Chin Augmentation Techniques: A Systematic Review

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Abstract:	Introduction: Chin augmentation has over the past decades maintained a high level of popularity among patients and facial plastic surgeons. Several procedures exist to enhance the appearance of a small chin. The aim of this study was to perform a systematic literature review to determine outcomes and complications associated to the different techniques described. Material and Methods: MEDLINE®, PubMed, PubMed Central (PMC) and Cochrane Central Registry of Controlled Trials (CENTRAL) database were screened using a search algorithm. The techniques were classified and related outcomes and complications tabulated and analyzed. Results: 54 studies on primary chin augmentation published from 1977 to 2020 met inclusion criteria, representing 4897 treated patients. Six main surgical techniques were identified: chin augmentation with implants (Silicone, Gore-Tex, Mersilene, Prolene, Medpor, Proplast, Hard Tissue Replacement (HTR), Porous Block Hydroxylapatite (PBHA), and Acrylic; n=3344); osteotomy (n = 885), autologous grafts (fat/bone/derma/cartilage; n = 398), fillers (hyaluronic acid, hydroxyapatite, biphasic polymer; n= 233), and local tissue rearrangements (n= 32), combination of implants placement and osteotomy (n= 5). All techniques provided consistently satisfactory cosmetic outcomes. The overall complication rate of the most represented groups was 15.7% for implants and 19.7% for osteotomy, including 2.4% and 16.4% cases of transient mental nerve related injuries respectively. Conclusions : All described chin augmentation techniques achieved good outcomes with high patient satisfaction. Perfect knowledge of each technique is essential to minimize each procedure's specific complications. Caution is generally needed to avoid nerve injuries and potential over- or under-correction.
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What should be the general public's take away from your research?	
Do you feel the manuscript qualifies as an outcomes study?	Yes
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Chin Augmentation Techniques: A Systematic Review

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Abstract

Introduction: Chin augmentation has over the past decades maintained a high level of popularity among patients and facial plastic surgeons. Several procedures exist to enhance the appearance of a small chin. The aim of this study was to perform a systematic literature review to determine outcomes and complications associated to the different techniques described.

Material and Methods: MEDLINE®, PubMed, PubMed Central (PMC) and Cochrane Central Registry of Controlled Trials (CENTRAL) database were screened using a search algorithm. The techniques were classified and related outcomes and complications tabulated and analyzed.

Results: 54 studies on primary chin augmentation published from 1977 to 2020 met inclusion criteria, representing 4897 treated patients. Six main surgical techniques were identified: chin augmentation with implants (Silicone, Gore-Tex, Mersilene, Prolene, Medpor, Proplast, Hard Tissue Replacement (HTR), Porous Block Hydroxylapatite (PBHA), and Acrylic; n=3344); osteotomy (n = 885), autologous grafts (fat/bone/derma/cartilage; n = 398), fillers (hyaluronic acid, hydroxyapatite, biphasic polymer; n= 233), and local tissue rearrangements (n= 32), combination of implants placement and osteotomy (n= 5). All techniques provided consistently satisfactory cosmetic outcomes. The overall complication rate of the most represented groups was 15.7% for implants and 19.7% for osteotomy, including 2.4% and 16.4% cases of transient mental nerve related injuries respectively.

Conclusions: All described chin augmentation techniques achieved good outcomes with high patient satisfaction. Perfect knowledge of each technique is essential to minimize each procedure's specific complications. Caution is generally needed to avoid nerve injuries and potential over- or under-correction.

Chin augmentation has persistently been a popular procedure over the past decades. According to the American Society of Plastic Surgeons, approximately 16’500 procedures were performed in 2019.[1]

The first description of chin augmentation was reported in 1928 by Aufricht[2], who used the osteocartilaginous hump obtained from a combined rhinoplasty. In 1942, Hofer[3] introduced horizontal osteotomy performed through an external incision. Later, Trauner and Obwegeser[4] described an intraoral approach. The use of alloplastic materials (Silicone) as implantable material for chin augmentation was first reported in the early 1950s by Brown et al.[5] Osteotomies and implant augmentations became the most used techniques. In recent years, noninvasive procedures including injectable fillers have gained popularity becoming largely used. Additionally, the interest and use of autologous grafts, especially fat, has grown.

An accurate facial analysis including precise assessment of overall balance of facial relationship is essential to establish correct indications for chin augmentation. Gonzalez-Ulloa highlighted the relevance of the chin, beside basic facial architecture, as a critical element of facial proportion, harmony and balance.[6] Treatment of chin disproportions enhances facial harmony, often improving the appearance of surrounding anatomical landmarks such as nose, mouth and lips.[7]
Despite the vast amount of publications on this topic, there is a lack of data on the overall complication and satisfaction rates associated with each technique. The aim of this systematic review was to summarize notions on various techniques and review outcomes and complications.

Materials and Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed to perform a systematic literature review[8]. The search was conducted using MEDLINE®, PubMed, PubMed Central (PMC) and Cochrane Central Registry of Controlled Trials (CENTRAL) to identify relevant articles on chin augmentation techniques. Both medical subject heading (MeSH) terms and free-text terms were combined to construct the following search algorithm: (“chin augmentation” or “genioplasty” or “mentoplasty”) AND (“augmentation” or “reconstruction” or “genioplasty/methods”). The reference lists of included studies were manually cross-referenced to retrieve additional articles eligible for inclusion. English and not-English literature were analyzed regardless of publication date. Inclusion criteria consisted of the following: (1) original clinical studies including case studies, case reports, case series, retrospective studies, prospective studies, clinical trials; (2) chin augmentation performed either as surgical or non-surgical method. Exclusion criteria were: (1) literature reviews and letters; (2) unclear presentation of specific chin augmentation technique (3) unclear report of outcomes and complications; (4) studies describing revision surgery. If the duration and the sources of study population recruitment overlapped in two or more articles by same authors, only the most recent study with larger number of cases was included.

The analysis was independently conducted by two investigators (V.G. and C.M.O.) who extracted and tabulated the following data form the papers according to pre-defined criteria: author name, date of publication, country of origin, number of patients, age of patients, surgical technique, outcomes, and complications. A third reviewer (D.F.K.) was involved in case of discrepancies. Papers were considered to be of good quality in case of representative study sample, comparison performed on comparable groups at baseline, randomization, credible tools for data collection,

limited attrition rate. Results and discussion will separately consider each identified procedure.

Results

After screening 511 citations, 22 duplicates were removed while 374 were excluded after examination of title or abstract, leaving 115 articles for full-text review. Fifty-four papers fully satisfied a priori criteria and were finally included for systematic analysis (figure 1). Between 1977 and 2020, a total of 4'897 patients with age ranging between 12 and 76 years were treated. The gender was not always specified. However, of the declared ones, the majority were female. We identified 36 retrospective studies, nine prospective studies, seven case series, and two case reports. Articles comparing different techniques were also represented.

Six techniques were identified: implant augmentation (n=3'344), osteotomy (n=885), autologous grafts (n=398), fillers (n=233), local tissue rearrangement (n=32) and implants/osteotomy (n=5). Implant augmentation was by far the most frequent technique. Four articles compared different techniques, allocated in different groups. Quantitative analysis was prevented by the inhomogeneity of methods of assessing satisfaction outcomes. However, high patient and surgeon satisfaction was reported by all papers who investigated this aspect. A possible bias could be represented by the tendency of authors to present favorable outcomes to promote their preferred techniques. Details are reported in Table 1.

Implant-based chin augmentation

We found 28 articles on implant-based chin augmentation[9–36], which employed the following materials: Silicone (n = 1693), Mersilene mesh (n = 541), Gore-Tex (n = 390), Medpore (n = 308), Prolene mesh (n = 192), as well as following materials no

longer in use: Proplast I/II (n = 123), HTR (hard tissue replacement) (n = 55), PBHA (porous block hydroxylapatite) (n = 12) and Acylic (n = 11). In 20 cases the material was not clearly indicated. The implant was placed through an intraoral incision in 21 studies (n = 2377) and using a submental approach in 11 studies (n = 967). Four of these articles used both techniques and compared them.

The procedure presented an overall complication rate of 15.7% (major 3.0%; intermediate 1.6%; minor 11%). The most common complication was alveolar ridge resorption (6.9%), followed by nerve related problems (2.4%). Secondary procedures were required in 2.2% of the cases, with either exchange or removal of the implant. All complications are listed in table 2.

The outcome was reported as positive, with improvement of the original appearance and/or satisfaction reaching the overall rate of 96.4%.

Osteotomy

In osteotomy-based chin augmentation[12,22,29,37–42] authors reported improvement of pre-operative condition in 97.1% of cases. The overall complication rate was 19.7% (major 0.9%; intermediate 1.9%; minor 16.8%), with mental neuropraxia reported as the most common complication (16.4%). However, this was in most cases temporary. All osteotomy complications are listed in table 3.

Autologous grafts

Autologous grafts included fat, bone, skin or cartilage (costal, conchal or nasal), described in 10 different papers[43–52]. The overall complication in this group was 16.3% (table 4), with resorption of the bone graft being the most common complication (8.5%). In the 2009' retrospective review of Tang et al.[48], 73.9% of the

bone grafts from the mandibular angle were partially or completely resorbed, showing the clear disadvantage of this technique.

Fillers

As a non-surgical technique, filler injection was performed using hyaluronic acid (HA)[29,53,54], hydroxyapatite[55] or biphasic polymer[56]. The complication rate was high (31.7%). However, complications assessed by the investigators were classified as minor or intermediate. The most common complication was erythema (20.6%), while filler specific complications were: occurring nodules (5.6%) and contour irregularities (0.4%). The nodules (n = 13), approximately 2mm in size, appeared after HA infiltration and were treated with hyaluronidase (table 5)[29].

Local tissue rearrangement

Chin augmentation with tissue rearrangement included the following procedures: mentalis muscle tightening[57] and subcutaneous gliding mentoplasty.[58]. This group consisted of only 32 patients in two different studies. In both articles the outcome of the procedure was described as successful with increased chin projection in 100% of the cases. The overall complications were low (6.3 %), consisting of 2 patients with contour irregularities detected postoperatively and which resolved spontaneously without secondary surgery (table 6).

Implant/osteotomy combination

The combination of implant augmentation and osteotomy was reported only in three studies on five patients [59–61]. Four of these patients exhibited severe chin hypoplasia, where implant augmentation or osteotomy alone would not have corrected the

deformity. The overall complication rate was very high (table 7), with all studies presenting complications.

Discussion

Appropriate management of aesthetic chin deformities contributes to facial harmony and improves overall facial appearance. A comprehensive knowledge of possible corrective options is required to recognize indications and best treat different aesthetic issues. Although recent reviews have been published on various techniques of chin augmentation[62,63], our work represents the first systematic review on the subject, rendering an overview of the evolution in chin augmentation, including historic as well as current surgical and non-surgical techniques. With our inclusion criteria, we selected 54 articles, representing 4'897 patients. We primarily focused on classifying the different techniques and describing advantages and disadvantages, placing our key focus on the two main groups of permanent correction of a deficient chin: implant augmentation and osteotomy. In order to create a complete overview, English and non-English literature was examined, regardless publication date, and overall complication and satisfaction rates of each technique was determined. Of the included citations, the majority were retrospective studies, with a maximum level of evidence of III. There are no prospective randomized controlled studies on this topic.

Implant-based chin augmentation

Chin augmentation with implants is the most studied technique, with 3'344 described cases. This technique is extremely beneficial in terms of cost, operating time and aesthetic outcome, and has withheld its popularity over time.[62]

There is a variety of materials available as implants, manufactured in different sizes and shapes, to be used ready-made or further customized intraoperatively.

Silicone is an inert material, relatively non-reactive[18], which can be removed without major tissue damage[10]. However, its use has been associated with bone resorption due to the elastic force exerted on the implant and consequently on the underlying bone by overlying muscle activity, especially when placed subperiosteally.[62,64] Overall bone resorption in the implant augmentation group was 6.9%, seen on lateral radiograms without reaching clinical significance, representing the most common complication. A high placement of the implant over alveolar bone seems to cause more bone loss than placement over lower mandible, and may lead to erosion of dental roots.[65,66]

The risk of implant migration or displacement is reduced by the large-porous structure of Medpor which permits more rapid tissue ingrowth compared to Silastic.[61] However, due to its lower pliability, it does not contour well against the mandible, requiring genial tubercules or mental protuberance removal before implant insertion, in order to reduce potential gaps.[32]

Two incisional approaches are described: submental and intraoral. A comparative study between the two approaches observed no significant difference in terms of infection rate.[20] The overall rate in our review was 1.1% for the intraoral (n=2377), and 0.5% for the submental (n=967) approach. Submental incisions are favored when simultaneous submental surgery is undertaken or intraoral pathologies exist. The intraoral approach may be preferred to avoid external scars.[10], however bears the possible disadvantage of a less precise implant placement[67] and a higher risk of implant migration.[62] Furthermore, a failure to adequately reapproximate the mentalis muscle with this approach, can lead to undesirable lip ptosis and lower incisor show.[68]

Three dissection planes for implant positioning are described, defined in relation to the periosteum: subperiostal, supraperiostal, and dual plane. In recent years most

authors choose the subperiosteal placement (n = 1682), with prudent pocket dissection to limit implant mobility and ensure stability with adequate soft tissue coverage.[10] Further immobilization of the implant can be achieved with screws to limit displacement and prevention of gaps between implant and mandible.[69] In our review, the overall malposition rate for implant group was very low (0.8%), regardless of plane or incisional approach chosen.

An overaugmentation or underaugmentation occurred in 1.3% within the implant group, resulting in patient's dissatisfaction. The combination of a too large implant and a deep B point will create an acute labiomental angle[70] and a massive appearing chin.

Osteotomy

Chin augmentation through osteotomy is a versatile procedure which permits mobilization of the mobile symphyseal segment in all dimensions and therefore can correct multiple chin deformities[71]. For instance, the height of the chin can be controlled by the direction of osteotomy lines: parallel to occlusal plane to heighten the chin, parallel to the Frankfort horizontal line to leave chin height untouched, and an obliquely to shorten the chin.[71] It is a more invasive technique than implant augmentation, and plastic surgeons do not always feel comfortable with the procedure.[72]

Protection of mental foramen and inferior alveolar neurovascular bundle are essential. The foramen must always be visualized and incisions made at least 6 mm below, as the nerve inside the terminal canal lies inferior to the exit point and loops anteriorly.[73]

A possible disadvantage is the frequent need for general anesthesia. Although it can be performed in local anesthesia with intravenous sedation[42], the vibrations of the

reciprocating saw are sometimes perceptible to patients, while general anesthesia may shorten operating times.[71] A two-center prospective trial recommended regional nerve blocks additionally to generous local anesthetic and intravenous sedation.[42] Osteotomy can address both functional and aesthetic issues. A simplified method for advancement mentoplasty was performed to also treat obstructive sleep apnea.[38] Postoperatively 71.9% no longer required continuous positive airway pressure (CPAP), 20.2% were able to better tolerate CPAP, while only 7.9% did not improve. There is no clear consensus on antibiotic prophylaxis in literature, of the nine studies assessed in our review on osteotomies, seven[12,22,36,39,41,42,58] administered antibiotics a varying amount of days.

A retrospective comparative study on objective and subjective outcomes favored osteotomy over implants because of greater and more predictable soft tissue response to hard tissue alteration, improvement of cervicomental angle, and no bone resorption and infection.[22] Two other large comparative studies[12,29] found that both osteotomy and implant placement produce similar patient satisfaction but osteotomy is more useful in correcting abnormalities in all three dimensions and is recommended in severe and complicated cases, or for deviated chin. For mild to modest retrogenia, both techniques can be used.

Autologous grafts

The use of autograft in aesthetic chin augmentation was first described in 1928 by Aufricht [2], who used material from a large hump nose. Ever since, further grafts have been employed, such as costal[43] or conchal cartilage[50], fat[44], dermal[46] and bone grafts[48,49], aiming at reducing donor site morbidity, or even better, using “spare parts” from concurrent procedures.

Autologous bone grafts can be harvested from a prominent mandibular angle.[48,49] A retrospective review of Asian patients noticed that a prominent mandibular angle is often associated with mild to moderate microgenia.[48] With this technique, an unpredictable amount of bone loss was however reported at radiographic observation, preventing a foreseeable outcome.

Some patients may not need simultaneous rhinoplasty or mandibular angle resection, neither be prepared to undergo implant augmentation, but might be willing to undertake fat grafting[44]. This technique has in recent years gained popularity, and may function as a primary form of augmentation, or as adjunct to other methods of chin augmentation surgery. A 2017 prospective controlled study evaluated aesthetic changes in fat grafting to the chin.[44] The mean amount of fat (7.5 ml) of fat was injected in a supraperiosteal (subcutaneous) plane with a blunt 2-mm cannula, using a fanning technique. All patients showed sagittal projection (7mm) and total volume increase (7.4 cc), with 82.3% of mean fat survival at six months follow-up. Minor complications occurred in 7.1% (erythema and contour irregularity), however no revisions were indicated. The method appeared reliable to improve chin volume and sagittal projection up to 10 cc and 11 mm respectively, however follow up never surpassed six months. A longer follow up (mean=21 months) is seen in a retrospective study from 2015, with patient's subjective assessment of much improvement and improvement after fat grafting to the chin, seen in 56.2% and 35.2% respectively.[74]

Fillers

Injectable collagen for soft-tissue restoration became available in early 1980s and laid the foundation for a new chin augmentation technique in patients not wanting surgery[75]. There are now a variety of facial fillers on market, most of them being

temporary because of absorption. A popular representative is HA, which has the advantage of being reversible with hyaluronidase[76], should adverse effects occur. A further convenience is the noticeably lower cost of injections compared to more extensive surgical procedures. However, to maintain long-standing results, repeated interventions are necessary.

In 2006, Belmontesi et al[54] augmented the chin with Restylane SubQ by using a tunneling technique, which typically involved eight to 10 passes of the cannula at each treatment. The injection points were centrally situated, or bilateral in the labiomental fold. Results were either very much or moderately improved in 72.7% of patients, after one-time injection with 2-4 ml HA.

A 2015 comparative study among osteotomy, implants and HA, treated the filler group by injecting 1 ml of Juvéderm Voluma above the periosteum or in deep dermal plane.[29] Patient`s overall satisfaction was highest in filler group, most likely due to lower postoperative complication rate. The mean postoperative value of chin advancement was 2.6mm, with a 100% stability at three years follow-up, maintained with two further injections every eight months, while nodules were successfully treated with hyaluronidase. The authors suggest considering the use of fillers when sagittal deficiency correction is limited to less than 4mm, especially in aging face and patients fearing high procedure costs. Bertossi et al highlight the importance of an accurate patient selection to optimize results and ensure predictable and stable outcomes.[76] Notably, a standardized grid-based approach was recently described, showing high rates of patient satisfaction associated to effectiveness and safety.[77]

Local tissue rearrangement

Chin augmentation with local soft tissue rearrangement was reported by two retrospective reviews[57,58], and is associated with the lowest rate of complications

(6.3%). Their outcomes show a safe and effective treatment with excellent cosmetic results, however doubts persist on long-term stability.

Viterbo et al[58] performed gliding mentoplasty, with subcutaneous and later subperiostal dissection in a caudal direction from intraorally, before placing key sutures in the now elevated submandibular periosteum, allowing the submandibular region to slide forward. In all cases, this technique increased chin projection and symmetry, and no tissue relapse was noted at 25 months follow-up. In particular, authors observed improved projection of subcutaneous tissue and mentalis muscle, with better definition of labiomental fold and enhanced pogonion projection. There was no mention of nerve related injuries.

Implant/osteotomy combination

Data on combined use of osteotomy and implant augmentation are limited to a few cases of severe microgenia.[59] In these cases, a large advancement after osteotomy could lead to loss of contact of the bony surfaces and palpable stepping at osteotomy site, or even worse, mobile and devascularized grafts. However, the application of very large implants could lead to serious complications of bone resorption because of limited bone stock[59]. Gui et al[12] recommend implant/osteotomy combined approach only for severe cases, with Medpor as implant material.

In the study by Findikcioglu et al, horizontal subapical sliding osteotomy was combined with simultaneous implant augmentation (Medpor), achieving an average 17 mm horizontal augmentation, with 13 mm soft tissue advancement.[59] All patients experienced complications, including mental neuropraxia, incisor show and palpable stepping at osteotomy site, most likely due to the considerable amount of augmentation.

Aesthetic outcome

Due to the heterogeneity of data in our review, explicit conclusions with regards to aesthetic outcome for each specific technique cannot be drawn. However, each technique renders potential positive and negative results.

Implant-based chin augmentation presents aesthetic outcomes favorable in cases showing simple bony deficiency of the chin, needing a horizontal augmentation. The aesthetic outcome is slightly limited by the shapes and sizes of implants available from the manufacturer, and even with intra-op customization, doesn't render as many possibilities to chin alteration as osteotomy techniques. Especially in cases requiring a vertical lengthening or a three-dimensional repositioning of the chin, osteotomy allows for an overall improvement of chin shape in all dimensions. Although less change in chin appearance can be achieved with fillers or fat grafting, the lack of surgical scaring makes these options appealing to the patient. Both techniques allow a three-dimensional shaping of the chin with pleasing aesthetic outcomes.

Conclusion

Six chin augmentation procedures are currently available, the prevailing techniques being implant augmentation and osteotomy. Overall, high patients` and surgeons` satisfaction was seen in every group. The combination of implants and osteotomy to treat more complex cases showed higher complication rates and worse outcome score. Other techniques proved to be safe and effective with none demonstrating to be superior to the others. Their rare complications can often be avoided with comprehensive knowledge of existing techniques and regional anatomy.

Figure legend

1. Flow diagram of the article selection process.

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Figure 1

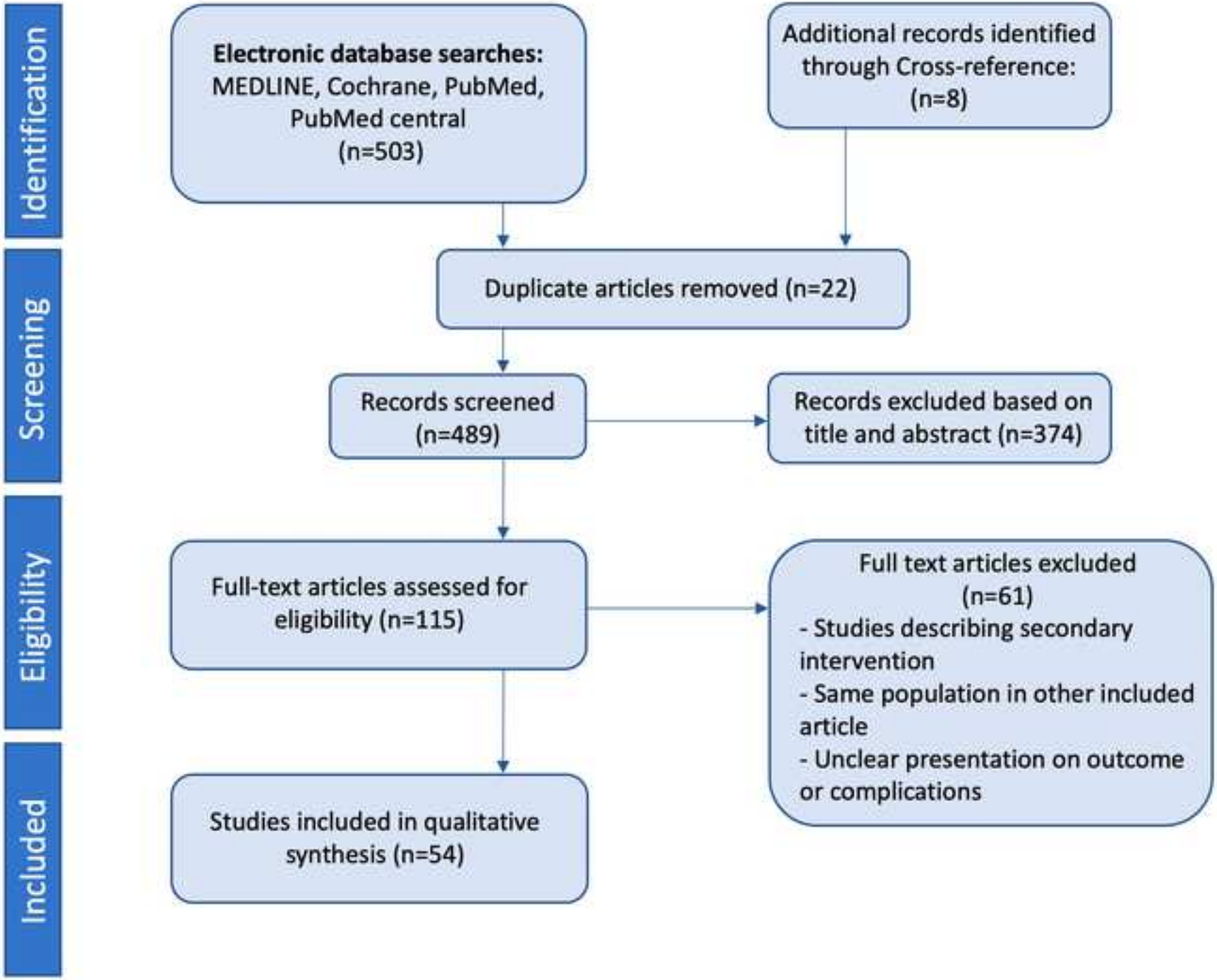

Table 1

Table 1. Summary of Studies on Chin Augmentation (Listed by Year of Publication)

Author (first listed); year	Study design	No. of patients (gender if listed)	Geographic location	Age of patients (y)	Chin augmentation technique	General outcome including satisfaction	Complications
Sahan, 2020	Retrospective review	50 (F)	Turkey	Range: 20-55; mean: 37.56	Filler (Hyaluronic acid)	Improved outcome in 100%. Touch-up procedure at 2-week control visit (n=3).	Ecchymosis (n = 4), slight/moderate erythema (n = 48).
Zhang, 2019	Retrospective review	28 (F)	China	Range: 18-43; mean: 24.5	Autologous graft (costal cartilage graft)	Satisfactory result: 75% at 6- to 18-months follow up.	None reported
Anlatici, 2018	Retrospective review	12	Turkey	Not specified in subgroup	Osteotomy (Advancement Genioplasty and wire fixation, intraoral incision, +midface lifting)	Patient satisfaction: 100%.	None reported
Yin, 2018	Retrospective review	19 (F, n=15; M, n= 4)	China	Range: 18-35; mean: 26	Implant augmentation (silicone or expanded polytetrafluoroethylene = Gore-Tex; with 3 vertical incisions; transoral)	Satisfactory result: 100%.	Superficial irritation at suture site (n = 1).
Findikcioglu, 2018	Case series	3 (F, n=1; M, n= 2)	Turkey	Range: 22-33; mean: 27.3	Combination implant/osteotomy: Advancement genioplasty (horizontal osteotomy) and implant genioplasty (Medpor)	Satisfactory result: 33.3%.	Incisor show due to mucosal contracture (n = 1), neuropraxia (n = 3), palpable stepping osteotomy site (n = 1).
Basile, 2017	Prospective study	42 (F, n=32; M, n= 10)	Brazil	Range: 19-50; mean: 28	Autologous grafts (AFG)	Satisfactory result and patient satisfaction: 92.9%.	Erythema (n=2); contour irregularity (n = 1), volume dissatisfaction (n = 3).
Chao, 2016	Retrospective review	40, overall 230 patients (F, n=169; M, n=46)	United States	Not specified for subgroup, Range: 16-65, mean; 37	Implant augmentation (premade silicone implants/ intraoral insertion)	Satisfactory result: 82.5%.	Malposition (n = 1); implant removal (n = 2), volume dissatisfaction (n = 4), revision (n = 4).
Chang, 2016	Retrospective review	13 (F)	Taiwan	Range: 22-46; mean: 33.1	Autologous grafts (AFG + complemeted bilateral masseter botulinum toxin A injection)	Satisfactory result and patient satisfaction: 100%	None reported
Chan, 2016	Retrospective review	126 (F, n= 45; M, n=81)	United States	Range: 14-67; mean: 39.8	Osteotomy (Advancement genioplasty)	Satisfactory result: 100%; improvement in obstructive sleep apnea 92%.	Plate extrusion (n = 2), infection (n = 2), nerve injury (n = 3), tooth root injury (n = 1).
Kim HK, 2016	Retrospective review	58 (F, n= 43; M, n=15)	South Korea	Range: 20 - 45; mean: 29,4	Autologous graft (double folded dermal graft; gluteal)	Patient satisfaction: 93.1%	Additional fat graft to increase chin volume (n = 2).
Bertossi, 2015	Retrospective review	345 (F, n= 240; M, n=95)	Italy	Range: 19-56; mean: 34.5	Group A: Osteotomy (sliding genioplasty) n=135; Group B: Implant augmentation n= 60; Group C: Filler (Hyaloronic acid; Juvéderm Voluma, Allergan Inc.) n = 150	Satisfactory result in Group A: 91.1%; Group B: 95%; Group C: 91.3%.	Group A: chin hematoma (n = 12), transient paresthesia (n = 135); Group B: displacement (n = 3; removal (n = 3); alveolar ridge absorption (n = 5); Group C: nodules (n = 13)
Yang, 2015	Retrospective review	15 (F)	China	Range: 18-26; mean: 22.5	Implant augmentation (Special technique with grooving, to address the potential complications embracing poor attachment and palpable edges with e-PTFE)	Patient satisfaction: 100%.	None reported
Kim BJ, 2014	Retrospective review	47 (F, n= 25; M, n=22)	Korea	Range; 15-55; mean; 25.8	Implant augmentation (GoreTex; dual plane)	Satisfactory result: 83.0%.	Infection (n = 3); removal (n = 2), neuropraxia (n = 2), volume dissatisfaction and revision (n = 5).

Seifeldin, 2014	Prospective clinical study	8 (F, n= 6; M, n=2)	Egypt/Saudi Arabia	Range: 20-30; Mean: 25	2 methods: Group A: Osteotomy (sliding Genioplasty; n=4); Group B: Osteotomy (shield Genioplasty; n=4).	Satisfactory result: 100%.	None reported
Singh, 2014	Prospective clinical study	20	India	Range: 15-35	2 methods: Group A (n=10): Osteotomy (control); Group B (n=10): experimental Group with chin shield osteotomy with interposition of hydroxyapatite collagen graft soaked in PRP as sandwich graft)	Satisfactory result: 100%.	Group A: transient neuropraxia (n = 2)
Viterbo, 2013	Retrospective review	12 (F, n= 7; M, n=5)	Brazil	Range; 19-59; mean: 32	Local tissue rearrangement: (Gliding Mentoplasty, subcutaneous)	Patient satisfaction: 100%.	Contour iregularity (n = 2)
Bracaglia, 2013	Retrospective review	79 (F, n= 48; M, n=31)	Italy	Range; 18-52; mean: 34.8	Implant augementation (Silastic; external approach with 2 threads lateral for placement)	Satisfactory result and patient satisfaction: 97.5%.	Neuropraxia (n = 1); hypertrophic scar (n = 2).
AlAtel, 2012	Retrospective review	20	Saudia Arabia	Range: 18-25	Local tissue rearrangement (mentalis muscle tightening)	Satisfactory result: 100%	None reported
Lin, 2012	Retrospective review	95 (F, n= 69; M, n=26)	China	Range: 18-42	Implant augmentation (MEDPOR + removal of genial tubercules or mental protuberance)	Satisfactory result: 94.7%	Revision (n = 3); removal (n = 2); neuropraxia (n = 46), volume dissatisfaction (n = 4).
Niechajev, 2012	Prospective clinical study	33 (Total: 102, F: n= 59, M, n=43))	Sweden	Range: 18-70, median: 29	Implant augmentation (MEDPOR; n=10 intraoral, n=13 submental)	Satisfactory result: 87.9%	Contour malposition (n = 2); volume dissatisfaction (n = 2).
Aynechchi, 2012	Case series	125 (F: n= 91, M, n=34)	United States	Range: 18-56, mean: 31	Implant augmentation (Silicone; transoral n=105; n=20 external aproach)	Satisfactory result and patient satisfaction: 100%	Superficial mucosal irritation n=2 ; volume dissatisfaction (n = 21).
Cingi, 2010	Case series	124	Turkey	Range: 19-42, mean: 32.7	Autologous grafts (osteocartilaginous nasal graft)	Satisfactory result: 96.0%	Infection (n = 5); removal (n = 2).
Ilhan, 2011	Retrospective multicenter study	192	Turkey	not specified	Implant augmentation (Prolene mesh)	Satisfactory result: 97.9%	Infection (n = 3); displacement (n = 1).
Mohammad, 2010	Prospective study	16 (F: n= 12, M, n=4)	India	Range: 15-35	Group A: osteotomy (sliding) n = 8; Group B: Implant augmentation (Medpore) n = 8.	Satisfactory result Group A: 100%; Group B: 100%	Group A: mild/transient neurosensory loss (n = 1); Group B: none reported
Li, 2010	Case series	9 (F)	China	Range 18-40	Implant augmentation (n = 3 Silicone, n = 2 Medpore, 4 n= ePTFE + computer aided design)	Satisfactory result and patient satisfaction: 100%	None reported
Tang, 2009	Retrospective review	46	China	Mean: 26	Autologous graft (Mandibular angle Osteotomy)	Patient satisfaction: 100%	Graft resorption (n = 34), temporary neurosensory loss (n = 7).
Gui, 2008	Retrospective review	650 total Group A: 500 (F, n=410, M, =90); Group B: 150 (F, n=121, M, =29)	China	Group A: Range 18-45; Group B: Range: 18-40	Group A: Osteotomy; Group B: Implant augmentation (Medpore)	Group A: Satisfactory results: 99.0%; Group B: Satisfactory results: 98.7%	Group A: Volume dissatisfaction and reoperation (n = 2), contour irregularities and reoperation (n = 2); parastehsia lower lip (n = 1); Group B: Revision (n = 2).

Gürlek, 2007	Retrospective review	20 (F: n= 12, M, n=8)	Turkey	Range: 18-39	Implant augmentation (Diced Porous Polyethylene Medpor)	Patient satisfaction: 100%.	Seroma (n = 3), temporary neurosensory loss (n = 8).
Du, 2006	Prospective study	15	China	not specified	Autologous grafts (Morselized autologous bone; from mandibular angle)	Satisfactory result: 80%.	Revision (n = 3).
Belmontesi, 2006	Retrospective review	11 (F: n= 8, M, n=3)	Italy	26-56	Filler (HA; Restylane SubQ)	Satisfactory result: 72.7%.	Erythema (n = 3), hematoma (n = 1),
Godin, 2003	Retrospective review	324	United States	not specified	Implant Augmentation (GoreTex; n=308 placed through external approach; n=16 transorally)	Satisfactory result: 97.8%.	Infection (n = 2); volume dissatisfaction (n = 4); removal (n = 5); revision (n = 2).
Viterbo, 2003	Case series	28 (F)	Brazil	Range: 15-76, mean: 38.1	Autologous grafts (conchal graft, transoral)	Satisfactory result: 92.9%.	Infection (n = 1), contour irregularities (n = 1).
Kahnberg, 2002	Prospective study	37 (F: n= 20, M, n=17)	Sweden	Range: 16-43, mean: 25	Implant augmentation (HTR-Polymer implants; transoral)	Satisfactory result and patient satisfaction: 100%.	Wound dehiscences (n = 2), infection (n = 1), bone resorption (n = 16).
Mottura, 2002	Retrospective review	36	Argentina	not specified	Autologous graft (nasal osteocartilaginous graft; external approach)	Satisfactory result and patient satisfaction: 100%.	Infection (n = 1).
Gross, 1999	Retrospective review	264 (F: n= 235, M, n=29)	United States	mean: 43	Implant augmentation (merislene mesh; external (n=138); intraoral approach (n=126))	Satisfactory result: 97.7%.	Infection (n = 2); removal (n = 1); displacement (n = 4); revision (n = 4); temporary paresthesia (n = 14).
Karacaoglan, 198	Retrospective review	8	Turkey	not specified	Autologous grafts (diced nasal cartilage; wrapped in surgicel)	Satisfactory result: 100%.	None reported.
Karras, 1998	Retrospective review	18 (F: n= 15, M, n=3)	United states	Range: 14-44, mean: 26.3	Implant augmentation (HTR (hard tissue replacement); transoral)	Satisfactory result: 100%.	None reported.
Vuyk, 1996	Retrospective review	40 (F: n= 29, M, n=11)	The Netherlands	Range: 19-50, mean: 28	Implant augmentation (solid silicone implant; external approach)	Satisfactory result: 97.5%; patient satisfaction: 100%.	Asymmetry (n = 2); malposition (n = 1); revision (n = 1); bone absorption (n = 8); postop haematoma (n = 2).
Ersek, 1995	Prospective study	13	United States	not specified	Filler (biphasic polymer)	Satisfactory result: 100%.	Persistent swelling (n = 1); removal (n = 1); contour irregularity (n = 1).
Glasgold, 1994	Case series	100	United states	not specified	Implant augmentation (custom silastic implants: submental approach; in n = 20 silicon extension wafer (2mm) used)	Satisfactory result: 98%; patient satisfaction: 100%.	None reported.
Kobayashi, 1993	Retrospective review	9 (F: n= 7, M, n=2)	Japan	Range: 18-27, mean: 20	Filler (Hydroxyapatite Blocks; intraoral approach)	Satisfactory result: 88.9 %, patient satisfaction: 88.9%.	Infection (n=1); removal (n = 1).
Sclaroff, 1992	Case report	1 (F)	United States	22	Combination implant/osteotomy	Satisfactory result: 100%.	None reported
McCollough, 1990	Retrospective review	277 (F: n= 237, M, n=40)	United Kingdom	Range: 20-60	Implant augmentation (merislene mesh; external and internal 119/158 approach) not included	Satisfactory result: 96.8%.	Infection (n = 7); removal (n = 5); displacement (n = 2), seroma (n = 4).
Guyuron, 1990	Retrospective review	76 (F: n= 64, M, n=12)	United states	Range: 13-64	Group A: Osteotomy (horizontal); Group B implant augmentation (Proplast; Transoral approach) A: n = 34,	Patient satisfaction Group A: 96.3%; Group B: 87.5%.	Group A: neurosensory loss: (n = 2); Group B: Infection (n = 2), neurosensory loss: (n = 3), bone resorption (n =

					B: n = 42).		42).
Moenning, 1989	Retrospective review	62 (F: n= 39, M, n=23)	United States	Range: 12-54; mean Group A: 24.3 Group B: 24.4 Group C: 27.2	Implant augmentation (Group A: Proplast 1 (n=25), Group B: Proplast II (n=25), Group C: PBHA (n=12); Intraoral approach).	Satisfactory result: 98.4%	Infection (n = 1); removal (n = 1); bone resorption (n = 42).
Rosen, 1988	Case series	8 (F: n= 7, M, n=1)	Unites states	Range: 16-52, mean: 38	Osteotomy (interpositional implantation of hydroxyapatite; n= 7 with sagital advancement also).	Satisfactory result: 87.5%.	Revision (n = 1).
Shaber, 1987	Case report	1 (F)	United States	27	Implant augmentation (Medpore)	Satisfactory result: 100%	None reported
Spear, 1987	2 center Prospective study	39 (**34**) (F: n= 25, M, n=14) - (5 sec. Proc. excluded)	United States	Range: 17-65, mean: 31	Osteotomy (Sliding)	Patient statisfaction high. Satisfactory results: 97.1%	Infection n=1, nerve injury n=1.
Pitanguy, 1986	Retrospective review	612 (F: n= 572, M, n=40)	Brazil	not specified	Implant augmentation (silastic/acrylic; approach intraoral, in n=10 submental)	Satisfactory result: 98.5%.	Prothesis extrusion (n = 4); displacement **(**n = 5); revision (n = 5); removal n= 1, bone resorption (n = 1).
Mahler, 1982	Retrospective review	480	Israel	not specified	Implant augmentation (silastic implant; intraoral; parallel cuts in implant)	Satisfactory result: 97.7%.	Infection (n = 5); removal (n = 7); revision (n = 2); volume dissatisfaction (n = 2).
Spitalny, 1982	Retrospective review	115	Germany	not specified	Implant augmentation (Silicone; intraoral)	Patients satisfaction: 85.2%	Infection (n = 3); dislocation (n = 6); contour irregularities (n = 10); removal (n = 9), revision (n = 6).
Dann, 1977	Retrospective review	31 (F: n= 18, M, n=13)	United States	Range: 13-35; mean: 19.2	Implant augmentation (Proplast implant; transoral)	Satisfactory result: 74.2%.	Incision dehiscence (n = 6) ; infection (n = 4), removal (n = 2); mobile to palpation (n = 1), bone resorption (n = 22), mental neuropraxia (n = 4).
Parkes, 1977	Retrospective review	50	United States	not specified	Implant augmentation (gel filled silicone implants; submental approach)	Satisfactory result: 98%.	Removal (n = 1).

Implant augmentation		
Complications	**No. of instances**	%
Major	**101**	**3.0%**
Implant removal	40	1.2%
Implant Revision	34	1.0%
Implant displacement/malposition	26	0.8%
Implant mobile	1	0.03%
Intermediate	**55**	**1.6%**
Infection	31	0.9%
Wound dehiscence	15	0.4%
Seroma	7	0.2%
Chin hematoma	2	0.06%
Minor	**369**	**11.0%**
Alveolar ridge resorption	232	6.9%
Mental neuropraxia	79	2.4%
Dissatisfaction with final volume	44	1.3%
Contour irregularity	12	0.4%
Hypertrophic scars	2	0.06%
Total	**525**	**15.7%**

Table 2: Summary of complication among 3344 patients treated with implant-based chin augmentation.

Osteotomy		
Complications	**No. of instances**	%
Major	**8**	**0.9%**
Implant Revision	6	0.7%
Palpable stepping at osteotomy site	2	0.2%
Intermediate	**17**	**1.9%**
Chin hematoma	12	1.4%
Infection	3	0.3%
Wound dehiscence	1	0.1%
Tooth root injury	1	0.1%
Minor	**149**	**16.8%**
Mental neuropraxia	145	16.4%
Dissatisfaction with final volume	2	0.2%
Contour irregularity	2	0.2%
Total	**174**	**19.7%**

Table 3: Summary of complication among 885 patients treated with osteotomy.

Autologous Grafts					
Type of graft	**No. of patients**	**Complications**	**No. of instances**	**%**	**Total No. of instances in group (n/%)**
Fat	55				6; 1.5%
		Dissatisfaction with final volume	3	5.4%	
		Erythema	2	3.6%	
		Contour irregularity	1	1.8%	
Cartilage	64				2; 3.1%
		Infection	1	1.6%	
		Contour irregularity	1	1.6%	
Bone	61				47; 77%
		Resorption of graft	34	55.7%	
		Mental neuropraxia	7	11.5%	
		Implant Revision	3	4.9%	
		Implant displacement/malposition	2	3.3%	
		Contour irregularity	1	1.6%	
Osteocartilaginous	160				8; 5%
		Infection	6	3.8%	
		Implant removal	2	1.3%	
Dermal	58				2; 3.4%
		Dissatisfaction with final volume	2	3.4%	
Total	**398**		**65**		**65; 16.3%**

Table 4: Summary of complication in autologous graft group (n=398), divided by graft type.

Filler (HA/biphasic polymer/hydroxyapatite)		
Complications	**No. of instances**	**%**
Erythema	48	20.6%
Nodules	13	5.6%
Ecchymosis	7	3.0%
Implant removal	2	0.9%
Chin hematoma	1	0.4%
Infection	1	0.4%
Dissatisfaction with final volume	1	0.4%
Contour irregularity	1	0.4%
Total	**74**	**31.7%**

Table 5: Summary of complication among 233 patients treated with fillers.

Local tissue rearrangement		
Complications	**No. of instances**	**%**
Contour irregularity	2	6.3%
Total	**2**	**6.3%**

Table 6: Summary of complication among 32 patients treated with local tissue rearrangement.

Combination implant/osteotomy		
Complications	**No. of instances**	**%**
Mental neuropraxia	3	75%
Palpable stepping at osteotomy site	1	25%
Incisor show	1	25%
Total	**5**	**100%**

Table 7: Summary of complication among 5 patients treated with implant/osteotomy combination.

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Title page
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Abstract
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Page 3
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Page 3, page 4
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Page 4
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	" "
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	" "
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	" "
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Page 4 and page 5
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Page 4
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Page 4
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Page 5
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Page 4
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Pages 4 and 5
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	" "
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	" "
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	" "
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	" "
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	" "
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Page 5
Certainty	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Page 5

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
assessment			
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Page 5
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	" "
Study characteristics	17	Cite each included study and present its characteristics.	Table 1
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Page 5
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Table 1
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Page 5
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Page 5
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Page 5
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Page 5
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Page 5
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Totality of Results
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Totality of Discussion section
	23b	Discuss any limitations of the evidence included in the review.	Page 8
	23c	Discuss any limitations of the review processes used.	Page 8
	23d	Discuss implications of the results for practice, policy, and future research.	Page 8, page 15, page 16, totality of discussion.
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Not registred
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	" "
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	" "
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Title page
Competing	26	Declare any competing interests of review authors.	Title page

Section and Topic	Item #	Checklist item	Location where item is reported
interests			
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Page 4

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71