LASER MECHANICAL AND ELECTROMECHANICAL RESHAPING OF EAR CARTILAGE

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ABSTRACT

Background

The quest for minimally invasive surgery has been eternal in the field of cosmetology. Deformed ear cartilage is the cosmetic challenge for plastic and reconstructive surgery, as any disfigurement is not socially acceptable. Hence, laser-based reshaping and electromechanical reshaping of ear cartilage have come been seen as a panacea.

Methodology

A MEDLINE and PUBMED literature search was performed on laser-based procedures to reshape ear cartilage and electromechanical reshaping of ear cartilage combined with cross-referencing. The period of the search was 1993 to 2021.

Result

For laser-based procedures, several clinical studies using three different wavelengths were analyzed during the search in the literature: 1,064 nm (Nd: YAG), 10,600 nm (CO_2), and 1540 nm (Er: Glass). Clinical outcomes, laser wavelength, and parameters, and patient satisfaction are discussed in each case. For electromechanical reshaping, available clinical studies using different voltage strengths and time applications were analyzed during the search in the literature. Studies varied in terms of a specimen and the voltage and duration of applicability.

Conclusion

Laser-based procedures and electromechanical reshaping of ear cartilage provide alternative treatment options to rectify auricular cartilaginous deformities. Both are minimally invasive procedures and holds a good promise in the future.

Keywords: Laser-based procedures, electromechanical reshaping, Auricular cartilage, minimally invasive surgery, cosmetic surgery

INTRODUCTION

Cartilage act as scaffolding that supports and maintains the aesthetic aspects of the face. It has various functions, including maintaining the patency of the airway, speech production, and joint movement.
Anatomical defects of the cartilages arise out of the various causes ranging from congenital malformations to trauma, chronic infection, malignancy, and scarring. Hence, with the development of surgical science, techniques for reshaping cartilages for aesthetic improvement have been among the greatest quests in modern medicine [1]. Classical surgical procedures for reshaping the cartilages of the facial structures are cutting, scoring, suturing, and moralizing to optimize the intrinsic elastic forces of the cartilage inherent within the tissue that resists the deformation.
Modern aesthetic surgery concepts rely upon avoiding open-ended surgical procedures and general anesthesia to optimize resource utilization and maximize patient comfort. An added advantage is the psychological benefit to the patient of not getting under the knife!
Open surgical procedure has disadvantages of escalating costs, infection, blood loss, prolonged recovering time, bad scars. The risk of surgical and aesthetic complications always goes hand in hand with the complexity of the procedure.[2]
Hence, surgeons have been trended for minimally invasive techniques that can reshape the cartilage for desired specifications. Although open surgical methods have been heavily relied on for ages, these surgeries may not take advantage of a cartilaginous structure's inherent property, which is a charged viscoelastic hydrogel.[3]
Laser-based ear reshaping is an outcome of the quest for a minimally invasive but cosmetically acceptable procedure. Practically, any heat source can reshape the cartilage. However, the main advantages of using laser radiation for the generation of thermal energy are that it causes reduction of cell injuries through the precise control of both the space time-temperature distribution and kinetics of time-dependent thermal denaturation and precise spatial localization with ease of delivery systems. Various sources of Laser can be used.

Electromechanical reshaping is a minimally invasive procedure through which the reshaping of cartilage can be performed using direct current, which is applied percutaneously with needle standard electrodes. This procedure combines mechanical deformation with the application of a very low voltage of DC electric fields. In EMR, cartilage is refashioned into a new shape by an instrument followed by platinum or other metal needle electrodes placed into areas of increased internal stress. Subsequently, a small current of <25 mA is delivered. Then, the jig is removed, and the cartilage naturally takes a new stable shape. Electromechanical reshaping is a novel and compelling technology that harnesses the native properties of cartilage structures to change their mechanical state by altering the electrical and chemical environment, which interacts with the charged cartilaginous tissue matrix.

Methodology

A MEDLINE and PUBMED literature search was performed on Laser-based procedures for reshaping ear cartilage and electromechanical reshaping of ear cartilage combined with cross-referencing. The period of the search was 1993 to 2020. Search terms used were: Laser, cartilage reshaping, protruding ears, LACR, electromechanical reshaping, auricular cartilage, minimally invasive surgery, cosmetic surgery for ear deformity.

Result

For Laser-based procedures, several clinical studies using three different wavelengths were analyzed during the search in the literature: 1,064 nm (Nd: YAG), 10,600 nm (CO_2), and 1540 nm (Er: Glass). Clinical outcomes, laser wavelength, and parameters, and patient satisfaction are discussed in each case. The advantage and disadvantages of various parameters used were elaborated, and safety issues were highlighted. In the studies with controls, the significance was documented.

For electromechanical reshaping, available clinical studies using different voltage strengths and time applications were analyzed during the search in the literature. Studies varied in terms of a specimen and the voltage and duration of applicability. Few studies also emphasized hazards from thermal factors.

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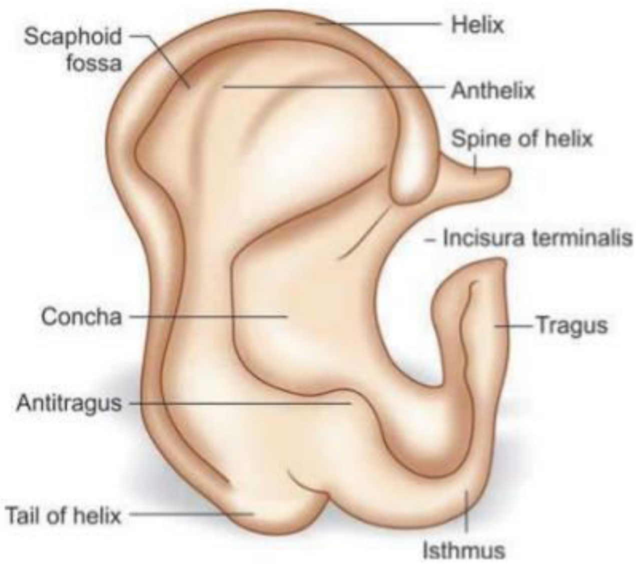
Discussion

Laser-based procedures

Cartilaginous structures are mechanically reformed under the constant load. This is through the accelerated stress relaxation that accompanies laser heating, resulting in plasticity and ensuing the shape change. As the cartilage consists of the composite amorphous polymeric gel material, the heating results in a phased transformation of the tissue structures guided through mass and heat transfer processes.[4]

Fig. 1 Anatomy of ear cartilage



Cartilage with a unique structure undergoes the temperature-dependent phase transformations (melts, crystallization, glass transition, etc.) occurring in synthetic polymers as in any industrial usage. Laser-mediated cartilage reshaping can modify the practice of plastic surgery of the face as the laser reshaping of cartilages can be performed using fiber-optics delivery systems that are minimally invasive.

The cartilage graft shape of cartilage is determined by the end result of electrostatic forces, ionic charges, and fluid flow. Tensile characteristics of collagen fibers within the cellular matrix also have an impact.

The cellular matrix is a gel that is fiber reinforced with a 3-dimensional lattice of type 2 collagen fibers that entangle the complex protein-polysaccharide that is proteoglycan macromolecule. They have negatively charged sulfate and carboxyl moiety groups.

The electrostatic repulsion within these negatively charged ionic molecules results in an expansion of the proteoglycan molecules, which was earlier surrounded by the framework of tensile collagen. Free counter ions like Ca+ and Na+ in liquid solutions can only partially balance the negatively charged density. As a result, the compressive or flexural strain is opposed by the potential between the negatively charged moieties adjoining adjacent proteoglycan units or the collagen matrix framework. The in detail cellular basis for cartilage reshaping of cartilage is still hypothetical in the research field., But the hypothesized mechanism states that during bound to free water phase transition in the matrix, which is observed at approximately 70 C, the reshaping of collagen occurs.[5]

Fig.2 YAG laser-assisted cartilage reshaping Points of application

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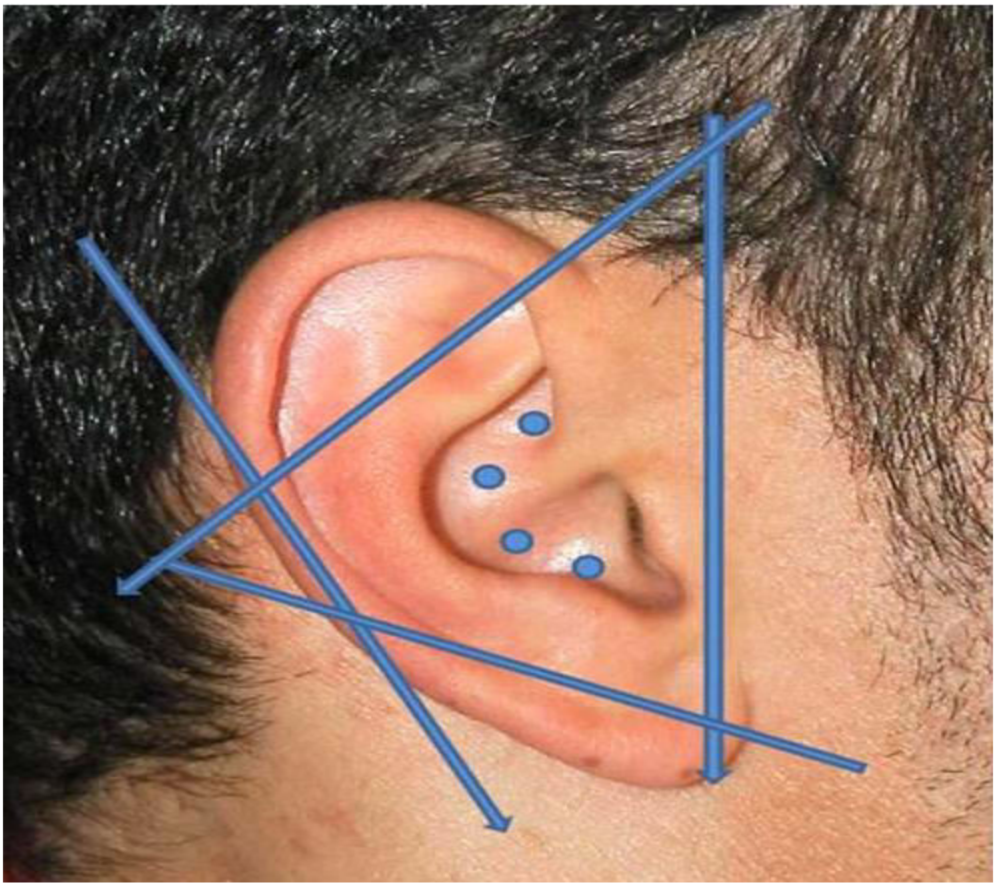

Under normal physiologic conditions and temperatures, H2o molecules are bound by hydrogen bonds and Van der Waals attractions between the matrix of proteoglycan. When heat is administered through Laser, it increases molecular vibrations, which can overcome these weak forces. This results in the liberation of this bound molecule of H2o. Subsequently, this binding of free water transition reduces the steric opposition and charges the shielding of proteoglycan subunits. The mechanical stress relaxation (reshaping) noted following laser heating may be attributed to several mechanisms, including the local mineralization of the matrix.

Optimal Laser-induced reshaping of cartilage can maximize the stress relaxation and simultaneously while minimizing thermal injury and resultant chondrocyte death. Determining the laser dosimetry parameter space that will satisfy the objective requires examining irradiance and exposure time pairs coupling for each wavelength of Laser.

However, limitations of the science are that presently, only a few laser wavelengths, their devices, and such other parameters have been scientifically evaluated. Determination of those laser parameters which are safe and equally effective demands the rigorous due process of tissue material properties and biologic behavior as a result of following laser irradiation.

Indirect methods that can evaluate the changes in the properties of collagen molecules of the tissue in the healing process are a must for the optimal development of laser techniques. However, real-time evaluation of the mechanical properties during laser heating is technically and practically challenging.[6]

On the positive side, changes in the molecular structure of the collagen matrix can alter gross tissue physical characteristics like optical & thermal properties, and elastic modulus can be easily measured using no contact techniques, real-time. Such measurements can be incorporated into clinical instruments to monitor the reshaping of cartilages. Heat-dependent dynamic changes in the optical, thermal, and mechanical properties of cartilage during reshaping have already been detailed and codified. Several hypothetical models of light distribution of light, mass, and heat transfer during the laser ablation process have also been proposed.[7]

The restoration of malformations of different causes in the head and neck region poses a challenge to plastic surgeons. Various such problems are because of the destruction of the cartilaginous structure.

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The success rate of reconstructive surgery depends on selecting a composite cartilage graft of proper size, shape, and thickness, replacing the missing cartilage. However, even with the best of surgeon intentions, the postoperative result is may not always be patient satisfactory due to the difficulty of the procedure – that's of obtaining cartilage of the proper shape. With the use of Laser, such precision is possible.

Heliconia et al. conducted a study on the reshaping of rabbit ear cartilage, which later became the landmark study in the laser reshaping of cartilage. Using a carbon dioxide laser, composite cartilage samples 0.4 - 1 millimeter thick taken from rabbit's ears were irradiated. Researchers used rabbit ear cartilage with covering epithelium. Specimens were reshaped, treated with a carbon dioxide laser, and then immersed in saline solution. Their study observed that it was possible to change the shape of the cartilage, which then tended to retain its new form for several days. Thicker composite grafts easily retained the unique reformed shape more satisfactorily. The significance of this experiment for future corrective surgery in various parts of the head and neck area became evident. The study evaluated that the laser technology will help reshape the grafted cartilage for use in complex reconstructions such as nasal, auricular, and tracheal deformities. The study utilized the latest available Laser technology – that is, carbon dioxide laser known to cause the lowest possible heat among different lasers.

However, critical analysis of their research showed that standardization of thickness of cartilage was lacking. As the Laser is an energy with a defined penetration power, varying cartilage thickness can compound the result. Also, the study did not measure the outcome in terms of mean days through which the cartilage retained the shape. Hence, mere heat produced through Laser might have changed the shape of the cartilage than the energy produced by Laser. Thus, the superiority of the Laser could not be established by this study.8

Kuon et al. studied the CO2 laser effect on the ear cartilage. His studies experimented that Carbon dioxide (CO2) spray may be used in conjunction with Laser to refashion ear cartilage in a similar way as cryogen spray cooling. This will also minimize thermal injury to the skin. Their pivotal study sought to evaluate changes in form and skin damage in five rabbit cartilage after laser therapy with CO2 cooling.

Researchers irradiated mid-portion of rabbit ears through a 1.45 μm wavelength diode laser (12 J /cm^2) with simultaneous CO_2 spray cooling (85-millisecond duration, four alternating heating and cooling cycles/ site, 5 to 6 irradiation sites/row for three rows/ear). Experimental and control cartilage ears were splinted in the flexed position for nearly thirty days after the exposure. A total of five ears each were assigned to the control groups and experimental groups.

All irradiated ears (average 70 3°) exhibited a shape alteration, according to the findings of the experiment. The difference between the control and experimental groups was statistically significant. (Medium 37 11 °C, p 0.05.) There was no significant thermal skin injury, and the skin thickness, microvasculature, and adnexal structures were all preserved. Confocal, alive, and viable chondrocyte cells are microscopically and historically observed surrounding irradiation sites.

The research found that the Laser may lead to acceptable clinical changes in the rabbit ear with CO2 spray cooling. This also reduces heat, skin, and cartilage damage to a minimum. In addition to current thermal cartilage reshaping techniques, this crucial study supports the possible application of CO2 sprays. Analysis of their experiment showed that carbon dioxide (CO_2) spray is better than conventional cryogen spray cooling. Time taken for cooling of the affected specimen can make or mar the very purpose of surgery: the cosmetic effect. Any excessive heat will cause burns which can further end up with scarring. Hence, Kuon et al. effectively showed that Co2 laser is better than conventional ones. 9

Leclere et al. started with laser-assisted cartilage reshaping as an adjunct to invasive surgery of otoplasty. They studied twenty-four subjects who underwent laser-assisted cartilage reshaping for treatment of protrusion of ear bilateral. Fourteen adults and ten children were treated (average age of 16 years). The procedure was performed without anesthesia. Either plane of the entire spiral and the concha were irradiated using a 1540 nm laser connected to a 4 mm spot handpiece with integrated cooling. Fluences in the range of 70- 84 J/cm were used. Soon after the irradiation, an elastomer with a silicon structure was placed inside the helix to mold it to the planned shape. 10

After three minutes, a solid mold was done. Subjects were informed to keep this mold in place always with a wrap through the head for the first three weeks and then for an additional three weeks only during the night. An NSAID was provided to the patients for three days. On days - 1, 30, 60, 90 after the Laser, ears were evaluated.

Post-surgical follow-up at one year was done telephonically. The laser procedure was tolerated well. There were no hematomas or cutaneous necrosis. Contact dermatitis was noted in 6 subjects as a result of inadequate mold design. These subjects stopped didn't wear the mold, and hence the shape of their auricular cartilage did not improve. For the remaining 18 subjects, the expected design of ear reshaping was done (fluence was 84 J/cm.). For three other adults, incomplete redesigning of the auricular cartilage was noted. It was correlated to a lower fluence (<70 J/cm). The study concluded that Laser performed without the use of any anesthesia was considered a safe and less invasive approach to clinical otoplasty.

The study had considered a broad-based sample from both adults and children, thus pre-empting any bias. The study also highlighted the mold design or the skill sets that are needed for a satisfactory outcome. The research also highlighted the procedure as a pure day procedure as anesthesia was avoided.

Analysis of their study brought the light upon realistic experimental in human beings. As the cartilage structure of rabbits differed from that of human beings, it was debated widely in the cosmetic field that such laser procedure may have a limitation, particularly in the adult population where cartilage is sturdier.

Ji-Hun et al. evaluated the Laser irradiation effect using a 1460 nm diodic laser device which produced a significant change in the shape of both human septal and rabbit ear cartilages. Damage on cartilage caused by thermal injury was correlated with the exposure time and the power of the Laser. Staining by Hoechst and PI denoted that chondrocyte death, which occurred through laser irradiation, was mainly due to necrosis and not by apoptosis. In an experimental group where lower power treatment was given (0.3 W or 0.5 W), all the chondrocyte cells regenerated within four weeks. The point to be noted was that in a group with 0.5 W treatment, chondrocytes were not regenerate until four weeks.11

The study concluded that reshaping ear cartilages with a 1,460 nm diode laser was performed simultaneously with minimal thermal injury to the chondrocytes. The extent of thermal damage on chondrocyte cells was based on the time of exposure time and the power of the Laser. It was noted in their study that damaged chondrocyte cells irradiated with lower power of laser power were able to get regenerated once re-implantation was done into a sub perichondrial pocket.

The study compared two energy spectrums and found that the one with 0.3 W was better. The study also made an inference about exposure time and power of Laser, thus hinting towards an optimal balance between the two.

The study by Ji-Hun et al. experimented with an optimal nm diode laser. The main aim of the study was to minimize thermal injury and subsequent burns. Their study provided graphical data of exposure time versus injury. Hence the superiority of the study is established by the methodology researchers have adapted. The study also charted the regeneration time that is required for the damaged chondrocytes. As their data provided vital decision-making to cosmetic surgeons in terms of evidence-based tools, their experiments are well appreciated across the world.

Regab et al. evaluated 16 subjects with 32 prominent ears prospectively. They sought to study the result of clinical and social satisfaction of subjects.Co2 laser evaporation of the perichondrial site followed, and partial thickness of the medial surface of ear cartilage and a pair of parallel laser incisions on capital and conchal lines was done. The cartilage of the ear was pasted with absorbable Vicryl mattress sutures. Demographical details, early and late postoperative results, and subjects' satisfaction in the follow-up were evaluated.

Overall, 32 ears underwent the procedure. Subject's ages ranged from 4-7 years with an average of 5.5 years. Subjects were followed up for 2.4 years. No matters needed revision procedure. In a later evaluation, it was found that 14 issues were happy about the overall experience, two were satisfied. More importantly, none of the subjects showed dissatisfaction. All subjects had 4-6 out of the six criteria for procedural success as defined by the protocol without complications.

The study concluded that the technique of CO2 LACR otoplasty provided an endurance of ear cartilage appearance and required symmetry. The procedure gave a satisfactory outcome to the subjects.12

On the positive side, the procedure's success rate was high, and dissatisfaction with the process was minimal. On the negative side, the age of subjects chosen was younger. Hence to what extent the results of the study could be generalized is questionable.

Critical analysis of their study shows that the emphasis of the study was not only on the clinical outcome but also on social acceptability. As true with any cosmetic procedure, it's the acceptability of a procedure that can provide a further impetus for the study. The acceptability depends on subjective perception by patients and their society as to what constitutes the best fit. Hence, the shape and symmetry of the reshaped ear have to fit into the de novo appearance the patient expects.AS their study proved, it was widely accepted. However, what is accepted in a particular society needs to be accepted by another society. The very definition of aesthetics may be for a toss in different parts of the world. Hence, an extensive social survey of post-procedure is required for further generalization.

Guo et al. summarised the laser-assisted cartilage reshaping among different types of LACR therapies that have been used for prominent ear. LACR with the 1064 nm Nd/YAG laser has been more obnoxious. The penetration depth of the 1064 nm Nd/YAG laser was greater than that of the 1540 nm Er/Glass laser, which causes large tissue injury. LACR with the 1540 nm Er/Glass laser has high absorption by the auricular cartilage and produces comparatively less injury to the adjoining tissue. With the advent of the CO2 Laser, it allowed for cartilage reshaping along with both vaporization and incisions, which complicates the technique, although with a low recurrence rate and definite effect.

The practice of wearing earmold is an important factor in getting satisfactory effectiveness for postoperative subjects. It's pertinent to look for the complications of LACR for prominent ears like perforation of the skin, hematoma, dermatitis, or infection, which should be apprehended. The study concluded that the application of LACR for prominent ear just has a limited number of cases and few relevant literature reports. Hence, the summary recommended that its effectiveness needs to be further studied and clarified.13

Analysis of Guo et al. points out their critical differentiation with the various wavelengths of lasers. It's well-known that wavelength confirms the unique power and energy of a laser. Not all wavelengths are absorbed by the skin and chondrocytes equally. Hence, as the absorption spectrum differs between the dermatophytes and chondrocytes, selecting a particular wavelength of Laser becomes crucial in achieving the result. The study highlighted the complications concerning varied wavelengths.

A study by Holden et al. examined the laser use on-ear cartilage in this prospective, randomized, internally controlled animal study. They used the right auricular of nine rabbits which were mechanically deformed and then irradiated with a 1450 nm diode laser combined with cryogen skin cooling. They applied 14 J/pulse with cryogen spray for 33 milliseconds per cycle and 6-mm spot size.

In their experiment, the left ear served as the control. The auricular cartilages were splinted for 1, 3, 4 weeks. The experimental animals were then administered a lethal dose of intravenous pentobarbital followed by removal of splints. Ears were examined and photographed. Light and confocal microscopy were done on the postoperative cartilage.

Their study noted that a change in shape was observed in all nine treated rabbit ears. However, while no significant change occurred in control ears (stenting alone). The reshaped ears were stout in terms of quality after one month of splinting than after 1- 2 weeks. There was no evidence of thermal injury, or anyone showed signs of post-procedural pain. Findings from cellular analysis in the treated cartilage areas pointed to evidence of an expanding chondrocyte cell population in the area of laser irradiation. It also documented few areas of perichondrial thickening and some fibrosis of the deep dermis. Confocal microscopy showed minimal cellular death at seven days.

The study concluded that cartilage reshaping using laser therapy is a safe transcutaneous procedure using cryogen spray cooling. This animal model is similar to human ears concerning dermal and cartilage thickness. Hence, the study hailed it as a stepping stone toward developing minimally invasive laser auricle reshaping of the ear in humans.

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On the positive side, a contralateral ear was taken as a control, and hence bias was minimized. Microscopic examination of irradiated cells showed minimal damage. On the negative side, fibrosis noted might be a weak point in the future. 14

Critical analysis of the study by Holden et al. highlights that cooling after a laser procedure can be a determining factor in the success or failure of the procedure. As the Laser has high energy, burns are inevitable if the timed cooling is not determined. An added factor is that resetting the shape of cartilage might need a definitive temperature of cooling and time. Hence the study reiterated a critical factor of the success of the laser procedure.

Electromechanical reshaping of ear cartilage

Molecular mechanisms of EMR are not precisely known. Ho et al. provided various possible mechanisms. One of the factors is a loss of H2o molecules through hydrolysis. H+ is reduced to form hydrogen gas at cathodes, while hydroxide ions are oxidized to produce oxygen gas at the anode.

Another feasible mechanism of EMR is ionic electrophoresis. Cartilaginous tissue comprises structured collagen fibrils with a proteoglycan matrix filled with sodium, potassium and calcium, and other ions. The transport of such charged ions between the electrodes during EMR will realign the negatively charged extracellular matrix to induce a permanent change in shape.

EMR experimented with huge, flat surface-connected electrodes in the beginning. Platinum needle electrodes have recently taken their place. With both electrode types, the degree of shape change varies with voltage and application duration. EMR performed with surface-attached electrodes on both sides of a cartilaginous surface, on the other hand, results in a wide area of thermal damage as well as both tissue–electrode interfaces that deepen with current and application duration.

Similarly, using surface-attached electrodes allows for bigger cutaneous incisions for electrode placement, partly negating EMR's effect as a less invasive alternative to conventional surgical methods. However, other procedures, such as complete auricular reconstruction, may benefit from such an approach.

In contrast, needle-electrode-based EMR can manage these limitations, as smaller gauge needles can be placed into auricular cartilage through the skin/mucosa. The extent of the cellular injury can be accepted based upon optimal electrode placement and partial electrical insulation of the needles.

Furthermore, the needle electrodes' position and configuration may be adjusted, allowing for the installation of an electrode that conforms to the geometry of probable shape change and internal stress redistribution.

To drive this technology forward, it is important to determine the relationships between shape change, voltage, and application time during EMR. Also, the degree of tissue damage produced during EMR in terms of voltage and duration of application becomes significant. Such procedure should also provide for stability, functionally acceptable, and long-term viability of electroformed cartilage grafts.

As with all emerging surgical technologies, efficiency needs to be documented in an animal model. This can fuel the clinic's academic interest and provide the required motivation to pursue more in-depth studies concentrating on both mechanisms and optimization.

Knowledge of the healing process of cartilage, remodeling, and shape maintenance after EMR can provide impetus to further develop and investigate methods to analyze, optimize, and control this process. Electromechanical reshaping is a simple but low-cost technology that has the potential to become a clinically useful surgical entity in reconstructive surgery.

In an experimental study by **Oliaei et al.,** Percutaneous needle electrode electromechanical reshaping (5 Volts at 4 minutes) was used to realign the ears of New Zealand white rabbits, which were then bolstered for one month. Ten ears were treated, with two receiving no treatment. Platinum metal electrodes with four-stranded rows of needles were placed across the regions of flexures in the auricular cartilages for the therapy. The model animals were killed after one month, and their ears were photographed and sectioned for light and confocal microscopy (live-dead fluorescent assays).15

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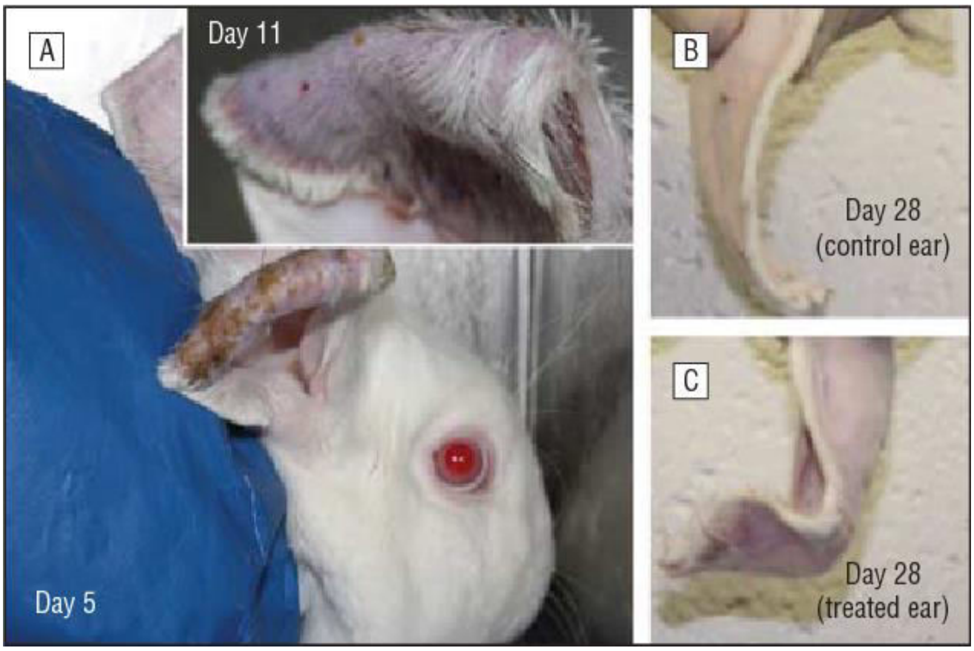
Fig. 3 Electromechanical reshaping of ear results: Timelines



The study noted a significant change in shape in all the treated ears. However, The shape preservation of control ears was limited (mean 14.5°; range 4°-25°). Reshaped ears have intact epidermal and adnexal components. All of the specimens' models showed neo eochondrogenesis. Confocal microscopy revealed a localized region of non-viable chondrocyte cells surrounding needle sites in all of the treated ears, measuring 2.0 mm in diameter.

The researchers found that electromechanical reshaping may modify the form of the rabbit auricle, resulting in excellent shape creation and retention with little skin and cartilage damage. Electromechanical reshaping using needle electrodes is a superior method for less invasive tissue reshaping. The researchers intended to use the findings in otoplasty, septoplasty, and rhinoplasty procedures.

Critical analysis of the study by Oliaei et al. highlights that voltage and time factors are the most important determinants of success. There is always a trade-off with volts and time. Higher the volts, however, there arises the concern of burn and shock injury. Though such injuries are at the cellular level, it may be a matter of time before side effects or complications of high volts start showing and thus hindering the intended shape. Oliaei et al. could, similar to studies on Laser, bring forth the graphical representation of volt versus time. Nonetheless, though a primitive graph, it sets the foundation for further experiments and direction.

In a study by **Badran et al.**, they aimed to demonstrate the dosimetry effect of electromechanical reshaping on shape change of cartilage structure, the structural integrity of the structure, viability of cells, and remodeling of grafts in an in vivo in a long-term animal model.

In their study, a sub-perichondrial cartilage defect was performed within the pinna base of thirty-one white rabbits of the New Zealand variety. Autologous costal cartilage grafts were taken and then electromechanically rechristened to rearticulate at the rabbit auricular base framework. It was then mechanically planted into the defect of the pinna base. Forty-nine costal cartilage specimens (4 control and 45 experimental) effectively underwent EMR using a paired set of voltage-time combinations and survived for 6 / 12 weeks. Change in shape was measured, and the specimens were examined using digital imaging, tissue histology, and confocal microscopy with live-dead viability assays.

As per the result of the study, change in shape was proportional to charge transfer of charges in all experimental models with significant difference ($P < .01$) and increased with voltage. All experimental models contoured well to the auricular base. Focal cartilage degeneration and fibrosis were noted at the site of needle electrode insertion, ranging from 2.2 - 3.9 mm—the effect of injury higher with an increasing transfer of charge and survival duration.

The study concluded that EMR results in inappropriate and required changes in shape in cartilage grafts. It causes chondrocyte injury, which is highly localized. This study suggested that factors of ear cartilage reconstruction may be viable using EMR. Extended survival duration and further balancing of voltage-time pairs are significant to examine the long-term effects and shape-change potential of EMR.16

Analysis of their study reiterated the dosimetry effect of the electromechanical reshaping of the ear. It just did not view cosmetic effect as an endpoint but several intermediated factors like cell integrity, elasticity which can explain the long-term effect of the procedure. Hence, the superiority of the study is established while looking at the long-term effects and acceptability of the EMR procedure. Most studies are done before this had not considered timelines.

Yau et al. attempted to demonstrate that electromechanical reshaping can effectively change In an in vivo animal model, the form of undamaged pinnae. The research also aimed to demonstrate that the degree of shape change and tolerable cell damage is not related to dosimetry. The study experimented on intact auricular cartilages of eighteen New Zealand white rabbits. Variable dosimetry parameters were used to reshape the models electromechanically (4 Volts for 5 minutes, 4 Volts for 4 minutes, 5 Volts for 3 minutes, 5 Volts for 4 minutes, 6 Volts for 2 minutes, 6 Volts for 3 minutes). A custom instrument with two strands of platinum needle electrodes was applied to bend ear cartilage at the pinna base's middle and perform electromechanical reshaping. Pinnae were splinted for 90 days along the bent region with soft silicone sheeting and a cotton bolster. In both proximal and distal sites, the process was performed two times each pinna. When pinnae specimens were bent and pierced inside the device, no voltage was applied as a control.

Before euthanasia, the ears were checked the day after the splints were removed. Photographs of the ears were taken, and the bending angles were measured. Tissue was sectioned for cellular analysis and confocal microscopy to assess changes in cellular structure and viability. The results of the research revealed that treated pinnae bent more and kept their form better than control pinnae. The mean (SD) bent angles were 55° (35°) for the control, 60° (15°) for 4 V for 4 minutes, 118° (15°) for 4 V for 5 minutes, 88° (26°) for 5 V for 3 minutes, 80° (17°) for 5 V for 4 minutes, 117° (21°) for 6 V for 2 minutes, and 125° (18°) for 6 V for 3 minutes in the seven dosimetry groups. Electrical charge transfer was proportional to form change, which was greater with higher voltage and application duration. The pinnae structures were stained with hematoxylin and eosin, which revealed isolated areas of cellular damage and fibrosis in the cartilage and surrounding soft tissue where the needle electrodes were placed. On the cell viability test, this circumferential zone of damage (approximately 1.5-2.5 mm) correlated to dead cells. This area had a greater circumference, with total electrical charge transfer reaching 2.5 mm at 6 V for three minutes.

In this extended in vivo investigation, the researchers found that electromechanical reshaping caused shape change in intact rabbit pinnae. A brief application of 4 - 6 Volts is suggested to induce the necessary pinnae restructuring. The quantity of total current delivered into the tissue and the restricted spatial distribution exacerbated tissue damage around the electrodes.

Critical analysis of their study showed that dosimetry is not proportional to the internal injury of chondrocytes. However, their emphasis on preventing cell injury is laudable, and no efforts were taken to consider the long-term effect of such a procedure.

Amanda et al. explored the mechanical effect of EMR on the cartilage in their study. They evaluated the tangent moduli of EMR-treated rabbit septal and auricular cartilage and compared with matched numbers. Voltage was tested from 2 to 8 Voltage while the application time was kept constant at 2 minutes 3 minutes for ear cartilage and 2 minutes for nasal cartilage.

Standard metal electrodes were utilized to apply voltage. Specimen were molded and the flatness of the specimens preserved and then precise mechanical testing through a uniaxial tension test of constant strain rate 0.01 millimeter/second.

Above 2 Volts, both ear and nasal cartilage demonstrated a minimal decrease in stiffness, as evaluated by the tangent modulus. A heat generation effect was noted above 4 Volts through the EMR application threshold to prevent the hazards associated with thermo modulating the cartilage.

The study concluded that balancing the electromechanical reshaping application parameters and understanding various hazards can assist in furthering electromechanical reshaping research and clinical use. 18

Wu et al. investigated the impact on specimen shape modification using platinum needle electrodes of direct current voltage and application time. A precision manufactured plastic tool was bent 90° to two hundred Rabbit cartilage specimens of 20 mm — 8 mm — 1 mm. Standard electrode location and voltage range have been assessed by mathematical modeling inside the cartilage specimen of the whole electric field.

Three platinum needle electrodes, spaced 2 millimeters apart and positioned 6 millimeters from the bent axis on opposing ends, were selected as the geometric arrangement. The anode was a single row of electrodes, while the cathode was the opposite pole. For 1, 2, 4, 6 minutes, a constant DC current was applied, and for 1, 2, 4 minutes, 8 V was applied. Rehydration in phosphate-buffered saline was then performed. After that, the samples were removed from The bending angle, and the jig was assessed. According to previous studies, when the voltage and application time increased, the bent angle increased. For four minutes, there was no clinically significant reshaping below a voltage threshold of 4 Volts. The highest bent angle obtained at 8 Volts and 4 minutes of application was 35.7 1.7°.19

These low-cost reshaping methods can potentially amenable to outpatient-based treatments. It is easier to perform, and the outcome is acceptable in animal models. Low morbidity was observed in these studies, except for acute crusting and relative alopecia at the needle insertion sites, which cured within a week.

In human treatment, the splint would likely be replaced with custom-fitted silicon moulage, mimicking the appropriate shape of an ideal ear. In the future, surgeons could stock a series of low-cost preformed moulages and select the proper size and shape for each individual. In addition, needle-based EMR likely has the potential expanding horizons in reconstructive surgeries.

EMR experimented with huge, flat surface-connected electrodes in the beginning. Platinum needle electrodes have recently taken their place. With both electrode types, the degree of shape change varies with voltage and application duration. EMR performed with surface-attached electrodes on both sides of a cartilaginous surface, on the other hand, results in a wide area of thermal damage as well as both tissue–electrode interfaces that deepen with current and application duration.

Similarly, using surface-attached electrodes allows for bigger cutaneous incisions for electrode insertion, partly negating EMR's effect as a less invasive alternative to conventional surgical methods. However, such a method may be useful in other procedures, which including complete auricular reconstruction.

In contrast, needle-electrode-based EMR can manage these limitations, as smaller gauge needles can be placed into auricular cartilage through the skin/mucosa. The extent of the cellular injury can be accepted based upon optimal electrode placement and partial electrical insulation of the needles.

Furthermore, the needle electrodes may be configured and the position of the needle electrodes can be changed, allowing for the installation of an electrode that conforms to the geometry of probable shape changes and internal stress redistribution.

Conclusion

Laser-based procedures provide alternative treatment options to rectify auricular cartilaginous deformities. Various researches on animal models and subsequent human trials have provided optimal parameters which are safe and effective. Further fine-tuning of the procedure in terms of voltage and application time and the type of Laser utilized will further advance the science of Laser-based therapies. A major positive impact has been the patient satisfaction and minimalistic of intervention.
Electromechanical reshaping is the minimally invasive and aesthetically acceptable procedure for reshaping ear deformities. It is less painful and can be performed under daycare or as an outpatient. It also has lesser complications compared to surgical management. It also offers less expensive and acceptable solutions to cosmetic management of ear deformities in specific and other facial cartilage deformities in general.

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