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Role of Robotics in Neuromodulator and Filler Injections of Face

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Abstract

In recent years, robots have been increasingly used in various fields of medicine, including surgery, dentistry, and ophthalmology. One of the newest and most promising applications of robotic technology in medicine is in the field of facial aesthetics, particularly in the injection of facial fillers and neuromodulators. While facial injections have traditionally been performed manually by trained physicians and nurses, the introduction of robots has the potential to revolutionize the field, offering a range of potential benefits, including increased precision, accuracy, and consistency of results. However, the significant disadvantages of robots are high cost, lack of flexibility and personal touch, limited experience, and risk of injury due to malfunction.

Keywords
- robotics
- robots
- filler injections
- artificial intelligence
- medical aesthetics
- botulinum toxin type A
- neuromodulators
- hyaluronic acid

Introduction

As technology advances, the field of aesthetics is also evolving in how procedures are performed especially the use of inctables,[1–3] similar to many surgical specialities. One such area of interest is using robots in toxin and filler injections. While manual injection techniques have been the norm for years, introducing robotics offers the potential for greater precision, accuracy, and safety in injectable administration. Robots use various technologies to identify anatomical landmarks on the body before starting an invasive procedure. Medical technologies such as ultrasound, computed tomography scans, and magnetic resonance imaging scans can be used to create detailed images of the external and internal structures of that body part. Robots can use these images to map the patient's anatomy, allowing for precise planning and targeting of the procedure. Robots can also be equipped with various sensors to detect and track anatomical landmarks in real time. These sensors can help the robot to adjust its movements and positioning to ensure that the procedure is performed with maximum precision and accuracy and minimum risk of complication. In some cases, surgical guides can help the robot navigate the patient's anatomy. These guides may be pre-fabricated or created using three-dimensional printing technology and can be customized to the patient's unique anatomy to ensure optimal outcomes.

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Fig. 1 Photograph showing LENA, light-enabled neuro-robotic arm. The photograph was clicked as it was on display during a conference in Paris in year 2023.

Brief History

The first known use of a robot in a surgical procedure was in 1985 when the PUMA 560 robotic arm was used successfully in a stereotaxic operation as it inserted the needle into the brain for biopsy, a procedure previously subject to error from hand tremors during placement of the needle.[4] In 1988, PROBOT, developed at Imperial College London, was used to perform transurethral prostate surgery, which required numerous repetitive cutting motions. The pioneering use of robotic technology in surgery led to the development of more advanced surgical robots like the da Vinci Surgical System, approved in 2000 by the Food and Drug Administration for use in minimally invasive surgeries.[5] In the facial region, the robots have already been in use for intraoral surgery,[6] plastic surgery,[7] ophthalmology,[8] dental procedures,[9] and hair transplant surgery.[10] The ARTAS device was one of the first robotic devices to automatically select/harvest the follicular unit grafts and perform the motion without human intervention.[11]

Robots can play a significant role in toxin and fillers injection for the face. Robots in facial injections are a relatively new and emerging field. NextMotion, a company led by Dr Emmanuel Elard, has created LENA, light-enabled neuro-robotic arm, (►**Fig. 1**) for injecting neuromodulators and fillers using artificial intelligence. The provider can program the tool to specify how much product to inject and where to inject it. It is a robot-assisted injection and relies on the know-how of the injector.

Robots equipped with sophisticated imaging technologies, precise control systems, and sensory feedback capabilities offer the potential to revolutionize the precision and consistency of filler injections. The robotic systems are likely to navigate the complexities of facial anatomy, accurately locate injection points, and administer the injection with high accuracy.

Advantages

Robots have several potential advantages when performing neuromodulator and filler injections.

- Increased accuracy and precision: Robots can inject with high accuracy and precisely and consistently into specific areas of the face, ensuring an even product distribution.
- Reduced pain and discomfort: Robots can inject fillers at a much slower and more controlled rate, using smaller needles and less pressure, potentially reducing pain and discomfort for the patient.
- Consistency and standardization: Robots can provide consistent results, as they are programmed to follow a specific protocol and replicate the same procedure multiple times. Robots can be programmed to make injections at specific depths, angles, and locations, which can help to standardize the filler injection process.
- Increased accuracy: Robots can measure the injection depth and adjust the filler amount accordingly, ensuring the product is placed at the correct depth for optimal results.
- Reduced risk of complications: Robots performing filler injections may also reduce the risk of complications by limiting human error and reducing the need for manual dexterity, as it has been found that the human hand cannot keep the needle in one place during the aspiration process and subsequent filler injection.[12]
- Safety: Robots can also be programmed to avoid certain danger zones of the face,[13] reducing the risk of complications.
- Faster treatment time: Robots have the potential to do injections faster than humans, which can lead to shorter treatment times. Robots can work quickly and efficiently, allowing faster treatment time than manual injections.
- Improved access in remote areas: Using robots may help increase access to facial injections in geographical areas with limited qualified practitioners.

Disadvantages

While robots have potential advantages for filler injections, they also have some disadvantages that should be considered.

- High cost of acquisition, maintenance, and repair: First, robots could be expensive to purchase and maintain, making them less accessible to most practitioners and

the procedure more costly for patients. The cost-effectiveness of using a robot to inject will depend on several factors, including the initial cost of the robot and associated equipment, ongoing maintenance and repair costs, and the number of injections that will be performed using the robot. The cost of using a robot for facial injections may be higher than having a human perform the injections, as robots are still relatively expensive and require skilled operators to program and maintain them.

- Limited flexibility: Robots can only make injections in specific areas, limiting the range of treatments that can be performed. Robots, due to limited flexibility, can only perform a specific set of procedures and may not be able to adapt to individual patient needs.
- Lack of personalization: Robots lack the ability to personalize treatment to the individual patient's specific needs and preferences. Additionally, robots may not yet be able to provide the same level of customization and individualized treatment as a skilled human injector. For example, robots may need help to adjust the amount or placement of filler based on the individual patient's needs, which may lead to poor results.
- Lack of creativity: Robots also lack creativity and can only make injections based on pre-programmed instructions, limiting their ability to customize treatments. Robots may lack the ability to make subtle adjustments based on the patient's unique features and needs.
- Lack of human touch: Robots are not able to provide the same level of care and attention as human practitioners, which can be crucial in building trust and rapport with patients.
- Limited feedback: Robots lack the ability to communicate with the patient to provide feedback on the procedure or to adjust the treatment as needed.
- Limited experience: Robots lack the experience and knowledge of a trained injector, which may result in poor outcomes or complications.
- Difficulty in dealing with pain: Robots do not have the ability to assess and alleviate pain or discomfort during the procedure.
- Risk of Injury: Robots may cause injury to the patient if they malfunction or are not correctly calibrated.
- Patient's choice and ethical concerns: Some patients may be uncomfortable with the idea of receiving injections from a machine rather than a human practitioner, and there may be ethical considerations to take into account when using robotic technology in medicine. Moreover, the use of robots in medicine warrants us to look at data storage and safety ethics, as doctor–patient confidentiality is one of the main tenets of medicine worldwide. Thus, before implementing such technology into medicine, physicians must look at how machines can be efficient and consider all the pillars of medical ethics.[14] Also, given the ethical concerns, it is vital for robotic technology in facial filler injections to be patient-centric and transparent. It involves informing patients about the role of robots in the procedure, addressing any concerns they may have, and allowing them to participate in the decision-making process actively. Open discussions about the benefits and limitations of robotic-assisted injections and the option for patients to choose between human or robotic administration can empower patients to make informed choices aligned with their values and preferences.

Despite many disadvantages, the future looks promising for robot injectors. Sensors on robotic arms can be used to visualize arteries under the skin using ultrasound before the injection of fillers to avoid complications. Robotic arms, equipped with ultrasound probes or sensors, can scan the patient's skin and create a real-time image of the underlying blood vessels. This image can then be used to guide the injection of fillers, helping to avoid accidental injection into a blood vessel,[15] which can cause complications such as bruising and vascular occlusion.[16,17] In addition to ultrasound, other imaging technologies, such as optical coherence tomography, near-infrared imaging, and magnetic resonance angiography (MRA),[18] can also be used to visualize blood vessels and other internal structures and can be integrated into robotic systems for improved precision and accuracy during filler injections. In a study, MRA was used to map the arteries of the face, and the information about the location of the arteries was compressed into an augmented reality image that was then projected onto the patient's face using an app on the phone so that injecting could be done with much more ease. This technique could be regarded as a valuable and accurate tool during dermal filler injections to potentially reduce some of the dangers associated with filler injections. Though this technology has only been used to guide manual filler injections, it could be used to guide robots while injecting as well.[19]

Overall, the use of sensors and imaging technologies can help to ensure that filler injections by robots are performed with the highest level of precision and safety possible, as most of these imaging techniques are risk-free due to the lack of radiation exposure, lack of contrast dye required, and due to their noninvasive nature.[18]

Currently, robots for facial filler injections rely mainly on preprogrammed algorithms and predefined injection protocols. This standardized approach may not fully account for individual variations in facial anatomy, patient preferences, or the nuanced artistic judgment needed for optimal results. However, ongoing research and development in the field are actively working to overcome these limitations. Emerging technologies, like artificial intelligence and machine learning, promise to enhance the personalization and creativity of robot-assisted procedures. By analyzing the large datasets of facial features, treatment outcomes, and patient feedback, these systems can learn and adapt to individual needs, allowing for more tailored and patient-specific treatments. Incorporating patient input, such as desired aesthetic goals and preferences, into the robotic systems' decision-making processes can improve personalization.

Using robots in filler injection for the face could improve the accuracy, consistency, and safety of the procedure,

making it a more effective and efficient option for both patients and practitioners in the future. In addition, as robotic technology continues to evolve and become more widely available, the cost of using robots for injections may decrease, and the potential benefits, such as increased precision[20] and reduced risk of human error, may become more compelling. It is worth noting, however, that while robots may offer some advantages for filler injections, they are not a replacement for skilled human practitioners yet. Robotic technology is still relatively new in this field, and further research is needed to evaluate its safety and effectiveness fully.

Authors' Contributions

K.M.K. was involved in planning, literature search, writing, and editing. A.K. and D.B. were involved in literature search, writing, and editing.

Conflict of Interest

None declared.

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