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The utilization of three-dimensional imaging and three-dimensional-printed model in autologous microtia reconstruction

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Background: The use of three-dimensional (3D) technology helps surgeons in performing autologous microtia reconstruction due to more accurate measurements and a better precision template model. However, the technical aspects of using a 3D imaging and 3D-printed model and the difference in outcomes postoperatively remain poorly reviewed.

Purpose: This systematic review aimed to provide the current evidence of the benefit and technical aspects of using 3D technology in autologous microtia reconstruction.

Method: A systematic literature search was conducted across multiple databases: Medline, Embase, Google Scholar, and Central until June 2022. Studies that evaluated the use of 3D imaging or 3D-printed models for autogenous microtia reconstruction were selected. The quality of the included studies was also assessed with respect to the study design.

Result: A systematic literature search yielded 17 articles with a combination of observational and case report studies. Overall, 3D imaging showed a precise measurement for preoperative costal cartilage assessment. Compared to the 2D template, the utilization of a 3D-printed template provided a higher similarity rate relative to the unaffected ear, higher patient and surgeon satisfaction, and lower surgical time. Most 3D templates were fabricated using polylactic acid material on fused deposition modelling printers. The template costs were ranging from $1 to $4.5 depending on the material used.

Conclusion: 3D imaging and 3D-printed templates could improve the outcome of autologous microtia reconstruction. However, the quality of the existing evidence remains low due to the heterogeneity of the reported outcomes. Further studies with more adequate comparability and defined outcomes are still required.

Keywords: 3D imaging, 3D-printed model, autologous, microtia, reconstruction

Introduction

Microtia is a congenital auricular malformation involving the abnormal development of the first and second zygomatic arch and the first sulcus[1,2]. The incidence of microtia varies across regions, ranging from 1 to 10 per 10 000 births, and usually occurs unilaterally[1–4]. The deformed auricle can cause functional problems such as hearing impairment and problems in wearing glasses, and it could significantly impact the self-confidence and quality of life of affected children[5,6]. The management of microtia involves surgical reconstruction with various approaches: autologous ear reconstruction using costal cartilage, ear prostheses using osseointegrated implants, and artificial implants using materials such as porous polyethylene.

Reconstructive options for treating microtia are divided into three categories: (1) autologous costal cartilage framework, (2) porous polyethylene implant as an artificial implant, and (3) prosthetic ear[7]. Autologous auricular reconstruction using costal cartilage remains the most common approach to treating patients with microtia. Cartilage provides better functional outcomes,

HIGHLIGHTS

- Autologous auricular reconstruction is still considered predominant due to relatively fewer complications ,better aesthetical results, and long-term durability. The autogenous nature of costal cartilage provides fewer chances of getting rejection and a better healing process.
- Addressing the three-dimensional (3D) templates could resolve the complexity of microtia reconstruction. The use of a 3D surgical guide could improve the anatomical resemblance between reconstructed and healthy ears.
- Using a 3D-printed surgical guide provides better anatomic resemblance that helps operators to attain higher aesthetical results. Patients who had undergone 3D template-assisted microtia reconstruction rated a higher satisfaction score.

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fewer complications, higher patient satisfaction, and a better quality of life than artificial materials[8,9]. Despite the demonstrated superior results when using autogenous rib cartilage, reconstructing the costal cartilage is challenging. First, surgeons must determine the timing of surgery by considering many factors, primarily the sufficiency of the cartilage. The fabrication of the helical rim plays an integral part in the reconstruction outcome[1,2,10]. In addition, despite the paucity of physical criteria to estimate the volume of the rib cartilage, the anatomical variance among individuals supports the use of patient-specific preoperative anthropometric measurement to determine which rib cartilage to harvest for the reconstruction. Further, surgeons have traditionally used two-dimensional (2D) X-ray films as a template to replicate the unaffected healthy ear. However, the complex anatomical features of the auricle make it difficult to use a 2D template to delineate the depths of some anatomical markings. This issue can be addressed using three-dimensional (3D) templates that display the unaffected ear more accurately[11].

The advancement of 3D technology from 3D imaging to 3D printing has contributed to the improvement of many aspects of surgical practice. First, 3D imaging allows more precise calibration of the measured object. Similarly, modern medicine has used 3D-printing technology to fabricate models for interventional and educational purposes. However, concerns have emerged regarding the details of the manufacturing process and the improvement of outcomes when using 3D technology. So far, these concerns have been poorly addressed. Evidence suggests that a thorough review of the applicability of 3D technology on autologous microtia reconstruction has yet to be completed. Thus, the present study aimed to comprehensively review the current practice of using 3D technology as a preoperative screening and surgical guide, evaluate the presence of outcome improvement, and provide details on manufacturing devices and costs to help medical centres implement this strategy more efficiently.

Methods

This systematic review and meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and Assessing the Methodological Quality of Systematic Reviews (AMSTAR). A detailed protocol has been previously registered in PROSPERO (CRD42022339943).

The population, intervention, comparison, and outcome (PICO) structure was used to define the inclusion and exclusion criteria for the exposure and outcomes. The populations of the included studies comprised patients with congenital microtia and the presence of other craniofacial malformations regardless of age. In addition, the included studies reported the outcomes of using a 3D template with and without comparison to the conventional 2D surgical template. The included studies were limited to those that reported on auricular reconstruction for microtia using an autologous costal cartilage graft.

Articles meeting the inclusion criteria discussed the utility of 3D imaging for preoperative costal cartilage planning through trials and cohort studies, technical notes, case reports, or case series. Reviews, abstract-only articles, pre-prints, and other non-peer-reviewed publications were excluded from the review. Studies that described patients with traumatic auricular malformation were excluded from further analysis; hence, data on congenital microtia patients were reported separately. A language restriction was not applied in the present study. The primary outcomes considered in this study were similar appearance to the contralateral (healthy ear), auricular anthropometric measurements, and patient satisfaction. The secondary outcomes were manufacturing costs and mean surgical time.

A systematic literature search was carried out by two independent investigators across multiple databases: Medline (PubMed interface), Embase, Google Scholar, and the Cochrane Central Register of Controlled Trials (CENTRAL) from database inception to 29 June 2022.

Two of seven authors (TM,FAD) conducted the data extraction independently. More specifically, they extracted information from the included studies to be summarized in a standardized form comprising the author, year of publication, study design, study aims, sample size, patient characteristics, outcome measurement, and main findings. The focus of this study was the use of 3D templates for the preoperative assessment and surgical guidance for microtia reconstruction. Furthermore, data on the manufacturing materials used in each study, total costs, and the reported duration of each surgical template's production were also collected. No third party was involved in case of a dispute; this could belong to the limitations of the study at hand.

The included studies were further assessed for quality and risk of bias concerning the study design. The quality of cohort studies was assessed using the Newcastle Ottawa Scale (NOS). The following aspects were evaluated: cohort selection, comparability of the cohort based on the design or analysis, how exposure was determined, and how outcomes of interest were evaluated[12]. The study used the Joanna Briggs Institute appraisal tool to assess the case reports and technical notes included. Again, refraining from resorting to a third party to resolve disputes could be considered an inherent limitation of the systematic review and meta-analysis at hand.

Results

The initial literature search yielded 552 articles from the combined databases and registries; 114 articles were removed due to duplication, leaving 438 remaining studies to be screened. Of the aforesaid 438 articles, 415 irrelevant studies were removed using automation tools, and the remaining 23 were assessed for eligibility. Eight of those 23 articles were excluded, leaving 15 studies to be analyzed in this systematic review, as seen in[5,6,13–27]. (Fig. 1).

Of the 15 studies included in the present systematic review, 6 were cohort studies, and nine were case series studies involving less than 10 patients (Fig. 2). The studies were grouped based on the study objective and methodology; two studies used 3D imaging to assess the costal cartilage as the graft preoperatively[13–17], and 13 studies used a combination of 3D imaging and 3D printing as a surgical guide[5,6,18–27]. The dates of publication ranged from 1993 to 2021, as seen in (Table 1).

Four studies examined the validity and reliability of 3D imaging and the preoperative assessment of the costal cartilage used for microtia reconstruction[13–16]. The results indicated a significant association between 3D imaging measurements and the intraoperative measurement of the costal cartilage. No significant difference was found in costal length, width, or thickness between the 3D and direct measurements[15]. One study provided a

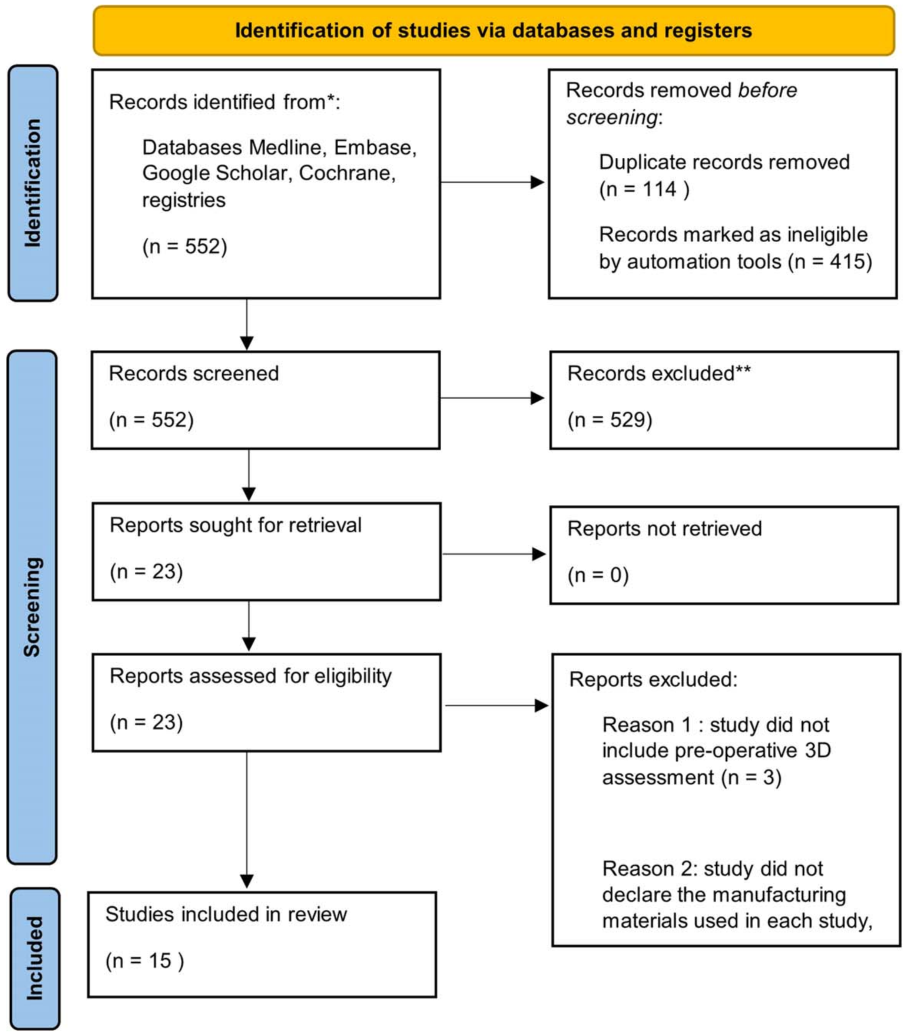

Figure 1. PRISMA chart.

descriptive measurement of the anthropometrical size of the rib cartilage[17]. The overall quality of the non-randomized observational studies indicated a low risk of bias.

One of our primary objectives involved evaluating whether using a 3D surgical guide could improve the anatomical resemblance between reconstructed and healthy ears. Three cohort studies found that the 3D guide provided better precision than the 2D guide. Using the 3D surgical guide led to higher similarity rates of nasal-tragus length and auriculocephalic angle compared to the 2D group (96.5% vs. 90.2%; $P<0.05$ and 88.1% vs. 78.2%; $P<0.05$, respectively)[19].

The use of 3D-printed templates also led to higher precision rates with lower mean errors for auricular length (0.39 ± 0.35 vs. 1.80 ± 1.44 mm; $P<0.001$) and width (0.30 ± 0.47 vs. 1.32 ± 0.88 mm; $P<0.001$) compared to X-ray films[6,27]. Furthermore, three technical notes and a case series demonstrated that the surgeons had noticed that using a 3D guide provided better accuracy[5,24,26]. The quality of the included cohort studies indicated a medium to low risk of bias.

Five studies examined patient satisfaction. In one, 54 out of 60 patients who underwent auricular reconstruction with a 3D template reported being “highly satisfied,” whereas six reported being “satisfied.”[19] In another study, 88% of the 100 patients in the 3D group rated their results as “highly satisfactory,” and 12% rated them as “basically satisfactory.” Their satisfaction levels were found to be higher than the 2D group. A third study assessed patients’ results using the Glasgow Children’s Benefit Inventory (GCBI) questionnaire, and satisfaction levels were found to be significantly higher in the 3D group compared to the 2D group (65.6 ± 13.2 vs. 55.3 ± 16.8; $P<0.05$)[20]. Other studies also reported higher satisfaction with 3D model-guided reconstruction than with the aid of the 2D model and increased confidence among surgeons using the former model compared to those using the latter[5,6,23].

As shown in Table 2, the primary sources of 3D imaging to design the model were computed tomography (CT) scans and stereophotogrammetry. Other sources included the 3D scanner and smartphone scanner app. Fused deposition modelling (FDM) 3D printing was the most commonly used process to mould the 3D model, and some earlier studies used stereolithography (SLA). Most studies used polylactic acid (PLA) as the primary material to fabricate the 3D model. (Table 2).

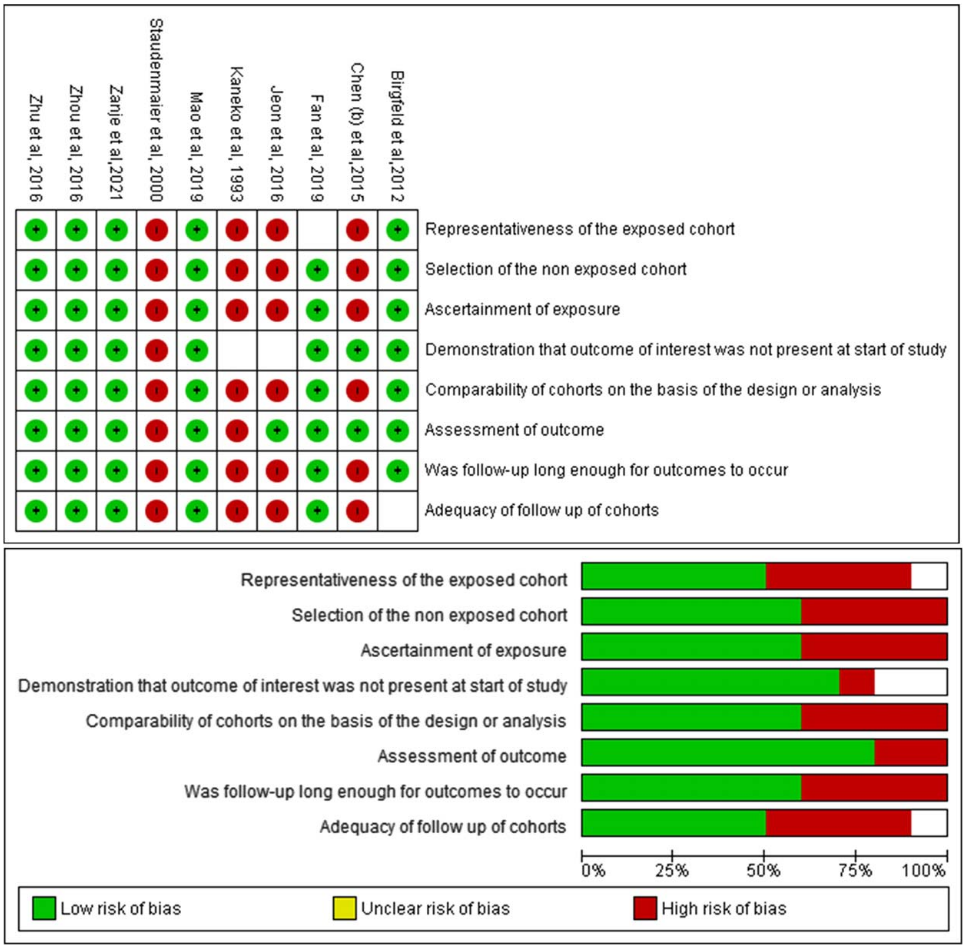

Figure 2. Risk of bias assessment using Newcastle Ottawa Bias Assessment for cohort study.

Material costs in 3D printing vary by the kind of material used. A PLA template costs around $1, whereas the thermoplastic polyurethane 95A (TPU 95A) used in one study costs $4.50[17,24,25]. Two studies reported that the cumulative manufacturing costs—including upfront costs—and technical personnel costs were $210 and $50, respectively[22,26]. As seen in Table 3, the duration of manufacturing an individualized 3D model also varied from 40 minutes to 5 hours, which included pre-processing[27]. (Table 3).

Discussion

Applying 3D-printing advancements to clinical interventions provides patient-specific benefits, especially in otology.

Despite emerging advanced methods, the autologous costal cartilage graft remains the gold standard for auricular reconstruction due to its relatively few complications, better aesthetical results, and long-term durability[28]. The autogenous nature of costal cartilage means fewer chances of rejection and a better healing process. However, this method entails deterrents related to costal cartilage harvesting, such as thoracic wall scars and chest deformities. Furthermore, practitioners continue to debate the timing of reconstruction surgery. Some studies have suggested performing auricular reconstruction before the patient reaches school age to prevent negative psychosocial impacts[29,30]. Other studies have reported a lower rate of chest wall deformity when harvesting is done between the ages of 6 and 12 years (8%) rather than between 2 and 3 years old (33%)[28,29]. The feasibility and outcomes of auricular reconstruction are closely related to the patient's age, which determines the size of the costal cartilage[13]. In addition, the growth of rib cartilage has been found to be variable, especially in the eighth rib[13,17].

The 3D imaging technique provides accurate information that may help surgeons initiate and determine the timing for auricular reconstruction. Using 3D imaging can confirm the rib status by recognizing any abnormalities (e.g. lack of volume) that are more difficult to verify without 3D calibration and may prevent the waste of costal cartilage[14]. Our search identified several studies that reported the benefits of using 3D imaging, mainly CT scan, in determining the adequacy of the rib cartilage used for auricular reconstruction[13–17]. However, the drawback of this approach comes from the additional cost that may burden patients who require surgical reconstruction.

Three-dimensional printing technology has evolved significantly to the extent that it has been used in various surgical procedures, including microtia reconstruction. It has also been used as a tactical replica and training model in various medical fields[18,21]. In microtia, autologous reconstruction using rib

Table 1

Characteristics of included studies

Author, year	Study design	Aim/purpose	No. patients with microtia	Patient characteristics	Outcome measurement	Main findings
Preoperative assessment of the costal cartilage						
Mao *et al.*, 2019[15]	Prospective cohort	To investigate the validity and reliability of anthropometri c analysis of the costal cartilage using 3D imaging	22	Unspecified microtia	Mean error	No significant difference was found on the length, width, and thickness of the 3D anthropometry compared to direct measurement. There was a underestimation of the volume in 3D assessment (calculation error $= -0.08 \pm 0.13$ ml)
Zanje *et al.*,2021[17]	Retrospective cohort	To investigate the utility of 3D CT rib study in surgical planning of auricular reconstruction	35	Unspecified microtia	Descriptive measurement of the length, height, and width of the 6th, 7th, 8th, and 9th rib	The average width of synchondrosis of 6th and 7th rib was 15.4 mm on right side and 14.7 mm on left side, average height of synchondrosis was 28.5 mm on right side and 30.7 mm on left side. Average length of the 8th rib costal cartilage was 88.6 mm on the right side and 90.5 mm on the left side Average length of the 9th rib was 63.2 mm on the right side and 58.2 mm on the left side
Surgical guide						
Alhazmi *et al.*, 2021[18]	Technical notes	To describe a technique to fabricate a multiscale sterilizable 3D-printed auricular templates	1	Unspecified microtia	Technical and production cost outcomes	The authors noted that the use of 3D-printing technology provides better accuracy in time efficient manner and can be used to produce more scalable templates with an average printing time of 35 min and the total additional cost of 4.5 US Dollars
Chen (a) *et al.*, 2015[19]	Technical notes	To describe a technique to fabricate a new 3D template for fabrication and localization of auricular reconstruction	60	Unilateral microtia	Mean surgical time Patient's satisfaction score	The use of 3D guide yielded in the reduction of mean surgical time of 30 min 90% of patients reported 'highly satisfied' with the results, while 10% reported 'satisfied'
Chen (b) *et al.*, 2017[20]	Case series	To compare the precision of 3D stereophotogrammetry with direct anthropometry	3	Unspecified microtia	Ear length and width Conchal length, width, and depth Lobule length and width Intertragal distance Upper, middle, and lower 3rd projections Helix to antihelix size Lobr posterior to antitragus size	Compared to direct measurement, significant differences were found in the mean of ear length, conchal length and depth, intertragal distance, upper 3rd projection, middle 3rd projection, lower 3rd projection, helix to antihelix length, and lobe posterior to antitragus length
Fan *et al.*, 2019[21]	Retrospective cohort	To explore the advantages of using 3D template over the traditional 2D template for auricle reconstruction	200	Unilateral microtia	Mean surgical time Similarity rate Patient's satisfaction score Quality of life after surgery	3D group had a significantly shorter surgical time Similarity rates of nasal-tragus length and auriculocephalic angle were found higher in 3D group Patient's satisfaction rate based on GCBI questionnaire was found higher in 3D group
Flores *et al.*,2017[22]	Technical notes	To provide a methodology to fabricate patient- specific 3D templates for auricular reconstruction	1	Unilateral microtia	Technical notes Production cost	The authors noted that using 3D-printed patient-specific model with the given technique provides a lower production cost compared to using commercially manufactured 3D ear model The material cost of the technique was approximately 1 US Dollars, and the total working cost for technicians was 500 US Dollars
Jeon *et al.*, 2016[5]	Case series	To compare the feasibility of using 3D template when compared to 2D template	7	Unspecified microtia	Percentage of difference Postoperative complications	The percentage of difference of 3D template was lower than 2D template when compared to casted patient's normal

						earOne patients had skin necrosis on the antihelix and another one had skin irritation caused by pouring resin Surgeon reported using 3D guide reduced surgical time and increased surgeon's confidence
Kaneko *et al.*, 1993[23]	Case series	To provide an approach of the auricular reconstruction using 3D shape measurement system	7	Unilateral microtia	Technical notes Satisfaction score Postoperative complication	The authors felt that the application of 3D guide and measurement was deemed as useful and worth to be explored further Five cases were graded as excellent, and one each was good and fair There were two cases of exposed tissue expander
Staudenmaier *et al.*, 2000[24]	Case report	To describe the technique and the potential of using stereolithographic model for auricular reconstruction	1	Unilateral microtia	Technical notes	The authors noted that the use of stereolithographic model can aid surgeons in planning for auricular reconstruction given a more tangible perspective from the model
Witek *et al.*, 2016[25]	Technical notes	To provide a methodology to fabricate patient- specific 3D templates for auricular reconstruction	1	Unilateral microtia	Technical notes Production cost	The time required for digital preparation of 3D-printed model was 5 hours with manufacturing cost of 0.78 US Dollars
You *et al.*, 2021[26]	Technical notes	To describe the workflow for the fabrication of patient- specific 3D-printed ear model using smartphone	1	Unilateral microtia	Technical notes Total manufacturing time Production cost	The authors noted using 3D model is helpful as an intraoperative reference in adjunct to the traditional 2D template The total time for imaging acquisition, editing, and fabrication was approximately3.5 h The upfront cost was around 210 US Dollars and the recurring cost was approximately 0.35 US Dollars per ear model
Zhu *et al.*, 2016[6]	Retrospective cohort	To describe a method to create an anatomical 3D model for microtia reconstruction and to evaluate the parent's satisfaction with the final results	40	Unilateral microtia	Technical notes Comparison of physicians' scores and patients' satisfaction scores between 3D group and 2D group	The authors noted a high anatomical resemblance in 3D-printed template relative to the healthy auricle The precision and accuracy of the 3D-printed model was found significantly higher based on physicians' score compared to 2D template Patients' satisfaction scores were also found higher compared to control group
Zhou *et al.*, 2016[27]	Cohort	To compare the use of 3D framework and the fabrication method for auricular reconstruction	40	Unilateral microtia	Mean surgical time Mean errors for length and width Postoperative appearance evaluation from doctors and patients	Mean surgical time was reduced by 15 min when using 3D-printed template compared to conventional 2D template Mean errors for length and width in 3D-printed guide group was significantly lower compared to conventional 2D template
Assessment of craniofacial features and prior history of surgery						
Birgfeld *et al.*, 2012	Retrospective cohort	Comparing the ease and similarity of phenotypic assessment of the craniofacial features in patients with CFM	11	50 Patients who were diagnosed of CFM, microtia (n = 11), hemifacial microsomia, or Goldenhar syndrome	Image quality ratings Interrater reliability for identification of surgery	The quality of image for assessing craniofacial features was found higher in 2D images based on Likert Scale Score. Identification of prior surgeries was found more reliable with 3D images

2D, two dimensional; 3D, three dimensional; CT, computed tomography.

Table 2

Summary of manufacturing specifications used by the included studies

Study	Methods of images and templates acquisitions			
	2D	**3D data source**	**3D printer**	**Material**
Alhazmi *et al.*, 2021[18]	NA	NR	Ultimaker 2 + , FDM	TPU 95A
Birgfeld *et al.,* 2012	12MP digital camera (Fujifilm S2 Pro, Fujifilm)	Stereophotogrammetry (3DMD)	NA	NA
Chen (a) *et al.,* 2015	NR	Computed tomography (Sensation 16, Siemens Medical Systems)	Quick450 (Xi'an Jiaotong University)	NA
Chen (b) *et al.*, 2015	NA	Stereophotogrammetry (3DMD)	NR	Resin
Fan *et al.*, 2019[21]	X-ray	Computed tomography (SOMATOM Force, Siemens Healthcare)	SPS600 Shanxi Hengtong	NR
Flores *et al.*, 2017[22]	NA	Stereophotogrammetry (3DMD)	Builder premium 3D printer, FDM	Polylactic acid (PLA)
Jeon *et al.*, 2016[5]	X-ray	3D laser scanner	Edison 3D printer, FDM	NR
Kaneko *et al.*, 1993[23]	NA	VOXELAN system (consists of laser beam generator, two rotating mirrors, charge- coupled device (CCD) camera and an image encoder, a personal computer, and a video monitor)	CAMM-3 Computer controlled milling machine (Roland)	Wax
Mao *et al.*, 2019[15]	NA	Computed tomography (Brilliance 64, Phillips Healthcare)	NA	NA
Staudenmaier *et al.*, 2000[24]	X-ray	Computed tomography	Stereolithography	UV-sensitive polymerizable resin
Witek *et al.*, 2016[25]	NA	Stereophotogrammetry (3DMD)	Builder premium 3D printer, FDM	Polylactic acid (PLA)
You *et al.,* 2021[26]	NA	Smartphone (iPhone XS, Apple) + Heges 3D Scanner app	Monoprice Select Mini V2 (Monoprice, Inc)	Polylactic acid (PLA)
Zanje *et al.*, 2021[17]	Plastic film	High-resolution computed tomography (HRCT)	NA	NA
Zhu *et al.*, 2016[6]	X-ray	3D scanner	FDM20-2525, FDM	Acrylonitrile Butadiene Styren (ABS)
Zhou *et al.*, 2016[27]	X-ray	3D scanner (Arctec Spider, Arctec Group)	MakerBot Replicator 2 (MakerBot Industries), FDM	Polylactic acid (PLA)

2D, two dimensional; 3D, three dimensional; NA, not applicable; NR, not reported.

cartilage remains the current standard of care. However, carving rib cartilage is technically challenging. The current practice still relies on drawing from 2D templates taken from the healthy ear. Usually, surgeons must check the 2D template and estimate the depth of a particular structure[5].

By contrast, 3D-printing technology enables surgeons to obtain sufficient anatomical details of the healthy auricle. Stereo information from a template rendered from 3D imaging helps surgeons copy the depth and locations of the concha and fossa of the auricle[5,21,22,25]. During the second phase of surgery, the 3D template provides a better reference for the size and auriculocephalic angle[19]. Owing to the additional anatomical details it offers, the use of a 3D-printed surgical guide was noted to increase the surgeon's confidence in microtia reconstruction[5]. In addition, some studies indicated that using a 3D-printed model reduced overall surgical time, mainly because of the reduced time spent carving the costal cartilage using a 3D template compared to X-ray imaging[18,19,21,27].

Superceding the above-delineated technical improvements experienced by the surgeons, patient satisfaction is the most important indicator of whether using a 3D-printed surgical guide provides an actual benefit. Five studies assessed patient satisfaction with the results[6,19,21,23,27]. Overall, patients who had undergone 3D template-assisted microtia reconstruction gave a higher satisfaction score based on the closer anatomical resemblance. This was due to the closer anatomic resemblance of the 3D template, which helped operators attain better aesthetic results. However, various shortcomings may impact the establishment of best-practice recommendations. First, the available studies had limited comparability, and the reported clinical outcome was lacking. Of the included studies, three compared a 3D template with a 2D template, and the former showed better similarity rates, lower surgical

Table 3

Summary of manufacturing costs and durations

Study	Material cost	Cumulative manufacturing costs	Manufacturing hours per unit (Hours: Minute)
Alhazmi *et al.*, 2021[18]	$4.5	NR	00:35
Flores *et al.*, 2017[22]	$1	$50 (Including technical personnel)	04:00
Kaneko *et al.*, 1993[23]	NR	NR	00:10 (Only for the shape measurements on both ears)
Witek *et al.*, 2016[25]	$0.78	NR	05:00 (Includes pre-processing)
You *et al.*, 2021[26]	$0.35	$210 (Upfront cost)	03:30
Zhou *et al.*, 2016[27]	NR	NR	00:20–01:00

NR, not reported.

time, and higher patient satisfaction[5,21,27]. Secondly, only a few studies assessed patient satisfaction systematically using a well-defined questionnaire[6,21,27]. This tool plays an integral part in evaluating the quality improvement of an intervention[31].

The precision features of the 3D template depend on the 3D imaging modalities and the printing device. Most studies used CT imaging to acquire data on the auricular deep structures. Although MRI has better features on soft tissue contrasts, CT imaging offers a better depiction with a minimal resolution tolerable for auricular reconstruction planning of 1.0 mm[32,33]. For younger patients unable to sit still, the model fabrication could be achieved by moulding and casting an ear model using wax[5].

A 3D-printing device has a myriad of applications as it enables the mass reproduction of printed items. However, the production costs depend highly on the printing device and material used to fabricate the model. The printing devices used varied among the included studies. Most studies used FDM 3D printing, while earlier studies used SLA[24]. FDM printers have a better printing process as they only heat the polymer filament to a semi-solid state and deposit it on the printing bed. They are also more widely available and more affordable than SLA printers[34]. Regarding the material, most of the included studies used PLA for the model. PLA provides better precision at a lower cost[22,25,26].

Some studies reported the total time spent on model production[18,22,23,25–27]. However, they did not always clearly specify the manufacturing time. The printing time varied from 40 min to 4 h, whereas the total production time, including image acquisition, was 3.5–5 h. This systematic review involved several shortcomings, including the lack of comparability of the included studies. Regarding the quality of the reviewed studies, the overall quality of the included case reports was impeded by the rarity of microtia. Although the included observational studies had a medium to low risk of bias overall, most studies that compared 3D and 2D templates had distinct outcome measurements. Utilizing 3D imaging and 3D-printed models for autogenous microtia reconstruction is a work in progress. Therefore, further studies to evaluate the advantages of using a 3D template compared to the traditionally used 2D template in microtia reconstruction should feature a larger sample size, adequate comparability, and reported clinical outcomes.

Conclusion

In microtia, autologous reconstruction using rib cartilage remains the current standard. However, it continues to rely largely on drawings from 2D templates taken from the healthy ear and carving rib cartilage as a challenging process.

Thanks to more recent technological developments, it appears that 3D-printing technology will help surgeons imitate the concha's depth and provide a better reference for the auriculocephalic angle during the second phase of surgery. Using a 3D-printed surgical guide will reduce overall surgical time and help attain better aesthetical results. It will result in higher patient satisfaction. 3D-printing technology has the potential to enhance the precision and outcomes of microtia reconstruction. However, it is very important to carefully evaluate its cost-effectiveness and consider the benefits to both patients and surgeons. As technology advances, the use of 3D templates in medical applications such as microtia reconstruction may become more widespread and accessible.

Ethical approval

This systematic review had been approved by The Ethics Committee of the Faculty of Medicine, University of Indonesia with protocol number 22-03-0278 on 14 March 2022.

Consent

Written informed consent was obtained from the patients for publication and any accompanying images.

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Author contribution

T.K.: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, supervision, validation, writing—original draft , and writing—review and editing. F.A.D.: conceptualization, data curation, formal analysis, funding acquisition, investigation, methodology, supervision, validation, writing—original draft , and writing—review and editing. M.H.R.: supervision, validation, writing—review and editing. E.D.S.: methodology, supervision, validation. R.A.A.: validation, writing— review and editing Dini. W.W.: validation, writing—review and editing. D.J.D.: writing—review and editing.

Conflicts of interest disclosure

The author declares no conflicts of interest.

Research registration unique identifying number (UIN)

Protocol of this systematic review has been registered to PROSPERO with ID CRD42022339943 Available in: https://www.crd.york.ac.uk/PROSPERO/display_record.php?RecordID=339943.

Guarantor

Trimartani Koento.

Data availability statement

Data for this systematic review are available.

Provenance and peer review

The authors declared this paper was not in publication or peer-review in other journal.

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