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Review of Otoplasty Techniques – Animal Models as Alternatives for Surgical Practice

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Rezumat

Review al tehnicilor de otoplastie – modele animale ca alternative pentru practica chirurgicală

Problemele etice şi financiare fac din ce în ce mai dificil accesul la cadavre umane pentru practica chirurgicală, astfel încât a devenit evidentă necesitatea găsirii de soluții alternative pentru continuitatea formării medicale. Modelele experimentale animale au fost introduse în procesul de formare a tinerilor medici pentru a facilita dobândirea de noi competențe. Otoplastia reprezintă o intervenție chirurgicală menită să restabilească aspectul estetic, majoritatea procedurilor fiind efectuate pentru defecte ale urechii externe care alterează încrederea în sine a pacientului. O implicație a operației de otoplastie este impactul psihosocial pe care intervenția îl are asupra subiectului. Chiar dacă rata de complicații nu este atât de mare, este important să fie urmărit cel mai bun rezultat. Prin urmare, este esențial ca tinerii medici să practice etapele chirurgicale pentru a dobândi un nivel înalt de perfecționare. În acest domeniu, cele mai utilizate modele de animale sunt porcul şi iepurele, deoarece au o anatomie asemănătoare, şi sunt uşor de obținut. Scopul acestui studiu este de a trece în revistă cele mai utilizate tehnici de otoplastie şi aplicabilitatea acestora la modele animale experimentale, de a stabili care sunt avantajele fiecărui model şi de a evalua care sunt perspectivele noilor tehnologii în domeniul formării chirurgicale.

Cuvinte cheie: otoplastie, antrenament, model animal, chirurgie experimentală, tehnică chirurgicală

Abstract

Ethical and financial issues make access to human cadavers for surgical practice more and more difficult, so it became clear that the need for training must find surrogate solutions. Animal experimental models have been introduced in the training process of young doctors to ease the acquisition of new skills. Otoplasty represents a surgical intervention meant to restore the aesthetic aspect of one's appearance. The majority of the procedures are done

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for defects of the external ear that alter the patient's self-confidence. An implication of otoplasty surgery is the psychosocial impact that the intervention has on the subject. Even though the complication rate is not that high, it is important to aim for the finest result. Therefore, it is essential that young doctors practice the surgical steps until they reach a level of mastery. In this field, the most used animal models are the pig and the rabbit, because they have similar anatomy, and are easy to obtain. The aim of this study is to review the most used otoplasty techniques and their applicability to experimental animal models, to establish which the advantages of each model are, and to assess what the prospects of new technologies in the field of surgical training are.

Keywords: otoplasty, training, animal model, experimental surgery, surgical technique

Introduction

Deformities and defects of the ear represent a major problem, being a cause of serious impairment for normal development, especially from a psycho-emotional point of view. Whether we are talking about a functional deficit or just an esthetic one it is very important to an individual to be satisfied with their own look so that their well-being has nothing to suffer (1). A recent study showed the fact that otoplasty can bring powerful positive psychosocial benefits, regardless of age (2).

The notion of quality of life was outlined almost 70 years ago, by the World Health Organization, as "a state of complete physical, mental and social well-being not merely the absence of disease" (3). Therefore, for a human being, the quality of life is a major aspect that affects their daily comfort. Any kind of esthetic defect can imply a decrease in confidence and in the ability to adapt to the environment. By applying a series of questionnaires regarding multiple psychological aspects (4), studies proved that otoplasty surgery for esthetic defects can majorly impact the quality of life.

Because the principal motivation for pinnaplasty is psychological, it is obvious that it can be very beneficial for the patient's self-acceptance and confidence. Nevertheless, awareness is needed for both the children and their families in case of an unsatisfactory outcome which can induce an increase in anxiety (5).

Defects like anotia, microtia, protruding or constricted ears can be observed from birth or in the first weeks of life. All these situations may need surgical treatment for an appropriate correction.

For a correct diagnosis of a malformed ear, a series of classifications were established. Protruding ears may be divided into three classes: class I - simple prominent ear, class II - mixed-type prominent ear, and class III – conchal-type prominent ear (6). Another classification system for the grading of constricted ear malformation severity is available and it divides these types of malformations into three classes as well (7). In this article, we make reference to multiple ear deformities, like microtia, protruding ear or constricted ear, and their treatment options. There is a second category of external ear defects that can be acquired later during life, after local traumas, or even tumors that need a large repair.

Throughout history, many surgical techniques have been developed in an attempt to solve these problems as much as possible. One of the first descriptions found in literature dates from 1959, when Furnas described otoplasty with a particular approach of using conchomastoid permanent sutures for the remodeling of prominent ears (8). A couple of years later, Mustardé developed another technique that became popular, and is still being used nowadays. He proposed the use of enduring conchoscaphal mattress stitches to build a new tube-like antihelix (9).

For a good result in an otoplasty surgery, the surgeon must have a thorough preparation, the training in this kind of intervention being a very important aspect. This specific field is still shared between two surgical specialties, otorhinolaryngology, and plastic surgery, but with no significant differences between outcomes (10).

The objective of this research is to comprehensively analyze the various otoplasty techniques that are frequently used in surgical practice, with a particular focus on their applicability to experimental animal models. By reviewing these techniques, the study aims to identify and highlight the specific advantages that each model offers in terms of anatomical accuracy, ease of implementation, and relevance to human anatomy. In addition to evaluating the existing otoplasty techniques, the study will investigate the prospects of integrating new technologies in surgical training. This includes exploring advancements such as virtual reality (VR), augmented reality (AR), and simulation-based training modules, which may serve to enhance the learning experience for surgeons. By incorporating these technologies, trainees can develop their skills in a controlled environment, allowing for repeated practice and a better grasp of complex procedures before they operate on human patients.

Material and Method

Three independent reviewers (MT, DGR, and MC) performed a structured literature search in PubMed, EMBASE, and Google Scholar for studies reporting otoplasty techniques. The search strategy was conducted according to Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines. The following index terms "otoplasty techniques", "animal model otoplasty training", "biotechnologies otoplasty", "virtual reality simulator otoplasty" were used to identify studies from the beginning of 2010 until December 2024. Free of charge and institution available articles were selected. A bibliographic review of selected relevant papers was used as a secondary source for full-length articles. The inclusion criteria were articles that describe external ear defects, reconstruction methods, and articles that describe techniques of surgical training on animal models. The exclusion criteria were duplicates, case reports, articles that describe other surgeries or subjects that are not related to otoplasty, articles that were in another language than English, and articles with no full text available.

Results

The initial search results identified 670 references (*Fig. 1*). After exclusion of duplicates and exclusion of references based on title and abstract, 131 full

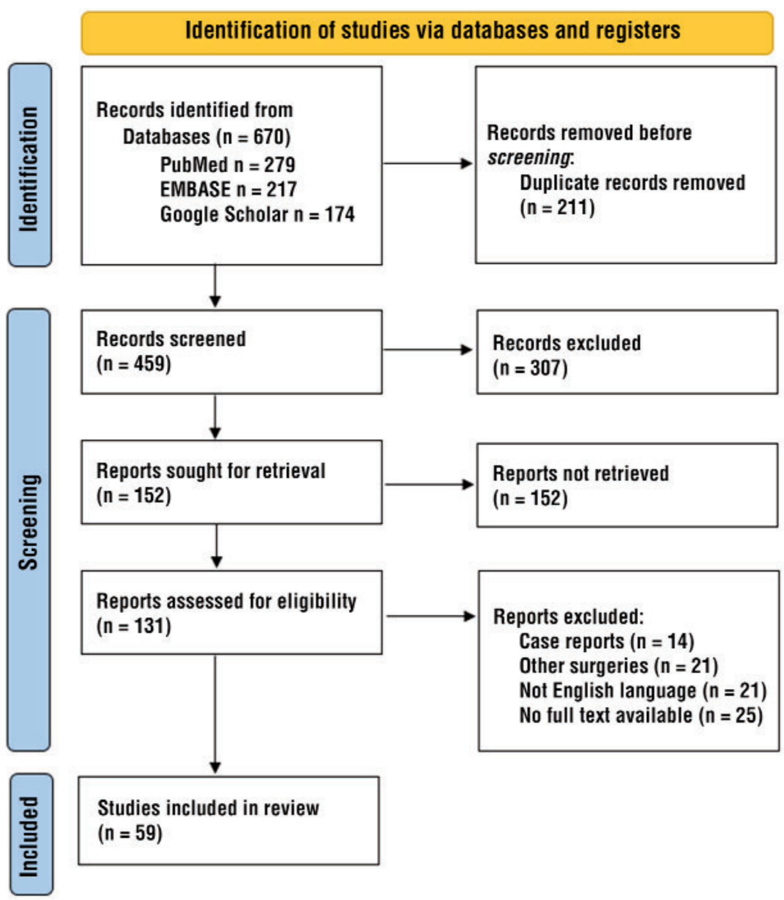

Figure 1. PRISMA 2020 flow chart diagram representing searching of thedatabases

texts were read. From the 131 articles, 72 were excluded. The most common reasons for exclusion were the unavailability of full-text, and non-English language papers. Finally, 59 studies were included in the review.

Discussions

Anatomy

The main components of the normal ear are cartilage and skin, the most important elements being the helix in the most external part, and the antihelix that has a main stem which normally bifurcates in an anterior crus and a posterior crus, delineating the triangular fossa. Going towards the orifice of the external auditory canal we find on one hand, the central, cartilaginous part of the pinna named the concha, and on the other hand, the tragus. At the most inferior extremity of the pinna, there is a non-cartilaginous structure named the lobule. There are other parts as well, these being less important, like Darwin's tubercle, the antitragus, or the intertragic notch.

With the process of aging, several changes happen at the level of the structure of the ear, the most important being the consistency of the cartilage. With the passing of years, the cartilage becomes more rigid and compact, this having a big impact on the procedure used to repair the prominent ear (9).

The external ear is vascularized mainly by the posterior auricular artery, which has an ascendent trajectory and branches out to the posterior surface of the auricular cartilage and the mastoid process, and the superficial temporal artery which generally supplies the lobule and the helix through two main ramifications, and the tragus trough smaller ones (11). These two vessels are both branches of the external carotid artery (12). The innervation is structured depending on the embryologic provenance. The nerves for the external ear are the great auricular nerve (anterior and posterior branches) which innervates most of the external ear, the auriculotemporal nerve dedicated mostly for the anterior surface of the helical fold and also for its root, and the lesser occipital nerve for the innervation of the posterior surface of the auricle (the superior and middle thirds) (13). The vagus nerve contributes as well to the innervation of the central part of the concha towards the external acoustic meatus through its mastoid branch called Arnold's nerve (14).

Physiology

The ear has two main roles in our lives, those of hearing and maintaining balance. From an anatomic point of view, the three big parts of the ear are the external ear which is mainly formed by the auricle and the external acoustic meatus, the middle ear, starting from the tympanic membrane and continuing with the ossicle chain, and the inner ear which contains the organs of hearing and balance. The sound moves onward from the outside via all the elements of the ear reaching, in the end, the brain. In this pathway, the pinna palys a very important role, as shown in different studies that have been conducted over time. For example, one of the functions of the pinna is the involvement in binaural hearing and sound localization (15).

The pinna has the role of capturing the sound-wave, slightly amplifying it and redirecting it further to the eardrum along the external acoustic meatus. Any abnormality of the pinna results in a certain grade of conductive hearing deficit that can be worsened if it is related to defects of other elements of the middle or inner ear (16,17).

Indications for Surgery

The main reason for this type of surgery remains the esthetic appearance. The vast majority of defects are congenital, and the subjects are born with them. Whether we talk about just the alteration of tissue quality, insertion, angulation with no other impairment, or about genetic syndromes which usually associate multiple organ involvement, surgery remains the main and unique corrective solution (6).

Apart from this category, there are some acquired conditions of the external ear that require the reconstruction of the pinna. Trauma can be caused by traffic accidents, bites, burns, and can lead to lacerations or even avulsions of the external ear (18). The most common are bite wounds, the upper third of the auricle being the most affected (19).

Another particular situation that requires an otoplasty intervention is the tumoral pathology of the external ear. Benign or especially malignant tumors of the auricle may need large resection, which leads to the need for reconstruction of the pinna. The most frequent cancer of the auricle is squamous cell carcinoma, and it generally arises along the superior skin of the helix (20).

A very important category of diseases that correlate with malformations of the ear is hereditary disorders. For example, one study showed that 15-60% of patients with microtia have additional abnormalities, the most common accompanying dysmorphic features being microphthalmia, malformations of the face, polydactyly, renal diseases, cardiac anomalies, and vertebral defects (21), as part of genetic syndromes like Goldenhar, Treacher-Collins, Apert or branchiotorenal syndrome (22-25)

A further aspect worth mentioning is the difference that must be made between malformation and deformation of the ear. Therefore, ear malformations are considered statuses in which some of the ear segments are deficient. This is usually caused by aberrant embryologic progress. On the other hand, ear deformations are constitutions where all the auricular components are existent, but they are deformed, curved, or creased (26).

Epidemiology

Studies concerning the prevalence of congenital diseases were conducted a long time ago. Researchers tried to find out risk factors for the most common deformities that occur at birth. For example, a paper concerning microtia reported a very high prevalence of the disease in Quito, Ecuador (17.4/10000), five times superior to six other countries from this continent. An explanation for this incidence has been found in the high altitude of this state, as an etiologic factor for hypoxia during the embryonic period (27).

Other risk factors for microtia are drug intake during pregnancy, maternal type I chronic diabetes mellitus who have an insulin dependency, high paternal and maternal age, high parity, and multiple births (28–32). In addition, there are a series of specific syndromes that can include abnormalities of the ear (21).

Otoplasty Techniques

The leading causes for the protruding ear are conchal overgrowth, incorrect formation of the antihelical fold, a scapho-conchal angle wider than 90 degrees, and the mix between the excess of the concha and the inadequate development of the fold of the antihelix (9). In most cases the deformities of the ears are bilateral, but the source of the deformity is not always the same for both ears (33). Therefore, it is important to address the causing underlying problem to correctly solve the problem. When proceeding with an otoplasty intervention it is important to consider McDowell's basic principles (34). Any procedure should aim for symmetrical and replicable results and avoid unnecessary costs, complexity, scars, and recurrence (9).

The most important techniques used in otoplasty can be separated into two fundamental groups: cartilage-sparing techniques and cartilage-cutting techniques. Over time, a series of surgical techniques for each of these categories has been described (35). For the cartilage-sparing category, the most used are the approaches of Mustardé and Furnas. These procedures imply performing sutures that are intended to reshape the ear. In the Mustardé approach, the antihelix is designed with multiple attachment sutures (36). The Furnas technique is used to reduce the concha-mastoid angle by fixating the concha to the mastoid using multiple sutures. On the other hand, cartilage-cutting procedures like conchal reduction require the removal of cartilage (35). Of course, there are combined techniques as well which try to achieve the best result depending on the pre-existing deformity of the ear (37).

In a recent study, Ersen described a new technique for protruding ear correction by creating two flaps: a sideward-based perichondroadipodermal one and an adipoperichondrial one, closer to the midline. This technique seems to be very useful, especially for the effacement of the antihelical fold and wide scaphoconchal angle with or without mild conchal hypertrophy. Even though revisions and further research have to be made, there were many benefits observed for this type of surgery (38).

It is to be noted that if we are talking about ear deformities, a few nonsurgical methods of correction are available. It is important to diagnose the defect as early as possible so that the levels of estrogen that can make the baby's cartilage more flexible are higher. Thus, by applying different devices in the first days of life the remodeling of the ear may be possible without any surgery (26).

Knowing that only approximately 30% of congenital ear deformities undergo an autonomic improvement, it is important to raise awareness about proper molding systems in the first several days of life. Neonatal molding of the ear reduces the need for surgical correction and the results can bring sufficient satisfaction (39). Some interesting results are presented by Kang et al. in their study about a durable inserted clip structure (Earfold® - Allergan plc, Dublin, Ireland) which is fixed through a small incision under local anesthesia (40).

Outcomes and Complications

When we talk about complications of otoplasty surgery there are two main categories: early and late complications. The category of immediate complications comprises bleeding or hematoma, contamination of the surgical site, pain, or pruritus, inflammation of the cartilage, and necrosis. As for the late sequelae, the most common is unesthetic appearance or patient dismay, unpleasant scarring, wound infections secondary to suture existence, and abnormal sensations in the regional skin (9).

The patient's level of satisfaction after the surgery can be evaluated by different methods mostly by applying standardized surveys that evaluate the psychosocial domain. Many studies have been conducted, and the results show that in both pediatric and adult subjects plastic surgeries of the ear can provide important psychological and behavioral satisfaction with increased quality of life (2).

Ex vivo Porcine Model for Practicing Otoplasty Techniques

Access to human cadavers is increasingly restricted, from ethical and financial points of view (41). The continuous need for the practice of young doctors, led throughout time to the development of alternative methods of training for this type of procedure. Being already used for different kinds of otology surgical maneuvers, the porcine head turned out to be a very good model for otoplasty training. Even though there are a series of particularities between the human and pig's anatomical aspects of the ear, this model is considered an excellent simulation tool for this sort of surgery (42).

The literature described how can a pig's head can be used for training in different otoplasty techniques, especially because it lacks the anti-helical fold, and the pinna cartilage is pliable, like the human one. Despite a series of variations between the anatomical structure of the porcine ear, it remains suitable for the execution of the Mustardé technique or the anterior scoring approach (43). One of the most studied aspects of ex vivo training on the pig model was the difference between the scoring technique and the bipolar diathermy on the ear cartilage. Utilizing an ex vivo porcine model, led to the conclusion that scoring combined with bipolar diathermy is remarkably synergistic and produces better results than scoring itself (44,45).

From another perspective, the porcine model can be useful as well in otoplasty training by fabricating costal cartilage used for total ear reconstruction. Shin et al. used the ribs of a porcine model for the reconstruction of an ear framework. With the help of a transparent film template and different cutting and carving surgical instruments a training model was performed (46). For a young unexperimented surgeon, it can be quite challenging to be able to create a perfect auricular framework that is stable and esthetic from the beginning. The possibility of practicing on an experimental model comparable to the human one gives the surgeon a better manipulation sense and the ability to recreate an ear wedge within a short time with restricted donor material.

The Rabbit Model for Practicing Otoplasty Techniques

Another very important animal model that is used for training in otoplasty is the rabbit, more specifically the New Zealand white rabbit, its ear cartilage structure being very similar to the human one (47). Since it is not possible to practice on human subjects, the rabbit rapidly became one of the best experimental models on which trainees can learn the basic steps for otoplasty, being used by many researchers for making comparisons between different otoplasty techniques (48,49).

A group of researchers described an electro-mechanical procedure for remodeling the auricle of the New Zealand white rabbit, with the help of a needle. In the attempt to find a way to reshape the ear cartilage without using surgical instruments or doing any incisions or sutures. They used a matrix and electrical current, and by arranging a series of needles in a matrix and passing a 4V to 6V current through them, while piercing the external ear, a diathermic effect is produced and so, the cartilage can be reshaped. A splint is mounted to obtain the correct shape (50).

Other techniques, like the use of a laser and its radiation properties, aiming to remodel the ear cartilage transcutaneously, mixed with lowering the temperature of the skin with the help of a cryogen spray, and in the end, the placement of a stent, to modify the cartilage, have also been described. The outcomes of the study describe how this method leads to an expanded chondrocyte culture around the laser-irradiated area, peri-chondral condensation, and fibrosis. This type of intervention can be safely performed even in the outpatient clinic and with promising results (51).

Other options are available and are being studied in the literature. Non-invasive cure of defects of the ear has been disclosed two centuries ago. Lately, a new procedure has been defined, injecting in a rabbit model proteolytic enzymes or agents aimed at these auricular elements, in order to make the cartilage more flexible without damaging it, and splinting it afterward (52).

Comparison Between the Two Most Used Animal Models

The porcine and the rabbit model have each their own advantages and disadvantages, as shown in *Table 1*, but in a broad perspective we can affirm that the porcine model is more suitable for advanced otoplasty training, while the rabbit model is more economical, but less accurate (47).

Biotechnology and Stem Cells for Regrowing Ears

Modern technologies and biomolecular engineering have developed at a fast pace in the last few years, opening new pathways for research. A model of stem cells harvested from human chondrocytes has been described, expanded in vitro, and implanted in nude mice to create neocartilage which was later used for ear reconstruction (53). Genetic testing and microarray analysis demonstrated the fact that there are no significant differences between the cells from microtia and normal ears so that microtia tissue can be used as a cell supply for auricular repair (53).

An important aspect in this field is represented by injected gels that promote engraftment to be used as three-dimensional patterns for new cartilage proliferation. Early experiments were done in 1995 when Vacanti and his team developed a model of slowly polymerizing calcium alginate gel as a means of delivering chondrocytes to create autologous grafts (54).

New Technologies

To achieve better results and to have a preview of the final appearance, computed technologies found their place in the medical domain as well. Being able to simulate an operation to see the outcomes is a major enhancement for surgical science (55). For example, in other surgical fields of otorhinolaryngology, studies have been conducted to demonstrate de usefulness of technology assisted training in functional endoscopic sinus surgery. The use of accelerometer-based sensors for practicing experimental surgeries enhances the capacity to monitor the hand motions, thus improving the surgical skills of young surgeons (56).

Facial editing through electronically processed graphics originates more than three decades ago. In an article published by Schoenrock, multiple utilization of computer-assisted patient evaluations and demonstrations of surgical results are shown. Using such techniques the doctor can show the patient a possible representation of the final results (57).

On the other hand, more recent studies focus on applying computer modeling for planning plastic surgeries. These kinds of programs are a useful tool for young or less experienced doctors to improve their ability to conceptualize the surgical steps and to visualize the possible outcomes, before actually proceeding to real surgery (58). Some of these simulation software can use radiological investigations of the patients, and the outcomes can be used in the operating theater with a great

Table 1. Comparison between the porcine and rabbit experimental models

Aspect	Porcine Model (42)	Rabbit Model (49)
Anatomy	Similar to humans; well-defined ear with cartilage	Different from humans; smaller ear with softer cartilage
Size	Larger, similar to human ears	Smaller, harder to replicate human ear size
Tissue Properties	Similar skin and cartilage to humans (thicker, stiffer)	Thinner skin and softer cartilage
Surgical Training	Best for practicing complex techniques (cartilage shaping)	More limited for complex surgeries
Wound Healing	Similar to humans, slower healing	Faster healing, but less realistic for human wounds
Ethical Concerns	Higher ethical concerns and animal care costs	Fewer ethical concerns, more economical
Cost	Higher due to larger size and care needs	Lower cost, more affordable
Postoperative Assessment	Better for assessing complex outcomes (cartilage shaping)	Limited for assessing realistic human-like outcomes

asset in terms of precision, cutback of surgical accidents, and decrease in training costs (59).

Conclusions

Defects and abnormalities of the external ear may have a big impact on one's development and psychosocial life. Therefore, it is very important to have the capacity to repair any kind of malformation of the outer ear, as an aid to a patient's quality of life. Otoplasty procedures were defined many years ago and are in a continuous developmental phase. From the point of view of a young, inexperienced doctor, the need to practice is always a difficult step that must be overcome. Taking into consideration the cumbersome access to human cadavers, different alternative experimental models have been found. The most used ones are the porcine and the rabbit model, various techniques of experimental interventions being described in the literature.

Nowadays, it is very important to take into consideration the modern aspects of medicine, combining classical approaches with new options. Genetic testing and biotechnologies open new horizons of which we should take advantage.

Authors' Contributions

MT, DGR and MC contributed to the databases research, analysis and interpretation of data and made substantial contributions to the design of the study. MT, AAM, and MCS performed the literature review. MIT, MC, AAM and VN made substantial contributions to the conception and design of the study. VN and VO supervised the present study and revised the manuscript for important intellectual content. Data authentication is not applicable. All authors have read and approved the final manuscript.

Conflicts of Interest

We have no conflict of interest to disclose.

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