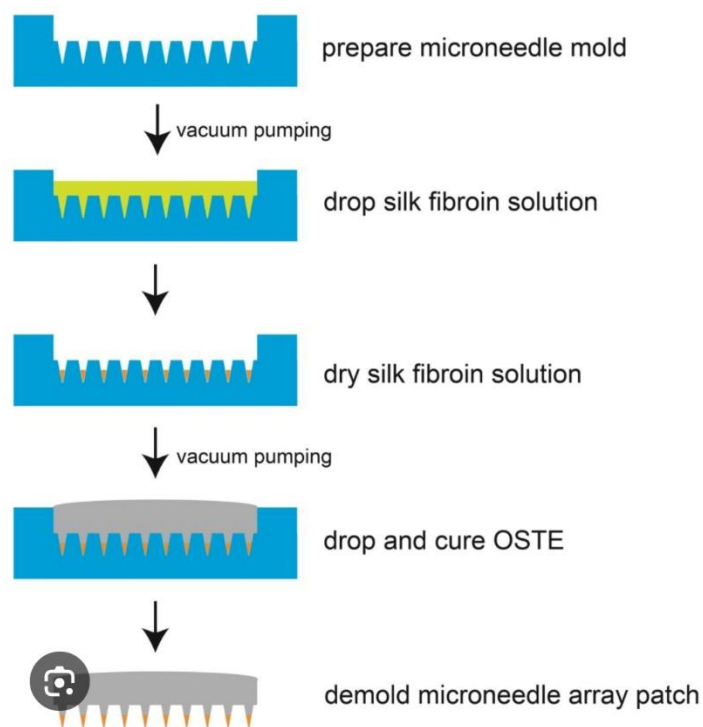


Figure 2: 1. Prepare the Mold

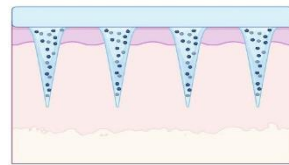
- 2.Cast silk fibroin:** Drop the silk fibroin solution onto the Mold until the cavities are filled, then let it dry completely.
- 3. Add OSTE:** Pour OSTE over the dried silk fibroin and cure it.
- 4. Demold:** Remove the OSTE microneedle array patch from the Mold.

Mechanism of Drug Delivery

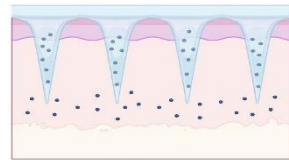
Drugs are delivered by biodegradable microneedles, which use their structure to pierce the stratum corneum, the outermost layer of skin, and then dissolve to release an encapsulated drug. This technique eliminates sharp medical waste and makes the procedure almost painless by creating micron-sized channels for drug delivery that bypass deeper blood vessels and nerves. The delivery method is frequently referred to as a "poke-and-release" strategy.

- 1. Skin Puncture:** An application force (usually between 0.1 to 3 Newtons) drives the microscopic needle tips into the skin. Because they stop short of the deeper dermis layer where pain receptors reside, the application is virtually painless.
- 2. Channel Stability:** The structural geometry of the needles holds the microscopic channels open against the skin's natural elasticity.
- 3. Interstitial Fluid Interaction:** Fluid from the skin interacts with the needles to trigger dissolution (dissolving types), coating detachment (coated types), or swelling (hydrogel types).
- 4. Capillary Uptake:** The released therapeutic agents passively migrate into the dense, local capillary networks situated in the upper dermis.
- 5. Systemic Distribution:** The bloodstream distributes the molecules throughout the body, effectively bypassing gastrointestinal degradation and hepatic first-pass metabolism.

Degradable microneedles



Degradable microneedle patches are equipped with microneedles comprising biodegradable materials which encapsulate the drug.



Post-penetration, the microneedles degrade over time, gradually releasing the drug directly into the systemic circulation.

Figure 3: Mechanism of degradable microneedle patches

Factors that influence drug release

The mechanism of drug delivery in microneedle patches is influenced by microneedle material properties, geometric design, skin parameters, and drug formulation characteristics. These factors control how the needles pierce the skin, dissolve or swell, and release the therapeutic compound into the tissue.

Material and Design Factors

- Material type: Dissolving, hydrogel-forming, or solid metal polymers affect degradation and release rates.
- Geometrical dimensions: Needle length, tip radius, density, and shape dictate skin penetration depth.
- Mechanical strength: Compressive failure force determines if needles can pierce the stratum corneum without breaking.

Skin and Application Factors

- Skin thickness and hydration: Variations across body sites alter insertion resistance and fluid uptake.
- Application force and velocity: Manual or applicator-driven force impacts insertion depth and consistency.

Formulation and Drug Factors

- Molecular weight: Smaller molecules diffuse faster than large proteins or nanoparticles.
- Drug solubility: Hydrophilic or hydrophobic properties govern release from the matrix.
- Loading dose: Concentration gradient drives diffusion rates into interstitial fluid.

Types of Microneedles

The five main types of microneedles are classified by their structure and how they deliver active ingredients through the skin barrier:

1. Solid Microneedles

- Mechanism: "Poke and patch" method.
- Function: Puncture the skin to create temporary microchannels, then a standard cream or patch is applied over top.
- Materials: Metals, silicon, or non-degradable polymers.

2. Coated Microneedles

- Mechanism: "Poke and release" method.
- Function: The drug is coated directly onto the outer surface of solid needles and dissolves rapidly into the skin after insertion.
- Materials: Solid core with a water-soluble drug layer.

3. Dissolving Microneedles

- Mechanism: "Poke and release" matrix method.
- Function: The entire needle is formulated from soluble materials encapsulating the drug; the needles completely dissolve inside the skin, leaving no sharp waste.
- Materials: Biodegradable polymers (like hyaluronic acid, PVP) or sugars.

4. Hollow Microneedle

- Mechanism: "Puncture and flow" method.
- Function: Work like miniature versions of traditional syringes; liquid medication is pumped through an internal channel in the needle centre.
- Materials: Silicon, glass, or metals.

5. Hydrogel-Forming Microneedles

- Mechanism: "Poke and swell" method.
- Function: Do not dissolve; instead, they absorb interstitial skin fluid and swell up into a gel conduit, allowing a steady diffusion of drugs from an attached patch reservoir.
- Materials: Crosslinked swellable polymers.

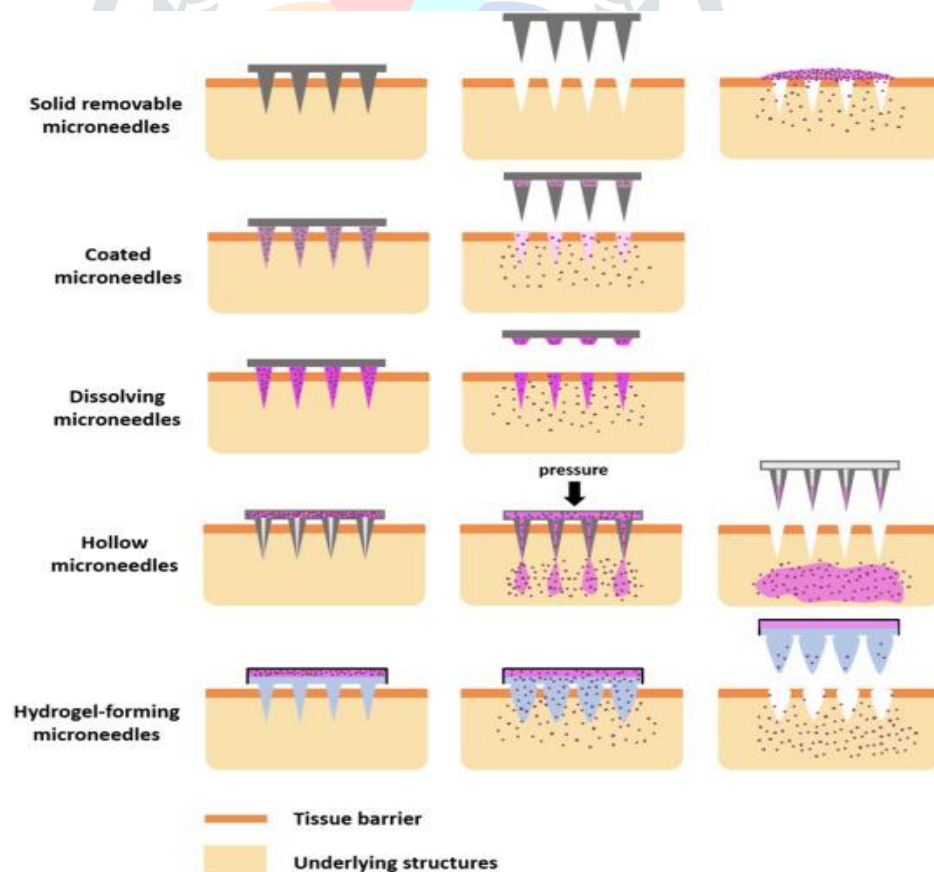


Figure 4: Types of Microneedles

Advantages of Biodegradable Microneedles patches

Biodegradable microneedle patches offer a painless, minimally invasive way to deliver drugs or vaccines through the skin. Made from safe, dissolving natural or synthetic polymers, they eliminate sharp needle waste, reduce infection risks, bypass the stomach's digestive acids, and allow for easy self-administration.

Patient Comfort and Safety

- **Painless application:** Micro-sized needles reach just past the outer skin layer without triggering nerve endings.
- **No sharp waste:** The needles dissolve completely inside the skin, leaving behind no dangerous medical sharps to discard.
- **Zero infection risk:** Because they vanish post-use and cannot be reused, they prevent cross-contamination and accidental needle-stick injuries.
- **No needle fear:** They reduce anxiety for patients who dread traditional hypodermic needles.

Drug Delivery and Efficiency

- **Bypass digestion:** Drugs enter the body directly, avoiding harsh stomach acids and liver breakdown (first-pass metabolism).
- **Controlled release:** Polymers can be tuned to release medications or vaccines slowly over time.
- **Better stability:** Many sensitive compounds, like specific vaccines, stay stable longer in solid dry patches than in liquid vials.
- **Self-administration:** Patients can apply the patches themselves without needing a trained nurse or doctor.

Disadvantages of Biodegradable Microneedle patches

While biodegradable and dissolving microneedle patches offer a painless, self-administrable alternative to traditional injections, they face several strict limitations. The primary disadvantages of biodegradable microneedle patches are their severely limited drug-loading capacity, susceptibility to environmental degradation, risk of incomplete skin penetration, and manufacturing complexities that compromise drug stability.

- **Low Dosing:** Restricted to small doses, typically under 1–5 mg per patch.
- **Weak Tips:** Polymeric or sugar needles can bend or break before fully penetrating the skin.
- **Incomplete Delivery:** Variable insertion angles or skin elasticity can cause unpredictable drug release.
- **Moisture Sensitivity:** Highly hygroscopic materials require strict, dry storage conditions to avoid melting.
- **Skin Issues:** Repetitive localized applications can cause mild redness, swelling, or scarring.
- **Longer Application:** Can require extended skin contact time compared to rapid hypodermic injections

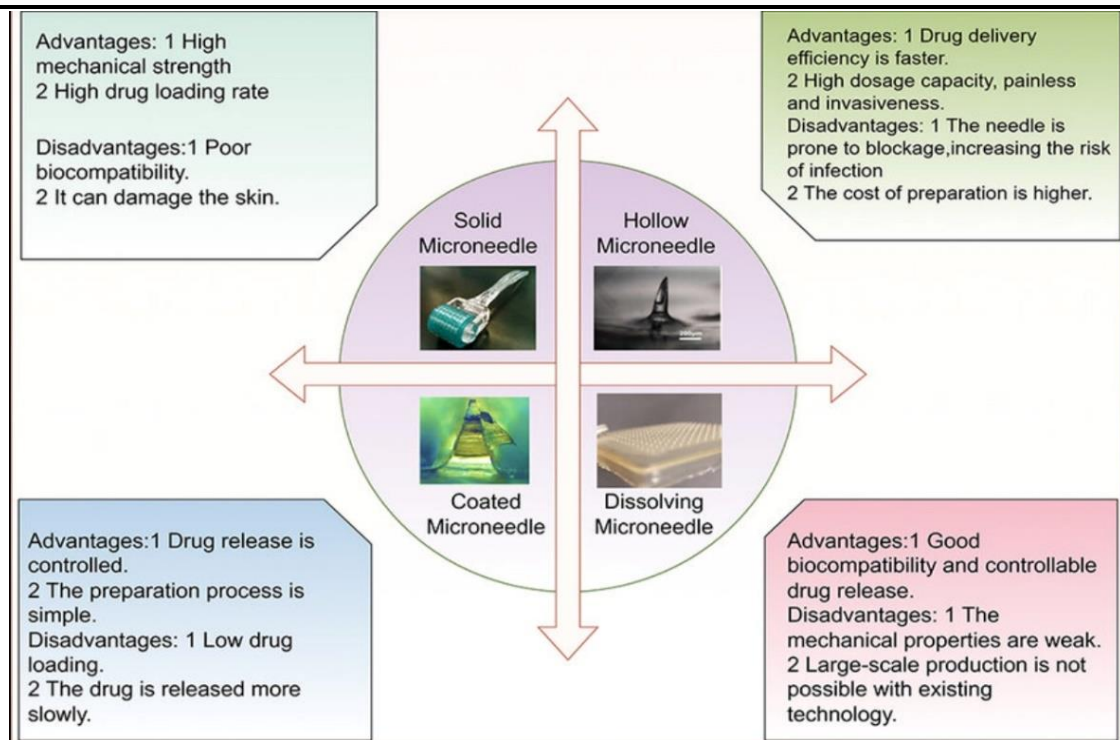
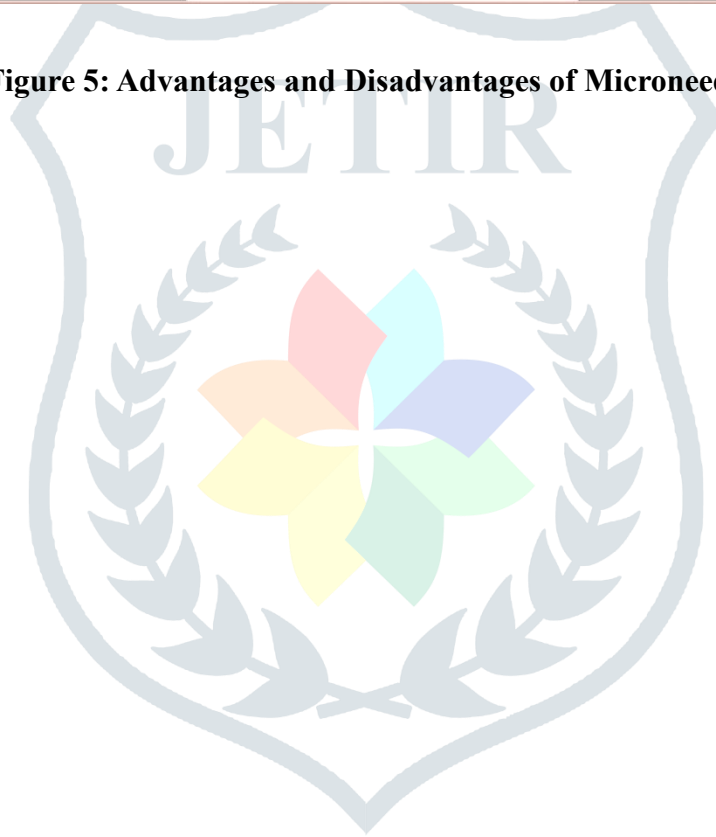


Figure 5: Advantages and Disadvantages of Microneedle Patches



Application of Biodegradable Microneedle patches

Drugs, vaccines, and cosmetics can be trans dermally administered with biodegradable microneedle patches in a painless, effective, and long-lasting manner. These patches, as opposed to solid or coated microneedles, totally dissolve in the skin, removing biohazardous sharp waste and enhancing patient compliance and comfort.

Biodegradable microneedle patches are tiny, band-aid-like patches covered in microscopic needles made of biocompatible polymers (like hyaluronic acid or PLA). They painlessly pierce the skin's outer layer and dissolve or degrade to release active ingredients directly into the body, eliminating the need for traditional syringes.

1. **Vaccine Delivery:** Used for painless, temperature-stable vaccinations (e.g., flu, rabies, COVID-19) that can be self-administered without medical waste.
2. **Chronic Disease Management:** Delivers hormones or drugs smoothly over time, such as glucose-responsive insulin delivery for diabetes or long-term contraception.
3. **Targeted Cancer Therapy:** Provides localized delivery of chemotherapeutic agents directly to tumour sites, minimizing systemic side effects.
4. **Dermatology & Cosmetics:** Enhances the delivery of anti-aging, acne, anti-wrinkle, and hyperpigmentation treatments directly into deeper skin layers.
5. **Health Monitoring & Diagnostics:** Extracts interstitial skin fluid instead of blood for minimally invasive, real-time tracking of glucose, cholesterol, or biomarker levels.
6. **Tissue Repair:** Applied directly to internal or external organs to promote targeted wound healing or tissue recovery (e.g., repairing heart tissue post-heart attack).

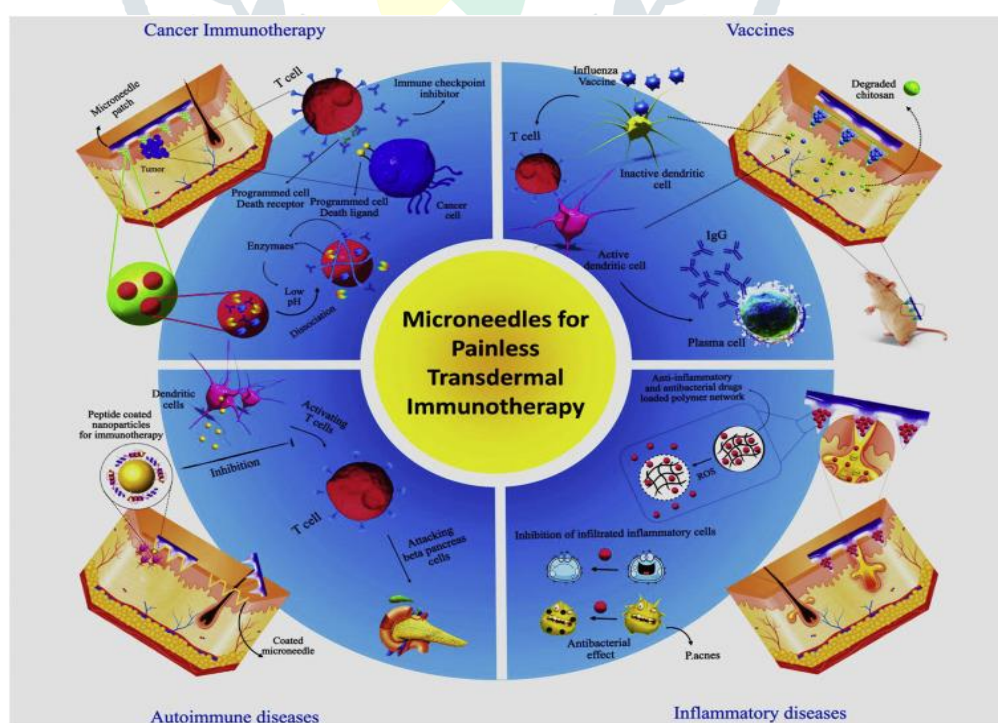


Figure 6: Application of Microneedle Patches

Challenges in Biodegradable Microneedles patches

Biodegradable microneedle patches still face major hurdles in mechanical strength, controlled degradation, stability, scalable manufacturing, and regulatory approval. While their key benefit over traditional silicon or metal microneedles is that they safely dissolve in the body, this same property also limits their widespread clinical use.

1. **Low Mechanical Strength:** Polymeric and biodegradable matrices often exhibit low fracture resistance. This causes tip breakage or needle bending against skin elasticity rather than successful penetration.
2. **Limited Loading Capacity:** The micron-scale volume limits the maximum active drug payload, restricting their clinical use to highly potent molecules or low-dose vaccines.
3. **Material/Drug Degradation:** Biologics (proteins, nucleic acids) can easily degrade or lose stability due to heat or solvent exposure during the patch fabrication and storage stages.
4. **Dosing Inconsistency:** Variability in skin hydration, application force, or patch dissolution speed leads to imprecise and unpredictable delivery efficiency.
5. **Manufacturing & Sterilisation Costs:** Scaling micro-molding or lithography techniques while keeping the product strictly sterile without damaging heat-sensitive drug components is highly expensive.
6. **Skin Irritation:** Though less invasive than hypodermic needles, the degrading polymer residues left in the skin can sometimes trigger localized inflammation or mild immune reactions.

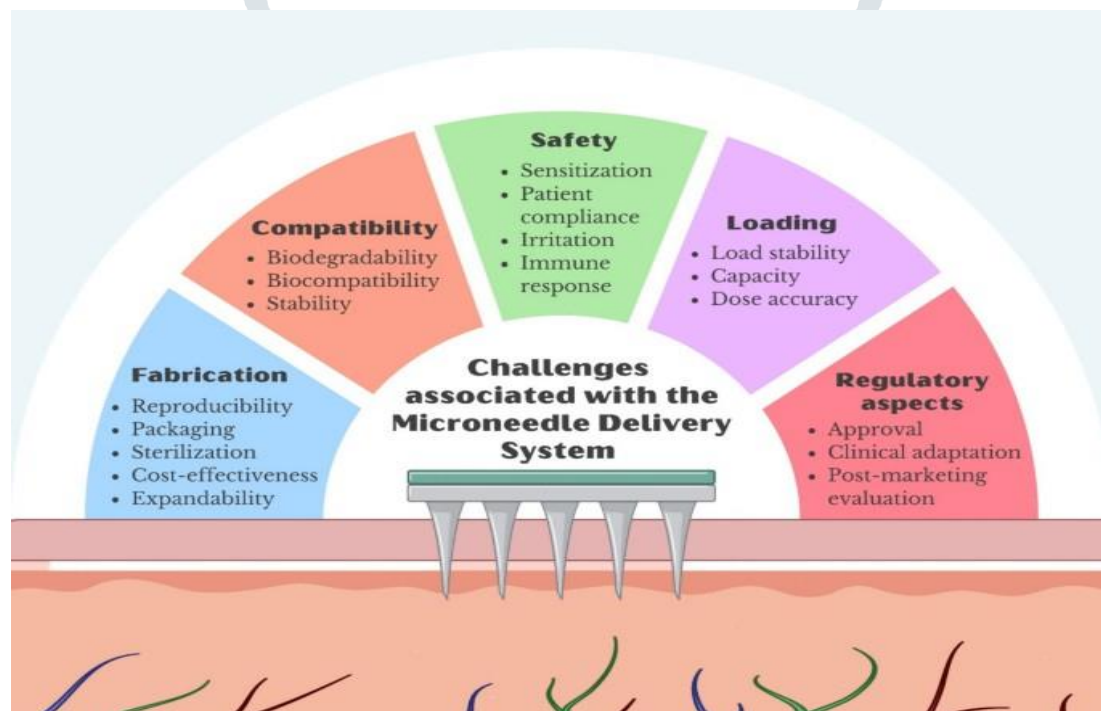


Figure 7: Challenges of Microneedle Patches

Limitation of Biodegradable of Microneedle Patches

Biodegradable microneedle patches offer a promising way to deliver drugs through the skin, but they face several key limitations:

Technical & Manufacturing Challenges

- **Low Loading Capacity:** They can only carry small doses of medication, making them unsuitable for drugs that require large amounts.

- **Material Fragility:** The microscopic needles can bend or break during manufacturing, storage, or insertion into the skin.
- **Storage Sensitivity:** Biodegradable polymers are highly sensitive to moisture and heat, requiring strict temperature-controlled storage (cold chain).

Delivery & Biological Constraints

- **Incomplete Delivery:** The needles often do not dissolve completely, or fail to penetrate the skin deep enough, leaving drug residue behind.
- **Delayed Release:** Depending on the polymer used, the needles may dissolve too slowly, making them poor for medications that need to work instantly.
- **Skin Irritation:** Repeated use can cause localized redness, swelling, or mild skin irritation.

Commercial Hurdles

- **High Production Cost:** Manufacturing them on a large, sterile scale remains expensive and complex compared to traditional needles or oral pills.

Future Applications of Biodegradable Microneedle Patches

Future uses of biodegradable microneedle patches are anticipated to transform a number of industries by providing transdermal delivery systems that are painless, self-administered, and incredibly effective. Bypassing the outer, protective barrier and delivering treatments straight into the skin's viable layers, where immune cells are plentiful, this technology combines the ease of a patch with the accuracy of a microneedle.

Advanced Medicine

- **Self-administered vaccines:** Eliminates needles and cold storage requirements.
- **Cancer immunotherapy:** Delivers chemo directly into skin tumors.
- **Long-acting contraception:** Dissolves slowly to release hormones over month.

Smart Diagnostics

- **Closed-loop diabetes care:** Automatically senses glucose and releases insulin.
- **Real-time health monitoring:** Samples skin fluids to track biomarkers.

Localized Healing

- **Chronic wound care:** Speeds up diabetic ulcer recovery.
- **Hair regrowth:** Delivers alopecia treatments directly to follicles.

Conclusion

Research shows that biodegradable microneedle patches are a promising minimally invasive method for transdermal drug delivery. Compared with traditional injections, they offer clear advantages for controlled and sustained-release therapies. However, challenges remain in manufacturing, drug-loading capacity, and regulatory approval. Advances in biomaterials and fabrication techniques are expected to speed up clinical translation. Overall, biodegradable microneedle patches represent a major, patient-friendly step forward in drug delivery. With continued improvements in technology, scale-up, and regulatory pathways, these devices could become a standard in medicine and help improve patient compliance and treatment outcomes across many diseases.

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References

- 1) Prausnitz MR, Langer R. Transdermal drug delivery. *Nat Biotechnology*. 2008; 26:1261- 1268.
- 2) Lee K, Lee HC, et al. Dissolving microneedles for transdermal drug administration prepared by stepwise controlled drawing of maltose. *Biomaterials*. 2011;32(11):3134- 3140.
- 3) Kim YC, Park JH, Prausnitz MR. Microneedles for drug and vaccine delivery. *Adv Drug Delivery Rev*. 2012;64(14):1547-1568.
- 4) <https://www.bing.com/search?q=MICRONEEDLE%20PPT>
- 5) <https://pubmed.ncbi.nlm.nih.gov/33919>
- 6) <https://www.bing.com/search?=MICRONEEDLE&form=SWAUA2#>
- 7) S. Henry, D.V. McAllister, M.G. Allen, M.R. Prausnitz Microfabricated microneedles: a novel approach to transdermal drug delivery *J. Pharm. Sci.*, 87 (1998), pp. 922-925, 10.1021/js980042
- 8) V. V. Ranade, M. A. Hollinger, and J. B. Cannon, “Drug Delivery Systems,” Aug. 2003, doi: 10.1201/9781420040142.
- 9) A. A. Date and M. S. Nagarsenker, “Parenteral microemulsions: an overview,” *Int J Pharm*, vol. 355, no. 1–2, pp. 19–30, May 2008, doi: 10.1016/J.IJPHARM.2008.01.004.
- 10) H. Om et al., “Combating atherosclerosis with targeted Diosmin nanoparticles-treated experimental diabetes,” *Invest New Drugs*, vol. 38, no. 5, pp. 1303–1315, Oct. 2020, doi: 10.1007/S10637-020-00905-6.
- 11) Arendt-Nielsen L, Egekvist H, Bjerring P. Pain following controlled cutaneous insertion of needles with different diameters. *Somatosens Mot Res*. 2006;23(1–2):37–43. doi: 10.1080/08990220600700925.
- 12) Tarnow K, King N. Intradermal injections: traditional bevel up versus bevel down. *Appl Nurs Res*. 2004;17(4):275–282.
- 13) Giudice EL, Campbell JD. Needle-free vaccine delivery. *Adv Drug Deliver Rev*. 2006;58(1):68–89. doi: 10.1016/j.addr.2005.12.003.
- 13) Peng Q, Sun X, Gong T, et al. Injectable and biodegradable thermosensitive hydrogels loaded with PHBHHx nanoparticles for the sustained and controlled release of insulin. *Acta Biomater*. 2013;9(2):5063–5069. doi: 10.1016/j.actbio.2012.09.034
- 14) Deadman CM, Kellaway IW, Yasin M, Dickinson PA, Murdan S. An investigation into the influence of drug lipophilicity on the in vivo absorption profiles from subcutaneous

- 15) microspheres and in situ forming depots. *J Control Release*. 2007;122(1):79–85. doi: 10.1016/j.jconrel.2007.06.013.
- 16) Donnelly RF, Garland MJ, Morrow DIJ, et al. Optical coherence tomography is a valuable tool in the study of the effects of microneedle geometry on skin penetration characteristics and in-skin dissolution. *J Control Release*. 2010;147(3):333–341. doi: 10.1016/j.jconrel.2010.08.008.
- 17) Ghosh P, Pinninti RR, Hammell DC, Paudel KS, Stinchcomb AL. Development of a codrug approach for sustained drug delivery across microneedle-treated skin. *J Pharm Sci*. 2013;102(5):1458–1467. doi: 10.1002/jps.23469
- 18) Gupta J, Park SS, Bondy B, Felner EI, Prausnitz MR. Infusion pressure and pain during microneedle injection into skin of human subjects. *Biomaterials*. 2011;32(28):6823–6831. doi: 10.1016/j.biomaterials.2011.05.061.
- 19) Hirobe S, Okada N, Nakagawa S. Transcutaneous vaccines – current and emerging strategies. *Expert Opin Drug Deliv*. 2013;10(4):485–498. doi: 10.1517/17425247.2013.760542.
- 20) van der Maaden K, Jiskoot W, Bouwstra J. Microneedle technologies for (trans)dermal drug and vaccine delivery. *J Control Release*. 2012;161(2):645–655. doi: 10.1016/j.jconrel.2012.01.042.
- 21) Jordan GH. Techniques of tissue handling and transfer. *J Urol*. 1999;162(3):1213–1217. doi: 10.1016/S0022-5347(01)68137-0.
- 22) Lambert PH, Laurent PE. Intradermal vaccine delivery: will new delivery systems transform vaccine administration? *Vaccine*. 2008;26(26):3197–3208. doi: 10.1016/j.vaccine.2008.03.095.
- 23) Nicolas JF, Guy B. Intradermal, epidermal and transcutaneous vaccination: from immunology to clinical practice. *Expert Rev Vaccines*. 2008;7(8):1201–1214. doi: 10.1586/14760584.7.8.1201
- 24) Yan G, Warner KS, Zhang J, Sharma S, Gale BK. Evaluation needle length and density of microneedle arrays in the pretreatment of skin for transdermal drug delivery. *Int J Pharm*. 2010;391(1–2):7–12. doi: 10.1016/j.ijpharm.2010.02.007
- 25) Noh YW, Kim TH, Baek JS, et al. In vitro characterization of the invasiveness of polymer microneedle against skin. *Int J Pharm*. 2010;397(1–2):201–205. doi: 10.1016/j.ijpharm.2010.06.050
- 26) Gomaa YA, Morrow DI, Garland MJ, Donnelly RF, El-Khordagui LK, Meidan VM. Effects of microneedle length, density, insertion time and multiple applications on human skin barrier function: assessments by transepidermal water loss. *Toxicol In Vitro*. 2010;24(7):1971–1978. doi: 10.1016/j.tiv.2010.08.012