ARCHIVES OF CRANIOFACIAL SURGERY
Arch Craniofac Surg Vol.25 No.4, 179-186
https://doi.org/10.7181/acfs.2024.00444

Original Article

Auricle reconstruction with autologous costal cartilage versus polyethylene implants in microtia patients: a meta-analysis

Yun Jung Kim[1], Kyunghyun Min[1], Young Seok Kim[1], Tai Suk Roh[1], Hyun-Soo Zhang[2], In Sik Yun[1]

[1]*Department of Plastic and Reconstructive Surgery, Gangnam Severance Hospital, Yonsei University College of Medicine, Seoul, Korea*
[2]*Biostatistics Collaboration Unit, Department of Biomedical Systems Informatics, Yonsei University College of Medicine, Seoul, Korea*

Background: Auricle reconstruction is among the most challenging procedures in plastic and reconstructive surgery, and the choice of framework material is a critical decision for both surgeons and patients. This meta-analysis compared the outcomes of autologous auricle reconstruction using costal cartilage with those of alloplastic reconstruction using porous polyethylene implants.
Methods: A literature review was conducted using the PubMed and Embase databases to retrieve articles published between January 2000 and June 2024. The outcomes analyzed included postoperative complications such as framework exposure, infection, skin necrosis, hematoma, and hypertrophic scars, as well as patient satisfaction. The proportions of reconstructive outcomes from each selected study were statistically analyzed using the "metaprop" function in R software.
Results: Fourteen articles met our inclusion criteria. The group undergoing polyethylene implant reconstruction exhibited higher rates of framework exposure, infection, and skin necrosis, whereas the autologous reconstruction group experienced higher rates of hematoma and hypertrophic scars. Of all the complications, framework exposure was the only one to show a statistically significant difference between the two groups ($p<0.0001$). In terms of patient satisfaction, those who underwent autologous cartilage reconstruction reported a higher rate of satisfaction, although this difference did not reach statistical significance in the meta-analysis ($p=0.076$).
Conclusion: There is no statistically significant difference in postoperative complications such as infection, hematoma, skin necrosis, and hypertrophic scars between auricle reconstructions using autologous costal cartilage and those using polyethylene implants. However, reconstructions with polyethylene implants show a significantly higher rate of framework exposure.

Keywords: Congenital microtia / Costal cartilage / Medpor / Patient satisfaction / Polyethylene / Postoperative complications

INTRODUCTION

Auricle reconstruction is among the most challenging procedures in plastic and reconstructive surgery, lacking a universally accepted approach [1]. For the reconstruction to be deemed successful, the reconstructed ear must faithfully replicate the complex anatomical features, which include various convexities and concavities, precise size, symmetrical positioning, and appropriate projection. Moreover, a well-vascularized skin flap is crucial to minimizing postoperative complications.

Over the past 70 years, plastic surgeons have developed several techniques for using rib cartilage in reconstructive frameworks. Notable among these are the four-stage procedures by Tanzer and Brent [2,3], and the two-stage techniques by Nagata and Firmin [4,5]. Although costal cartilage is favored for its du-

Correspondence: In Sik Yun
Department of Plastic and Reconstructive Surgery, Gangnam Severance Hospital, Yonsei University College of Medicine, 211 Eonju-ro, Gangnam-gu, Seoul 06273, Korea
E-mail: eqatom@yuhs.ac

How to cite this article:
Kim YJ, Min K, Kim YS, Roh TS, Zhang HS, Yun IS. Auricle reconstruction with autologous costal cartilage versus polyethylene implants in microtia patients: a meta-analysis. Arch Craniofac Surg 2024;25(4):179-186. https://doi.org/10.7181/acfs.2024.00444

Received July 31, 2024 / Revised July 31, 2024 / Accepted August 17, 2024

www.e-acfs.org
pISSN 2287-1152
eISSN 2287-5603

rability and lower infection rates in the hands of experienced surgeons, it can also cause complications such as chest wall pain and scarring, chest deformities, pneumothorax, and suboptimal aesthetic outcomes, including inadequate projection and cartilage resorption [6-8].

To address these limitations, a porous high-density polyethylene implant (Medpor; Porex Surgical Inc.) has been developed as an alternative to costal cartilage. This implant offers durable, long-lasting structural support and integrates well with surrounding tissues. Since Wellisz et al. [9] first reported its use in auricle reconstruction, subsequent studies by Romo et al., Reinisch et al., Yang et al., and Berghaus et al. have demonstrated successful outcomes with polyethylene implants, despite initial concerns regarding alloplastic materials [9-14]. Unlike rib cartilage, Medpor eliminates the risk of chest wall complications and allows for earlier reconstruction. However, the use of temporoparietal fascial flaps with a polyethylene implant carries a risk of hair loss, and due to its alloplastic nature, it is associated with a higher incidence of extrusion and infection.

Our study aims to evaluate and compare the outcomes and complication rates of autologous auricular reconstruction using costal cartilage versus alloplastic reconstruction using a polyethylene implant. In this meta-analysis, we have defined PICO (population, intervention, comparator, and outcome) as follows: (1) Population: patients with congenital microtia; (2) Intervention: autologous auricular reconstruction using costal cartilage; (3) Comparator: alloplastic reconstruction using a Medpor implant; and (4) Outcomes: implant or cartilage exposure, infection, hematoma, necrosis, and hypertrophic scars.

METHODS

A literature review was conducted using PubMed and Embase to retrieve articles published between January 2000 and June 2024. The search strategy involved a combination of MeSH terms and keywords. Table 1 presents the detailed retrieval strategy for PubMed. An automated filter was applied to restrict the search to English-language articles involving human subjects.

Inclusion and exclusion criteria

This meta-analysis included retrospective and prospective cohort studies, as well as case series. Case reports, letters, commentaries, and opinions were excluded.

The patient population was comprised of individuals born with microtia or anotia. Studies that involved ear reconstruction for acquired deformities or traumatic injuries were excluded to avoid confounding variables. To date, there have been no randomized controlled trials that specifically compare autologous reconstruction to Medpor reconstruction in patients with congenital microtia or anotia.

Table 1. Search strategy used in PubMed

Search	Query
#1	Congenital Microtia[MeSH Terms]
#2	(microtia) OR (anotia)
#3	#1 OR #2
#4	Reconstructive Surgical Procedures[MeSH Terms]
#5	(((reconstructive surgical procedures) OR (reconstructive surgical procedure)) OR (reconstructive surgery)) OR (reconstructive surgeries)
#6	#4 OR #5
#7	((((implant) OR (alloplast)) OR (Medpor)) OR (porous polyethylene)) OR (polyethylene implants)
#8	(autologous) OR (Rib Cartilage) OR (cartilage grafts)
#9	#7 OR #8
#10	#3 AND #6 AND #9

Surgical methods were limited to autologous reconstruction with costal cartilage and ear reconstruction using polyethylene implants. Reconstructions that involved cadaveric costal cartilage, tissue-engineered cartilage, homografts, or prosthetic methods were excluded. Additionally, patients who had previously undergone total ear reconstruction or those undergoing concurrent canaloplasty were excluded to eliminate confounding factors.

Studies that did not address postoperative complications or aesthetic outcomes were also excluded.

Data extraction

Two authors (YJK and ISY) conducted a systematic review, initially examining the titles and abstracts of the studies and excluding those deemed irrelevant. They then performed a full-text review of the remaining articles, excluding any that did not meet the inclusion criteria (Fig. 1). After this selection process, they extracted specific data relevant to the topic from the articles that met the inclusion criteria. Complications were recorded only if explicitly reported and accompanied by the number of affected patients. If a particular complication was not mentioned in the studies, it was not included in the final calculation, rather than assuming an incidence of zero.

Statistical analysis

The summary statistics from 14 selected studies served as data points for the meta-analyses of postoperative complications and patient satisfaction. These studies differed significantly in terms of sample size and the specific complications assessed, which included cartilage or implant exposure, infection, hematoma, skin necrosis, and hypertrophic scars. Given this variability, a

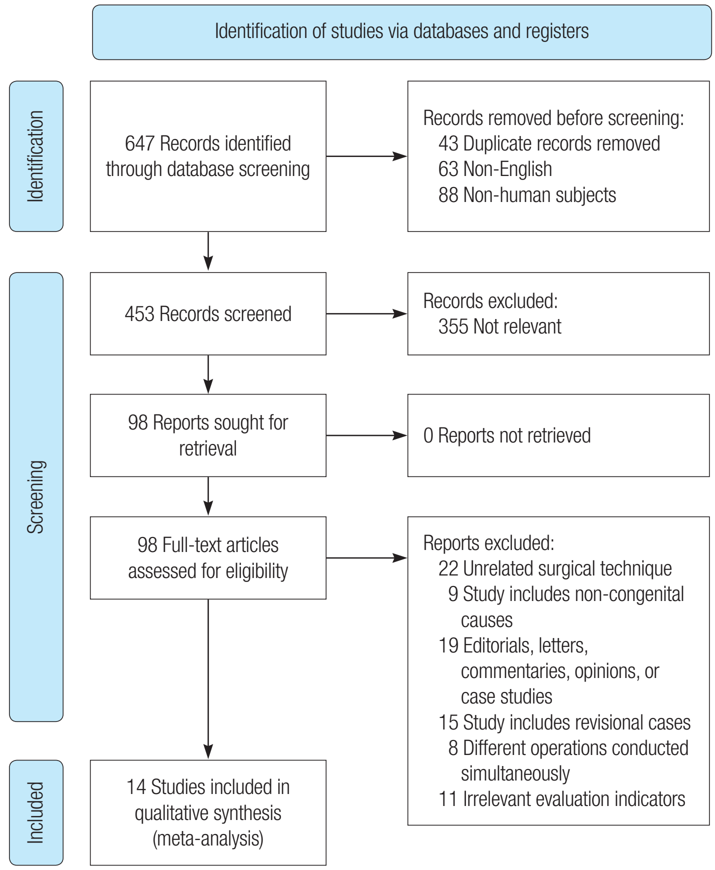

Fig. 1. PRISMA flow diagram.

random effects model was utilized to accommodate differences in sample sizes and to offer a more conservative estimate of the pooled proportions [15].

The inverse variance method was employed to assign appropriate weights to each study, facilitating the calculation of pooled proportions and their corresponding 95% confidence intervals (CIs). The DerSimonian-Laird τ^2 value, along with the I^2 statistic, was used to quantify study heterogeneity [16,17]. Furthermore, the Freeman-Tukey double arcsine transformation was applied to stabilize the variance of extreme proportions and to adjust them to more closely approximate a normal distribution, thereby rendering them suitable for further statistical inference, such as the Z-test under normality [18].

Due to the lack of direct comparative studies on surgical outcomes between autologous and polyethylene implant reconstructions, we pooled the complication rates and patient satisfaction proportions for each method separately. We then employed both the independent two-sample Z-test and the Cochran Q-test on the subgroups of surgical methods to ascertain if there were statistically significant differences in the rates of complications or patient satisfaction between the two reconstruction techniques. Additionally, the Egger test of funnel plot asymmetry was performed to detect potential publication bias in the studies included in our meta-analyses of surgical complications and patient satisfaction outcomes [19].

All statistical tests were two-sided, and *p*-values less than 0.05 were considered statistically significant. The analyses were conducted using R version 4.3.2 (The R Foundation for Statistical Computing). Meta-analyses were performed using the "metaprop" function from the "meta" package in R software.

RESULTS

Literature inclusion

A total of 647 potential studies were initially retrieved for review. After the exclusion of duplicates, non-English articles, and studies not involving human subjects, 453 articles remained. These articles underwent screening based on their titles and abstracts to assess their relevance to the topic, which narrowed the selection to 98 studies. Of these, 14 studies met the inclusion criteria for meta-analysis [8,20-32]. Eight of these studies, encompassing 3,754 cases, focused on auricular reconstruction using autologous costal cartilage. Four studies, covering 118 reconstructions, investigated the use of polyethylene implants.

Table 2. Summary of patient data

Study	Surgical technique	Total cases	Male	Female	Age (yr), mean (range)	Right sided	Left sided	Bilateral
Chen et al. (2017) [21]	Single-stage alloplastic reconstruction with Medpor	6	4	2	7.6 (5–11)	5	1	0
Kludt and Vu (2014) [24]	Three-stage alloplastic reconstruction with TE and Medpor	15	8	7	7 (6–12)	NA	NA	0
Wang et al. (2021) [28]	Three-stage alloplastic reconstruction with TE and Medpor	70	54	14	12 (3–23)	34	32	2
Zhang et al. (2012) [30]	Three-stage alloplastic reconstruction with TE and Medpor	27	18	9	9.2 (5–21)	10	17	0
Fu et al. (2019) [23]	Two-stage modified Natata method or 3- or 4-stage modified Brent method with autologous costal cartilage	470	366	104	12.27 ± 5.01 (6–32)	277	193	0
Li et al. (2018) [25]	Two-stage autologous reconstruction with the modified Nagata method	1,427	797	553	NA	837	436	77
Badawy and Elshahat (2022) [20]	Two-stage autologous reconstruction, utilizing vestigial cartilage	34	21	13	6.8 (5–12)	NA	NA	0
Ma et al. (2018) [26]	Two-stage autologous reconstruction with the modified Nagata method	254	151	92	18.9 ± 10.48 (6–62)	128	104	11
Zhang et al. (2009) [31]	Two-stage autologous reconstruction with a modified combination of the Nagata and Brent methods	362	254	96	NA	199	139	12
Dashan et al. (2008) [22]	Three-stage autologous reconstruction with TE	366	257	85	NA	207	135	12
Xing et al. (2018) [29]	Three-stage autologous reconstruction with TE	738	443	240	9.12 (6–35)	NA	NA	NA
Zhou et al. (2012) [32]	Three-stage autologous reconstruction with TE	103	59	44	21.5 (16–43)	NA	NA	0
Constantine et al. (2014) [8]	Four-stage autologous reconstruction	17	NA	NA	8	NA	NA	NA
	Two-stage alloplastic reconstruction with Medpor	17	NA	NA	6.9	NA	NA	NA
Wang et al. (2021) [27]	Three-stage autologous reconstruction with the modified Nagata method	179	76	74	12.0 ± 2.5 (6–16)	59	62	29
	Three-stage alloplastic reconstruction with TE and Medpor	177	78	72	12.3 ± 2.4 (6–17)	58	65	27

TE, tissue expander; NA, not applicable.

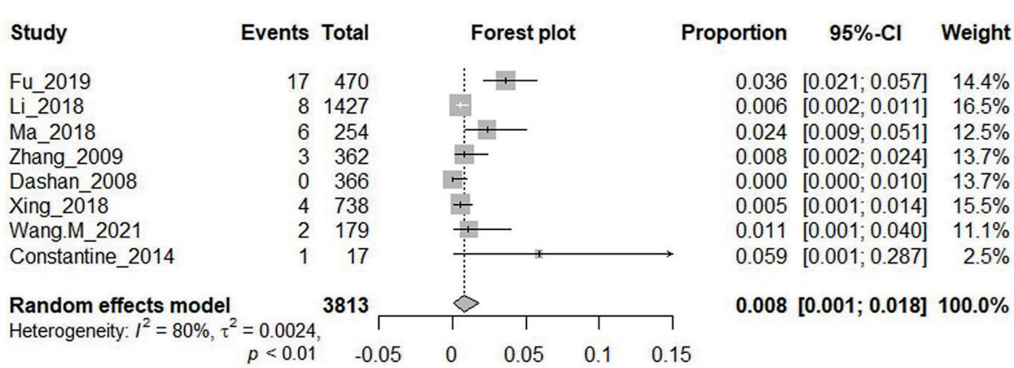

Fig. 2. Meta-analysis of cartilage exposure with auricle reconstruction using autologous costal cartilage. CI, confidence interval.

Two studies directly compared the two methods, involving 196 cases of autologous costal cartilage reconstruction and 194 cases of polyethylene implant reconstruction. The characteristics of participants in each study are detailed in Table 2.

Meta-analysis results

From the 14 selected studies, meta-analyses were conducted on the proportions of five surgical complications: cartilage or implant exposure, infection, hematoma, skin necrosis, and hypertrophic scars, as well as patient satisfaction. The pooled proportions of these outcomes were compared between reconstructions using autologous costal cartilage and those using polyethylene implants.

The proportion of cartilage exposure in autologous reconstruction was 0.008 (95% CI, 0.001–0.018) (Fig. 2), compared to 0.106 (95% CI, 0.070–0.147) for polyethylene implant exposure in alloplastic reconstruction (Fig. 3). The difference in exposure proportions (0.106–0.008 = 0.098) between the two procedures was highly statistically significant, with a p-value of less than 0.0001. This significance was confirmed using either the Z-test under the normality assumption of the Freeman-Tukey transformed proportions or the Cochran Q-test for subgroup differences under a random effects model (Table 3). The infection rate in autologous surgery was 0.004 (95% CI, 0.001–0.009)

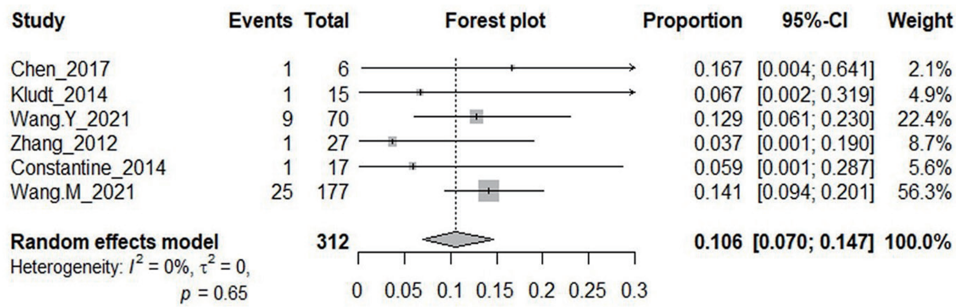

Fig. 3. Meta-analysis of polyethylene implant exposure with auricle reconstruction using Medpor. CI, confidence interval.

Table 3. Meta-analysis results for complications

Complication	Surgical methods	Random-effects model, rate (95% CI)	Pooled proportions (%)	I^2 statistics (%)	*p*-value (Z test)	*p*-value (Cochran)
Framework exposure	Autologous	0.008 (0.001–0.018)	0.8	80.2	< 0.0001	< 0.0001
	Implant	0.106 (0.070–0.147)	10.6	0		
Infection	Autologous	0.004 (0.001–0.009)	0.4	54.8	0.147	0.153
	Implant	0.012 (0.000–0.049)	1.2	42.9		
Hematoma	Autologous	0.043 (0.002–0.124)	4.3	87.1	0.759	0.727
	Implant	0.055 (0.001–0.161)	5.5	57.6		
Skin necrosis	Autologous	0.013 (0.003–0.027)	1.3	87.9	0.829	0.830
	Implant	0.000 (0.000–0.128)	0	NA		
Hypertrophic scar	Autologous	0.046 (0.010–0.105)	4.6	92.9	0.977	0.972
	Implant	0.043 (0.009–0.120)	4.3	NA		

CI, confidence interval; NA, not applicable.

Table 4. Meta-analysis results for satisfaction rate

Surgical methods	Random-effects model, rate (95% CI)	Pooled proportions (%)	I^2 statistics (%)	*p*-value (Z test)	*p*-value (Cochran)
Autologous	0.836 (0.808–0.863)	83.6	68.3	0.076	0.081
Implant	0.763 (0.675–0.842)	76.3	50.9		

CI, confidence interval.

Table 5. Egger test results

Evaluation indicators	Framework exposure	Infection	Hematoma	Necrosis	Hypertrophic scars	Satisfaction rate
Autologous	0.279	0.976	0.284	0.893	0.274	0.331
Implant	0.342	0.365	NA	NA	NA	0.377

NA, not applicable.

compared to 0.012 (95% CI, 0.000–0.049) in polyethylene implant reconstruction, indicating a lower rate of infection for autologous reconstruction, although this difference was not statistically significant. Autologous reconstruction also had a lower proportion of hematoma with a pooled rate of 0.043 (95% CI, 0.002–0.124) compared to 0.055 (95% CI, 0.001–0.161) in polyethylene implant surgery, but this difference was not significant. In contrast, polyethylene implant reconstruction showed slightly lower pooled proportions of skin necrosis and hypertrophic scars compared to autologous surgery, but these differences were also non-significant.

For patient satisfaction rates, the proportion of satisfied patients was 0.836 (95% CI, 0.808–0.863) in autologous reconstruction, compared to 0.763 (95% CI, 0.675–0.842) in polyethylene implant reconstruction (Table 4). Although the Z-test and Q-test *p*-values of 0.076 and 0.081 did not reach statistical significance at the 0.05 level, these relatively low *p*-values ($p < 0.10$) suggest borderline significance, indicating potentially higher satisfaction among those who underwent autologous reconstruction.

Due to the varying sample sizes across the selected studies and the relatively small number of studies focusing on polyethylene implant reconstruction cases, the I^2 statistics for heterogeneity were often high. Consequently, the pooled estimates were calculated using a random effects framework and interpreted with this in mind. Publication bias was assessed using the Egger test for funnel plot asymmetry, as presented in Table 5. Certain specific complications, such as hematoma, skin necrosis, and hypertrophic scars, could not be evaluated due to the limited number of studies on polyethylene implant reconstruction. However, the *p*-values for the other factors analyzed did not suggest any publication bias in the studies included in our meta-analysis.

DISCUSSION

There is no universally accepted treatment for auricle reconstruction that meets all clinical and patient needs, as each method has its own set of advantages and drawbacks. Over the years, ear reconstruction has seen significant advancements, with improvements in surgical techniques and materials to better address the challenges of auricular deformities.

This study aimed to compare the complication rates associated with ear reconstruction using autologous costal cartilage and polyethylene implants. For our meta-analysis, we intentionally selected studies published from the year 2000 onwards. Although Wellisz et al. [9] introduced polyethylene implants for ear reconstruction in 1992, they did not gain widespread acceptance until the mid- to late-1990s due to concerns about alloplastic materials. By the 2000s, significant refinements to polyethylene implants, advancements in surgical techniques, and additional research established Medpor as a viable option in ear reconstruction. Surgeons began to explore combinations of polyethylene implants with other techniques, such as various fascia flaps and tissue expanders, to improve implant coverage and reduce the risk of exposure [13,33,34]. Focusing on studies from 2000 onwards ensures methodological consistency by concentrating on relatively recent surgical techniques, providing more accurate and relevant comparisons across studies.

In categorizing the cases for this study, we focused on the materials used in the initial stage of ear reconstruction, regardless of any additional materials used in subsequent stages. For instance, Zhang et al. [31] employed alloplastic materials such as bone cement in the second stage for ear elevation. In contrast, Ma et al. [26] primarily utilized autologous costal cartilage, occasionally supplementing with Medpor nasal prostheses when the cartilage proved insufficient during the second stage. We categorized these cases under the autologous costal cartilage group if this material was employed in the construction of the initial framework. Given that the initial framework establishes the foundation for the final structural integrity and influences the long-term outcomes of the procedure, we considered it the most critical factor affecting the results and potential complications of the reconstruction process.

The results of our meta-analysis revealed no statistically significant differences in the rates of infection, hematoma, skin necrosis, and scar hypertrophy between reconstructions using autologous costal cartilage and those using Medpor. However, there was a significantly higher rate of framework exposure associated with polyethylene implants ($p < 0.0001$). This outcome supports the existing concerns regarding the exposure risks of foreign materials in reconstructive surgery and underscores the persistent challenge of framework exposure in alloplastic approaches, despite significant advancements in surgical techniques [11].

Analyzing patient satisfaction rates proved challenging due to the absence of standardized measurement tools and the variability in interpreting aesthetic outcomes across different studies. For instance, in a review of ten studies focusing on patient satisfaction, three utilized a four-grade scale (excellent, good, fair, poor), four adopted a three-grade scale (satisfied, acceptable, unsatisfied), and three employed a 2-point scale (satisfied, unsatisfied). For neutral assessments such as "fair" or "acceptable," we adhered to the original authors' classifications, categorizing these as either satisfactory or unsatisfactory. Although the meta-analysis did not show a statistically significant difference between the two groups ($p = 0.076$), there was a noticeable trend of higher satisfaction rates in patients who underwent autologous cartilage reconstruction.

A total of 14 studies involving 4,262 auricular reconstructions were included in this study. Of these, 3,950 cases involved reconstruction using autologous costal cartilage, while 312 cases used polyethylene implants. To our knowledge, this is the first meta-analysis to directly compare the outcomes of these reconstruction techniques specifically in patients with microtia or anotia. However, several limitations should be noted. One primary limitation is the substantial difference in the number of cases between the two surgical methods. This discrepancy likely stems from the broader adoption and longer history of autologous costal cartilage surgeries compared to polyethylene implant reconstructions, which have not yet achieved the same level of widespread clinical application. Although a large imbalance in sample sizes may skew the results in favor of the more extensively studied method, we employed a random effects model to address these complexities, providing more generalizable and realistic estimates, and effectively balancing the influence of studies with varying sample sizes.

Further limitations of this study include: (1) a scarcity of literature directly comparing the two surgical procedures; (2) a shortage of articles addressing hematoma, skin necrosis, and hypertrophic scars, which makes it impossible to determine statistical heterogeneity; and (3) limited racial diversity among the included studies, with 10 originating from China, one from Taiwan, two from the United States, and one from Egypt. This predominance of Eastern populations may restrict the applicability of our findings to Western populations.

In conclusion, meta-analysis reveals that there is no statistically significant difference in postoperative complications such as infection, hematoma, skin necrosis, and hypertrophic scars between auricle reconstruction using autologous costal cartilage and polyethylene implants. However, polyethylene implants were associated with a significantly higher rate of framework exposure. The technical challenges associated with alloplastic materials and implant exposure need ongoing attention and exploration to achieve safer and more reliable reconstruction outcomes.

NOTES

Conflict of interest

No potential conflict of interest relevant to this article was reported.

Funding

None

ORCID

Yun Jung Kim	https://orcid.org/0009-0007-9964-1818
Kyunghyun Min	https://orcid.org/0000-0002-7807-0143
Young Seok Kim	https://orcid.org/0000-0002-0981-2107
Tai Suk Roh	https://orcid.org/0000-0001-8681-159X
Hyun-Soo Zhang	https://orcid.org/0000-0002-4973-9792
In Sik Yun	https://orcid.org/0000-0003-1103-7047

Author contributions

Conceptualization: In Sik Yun. Data curation: Yun Jung Kim. Formal analysis: Yun Jung Kim, Hyun-Soo Zhang. Methodology: Kyunghyun Min. Project administration: Young Seok Kim, Tai Suk Roh, In Sik Yun. Writing - original draft: Yun Jung Kim. Writing - review & editing: Kyunghyun Min, Young Seok Kim. Investigation: Tai Suk Roh. Resources: Yun Jung Kim. Software: Hyun-Soo Zhang. Supervision: In Sik Yun.

REFERENCES

1. Luquetti DV, Heike CL, Hing AV, Cunningham ML, Cox TC. Microtia: epidemiology and genetics. Am J Med Genet A 2012;158A:124-39.
2. Tanzer RC. Total reconstruction of the external ear. Plast Reconstr Surg Transplant Bull 1959;23:1-15.
3. Brent B. Technical advances in ear reconstruction with autogenous rib cartilage grafts: personal experience with 1200 cases. Plast Reconstr Surg 1999;104:319-34.
4. Nagata S. A new method of total reconstruction of the auricle for microtia. Plast Reconstr Surg 1993;92:187-201.
5. Firmin F. Ear reconstruction in cases of typical microtia: personal experience based on 352 microtic ear corrections. Scand J Plast Reconstr Surg Hand Surg 1998;32:35-47.
6. Thomson HG, Kim TY, Ein SH. Residual problems in chest donor sites after microtia reconstruction: a long-term study. Plast Reconstr Surg 1995;95:961-8.
7. Ohara K, Nakamura K, Ohta E. Chest wall deformities and thoracic scoliosis after costal cartilage graft harvesting. Plast Reconstr Surg 1997;99:1030-6.
8. Constantine KK, Gilmore J, Lee K, Leach J. Comparison of microtia reconstruction outcomes using rib cartilage vs porous polyethylene implant. JAMA Facial Plast Surg 2014;16:240-4.
9. Wellisz T, Dougherty W, Gross J. Craniofacial applications for the Medpor porous polyethylene flexblock implant. J Craniofac Surg 1992;3:101-7.
10. Wellisz T. Clinical experience with the Medpor porous polyethylene implant. Aesthetic Plast Surg 1993;17:339-44.
11. Romo T, Presti PM, Yalamanchili HR. Medpor alternative for microtia repair. Facial Plast Surg Clin North Am 2006;14:129-36.
12. Reinisch JF, Lewin S. Ear reconstruction using a porous polyethylene framework and temporoparietal fascia flap. Facial Plast Surg 2009;25:181-9.
13. Yang SL, Zheng JH, Ding Z, Liu QY, Mao GY, Jin YP. Combined fascial flap and expanded skin flap for enveloping Medpor framework in microtia reconstruction. Aesthetic Plast Surg 2009;33:518-22.
14. Berghaus A, Stelter K, Naumann A, Hempel JM. Ear reconstruction with porous polyethylene implants. Adv Otorhinolaryngol 2010;68:53-64.
15. Borenstein M, Hedges LV, Higgins JPT, Rothstein HR. Random-effects model. In: Borenstein M, Hedges LV, Higgins JPT, Rothstein HR, editors. Introduction to meta-analysis. 2nd ed. John Wiley & Sons Ltd; 2009. p. 69-75.
16. DerSimonian R, Laird N. Meta-analysis in clinical trials. Control Clin Trials 1986;7:177-88.
17. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ 2003;327:557-60.
18. Freeman MF, Tukey JW. Transformations related to the angular and the square root. Ann Math Stat 1950;21:607-11.
19. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. BMJ 1997;315:629-34.
20. Badawy MS, Elshahat A. Retroposition of the vestigial cartilage in patients with microtia: a novel technique to enhance projection of the reconstructed ear. J Craniofac Surg 2022;33:1197-200.
21. Chen HY, Ng LS, Chang CS, Lu TC, Chen NH, Chen ZC. Pursuing mirror image reconstruction in unilateral microtia: customizing auricular framework by application of three-dimensional imaging and three-dimensional printing. Plast Reconstr

Surg 2017;139:1433-43.
22. Dashan Y, Haiyue J, Qinghua Y, Bo P, Lin L, Tailing W, et al. Technical innovations in ear reconstruction using a skin expander with autogenous cartilage grafts. J Plast Reconstr Aesthet Surg 2008;61 Suppl 1:S59-69.
23. Fu YY, Li CL, Zhang JL, Zhang TY. Autologous cartilage microtia reconstruction: complications and risk factors. Int J Pediatr Otorhinolaryngol 2019;116:1-6.
24. Kludt NA, Vu H. Auricular reconstruction with prolonged tissue expansion and porous polyethylene implants. Ann Plast Surg 2014;72 Suppl 1:S14-7.
25. Li Q, Zhou X, Wang Y, Qian J, Zhang Q. Auricular reconstruction of congenital microtia by using the modified Nagata method: personal 10-year experience with 1350 cases. J Plast Reconstr Aesthet Surg 2018;71:1462-8.
26. Ma T, Xie F, Zhang Z. Modified 2-stage method for auricular reconstruction. Ann Plast Surg 2018;80:628-33.
27. Wang M, Xiao Z, Huang M, Xie J, Liu G. Clinical effect evaluation and complication analysis of different auricle reconstruction of congenital microtia. Am J Transl Res 2021;13:13878-85.
28. Wang Y, Zhang J, Liang W, Xiao X, Zhang J, Zhang J, et al. Ear reconstruction with the combination of expanded skin flap and Medpor framework: 20 years of experience in a single center. Plast Reconstr Surg 2021;148:850-60.
29. Xing W, Kang C, Wang Y, Zhang Q. Reconstruction of microtia using a single expanded postauricular flap without skin grafting: experience of 683 cases. Plast Reconstr Surg 2018; 142:170-9.
30. Zhang GL, Zhang JM, Liang WQ, Chen YH, Ji CY. Implant double tissue expanders superposingly in mastoid region for total ear reconstruction without skin grafts. Int J Pediatr Otorhinolaryngol 2012;76:1515-9.
31. Zhang Q, Zhang R, Xu F, Jin P, Cao Y. Auricular reconstruction for microtia: personal 6-year experience based on 350 microtia ear reconstructions in China. Plast Reconstr Surg 2009;123: 849-58.
32. Zhou X, Zhang Q, Liu T, Han X, Xie Y, Wang Y, et al. Modification in the technique of ear framework fabrication for congenital microtia. J Craniofac Surg 2012;23:1296-300.
33. Romo T, Reitzen SD. Aesthetic microtia reconstruction with Medpor. Facial Plast Surg 2008;24:120-8.
34. Ali K, Trost JG, Truong TA, Harshbarger RJ. Total ear reconstruction using porous polyethylene. Semin Plast Surg 2017;31: 161-72.