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A systematic review on soft-to-hard tissue ratios in orthognathic surgery part II: Chin procedures

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Purpose: Precise soft-to-hard tissue ratios in orthofacial chin procedures are not well established. The aim of this study was to determine useful soft-to-hard tissue ratios for planning the magnitude of sliding genioplasty (chin osteotomy), osseous chin recontouring and alloplastic chin augmentation.

Material and methods: A systematic review of English and non-English articles using PubMed central, ProQuest Dissertations and Theses, Science Citation Index, Elsevier Science Direct Complete, Highwire Press, Springer Standard Collection, SAGE premier 2011, DOAJ Directory of Open Access Journals, Sweetswise, Free E-Journals, Ovid Lippincott Williams & Wilkins total Access Collection, Wiley Online Library Journals, and Cochrane Plus databases from their onset until July 2014. Additional studies were identified by searching the references. Search terms included soft tissue, ratios, genioplasty, mentoplasty, chin, genial AND advancement, augmentation, setback, retrusion, impaction, reduction, vertical deficit, widening, narrowing, and expansion.

Study selection criteria were as follows: only academic publications; human patients; no reviews; systematic reviews or meta-analyses; no cadavers; no syndromic patients; no pathology at the chin or mandible region; only articles of level of evidence from I to IV; number of patients must be cited in the articles; hard-to-soft tissue ratios must be cited in the articles or at least are able to be calculated with the quantitative data available in the article; if all patients of one article have had bilateral sagittal split osteotomy (BSSO) performed along with chin osteotomy, there should be an independent group evaluation of the data concerning to the chin; and no restriction regarding the size of the group. Independent extraction of articles by two authors using predefined data fields, including study quality indicators (level of evidence).

Results: The search identified 22 articles. Eleven additional articles were found in their reference sections. Of these, two were evidence level IIIb, three were evidence level IIb, and the rest were evidence level IV. Three studies were prospective in nature. A high variability of soft-to-hard tissue ratios regarding genioplasty seemed to disappear if data were stratified according to confounding factors. With the available data, a soft-to-hard pogonion ratio of 0.9:1 and 0.55:1 could be used for chin advancement and chin setback surgery, respectively.

Conclusion: Advancement and extrusion movements of the chin segment show respectively a 0.9:1 of sPg:Pg horizontally and 0.95:1 of sMe:Me vertically. Setback and impaction movements show respectively a −0.52:1 of sPg:Pg horizontally and −0.43:1 of sMe:Me vertically. Prospective studies are needed that stratify by confounding factors such as type of osteotomy technique, magnitude of the movement, age, sex, race/ethnicity, and quantity and quality of the soft tissues. More specifically, studies are needed regarding soft-to-hard tissue changes after chin extrusion ("downgrafting"), intrusion ("impaction"), and widening and narrowing surgery.

1. Introduction

Facial harmony is the consequence of proper balance between the different parts of the face. A well-proportionated chin can

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dramatically contribute to facial harmony, especially in profile view (Chen et al., 2007). Moreover, a prominent chin is associated with the perception of a strong character (Annino, 1999).

In order to achieve a specific shape and projection of the chin, a set of mandibular osteotomies has been defined in the course of years to allow spatial movements of advancement, retrusion, extrusion, intrusion, widening, and narrowing.

The most common procedure to correct a retruded chin is chinbone advancement, which is performed with a horizontal "sliding" osteotomy at the inferior border of the mandible. Otto Hofer (1942) was the first surgeon to describe the chin advancement osteotomy, which was performed by an extra-oral approach, although the "patient" seems to have been a cadaver. Gillies and Millard (1957) performed the same procedure on a living patient, also using an external approach. Trauner and Obwegeser (1957) were the first surgeons to perform a chin advancement osteotomy through an intraoral approach and dubbed the technique "genioplasty". Chin setback can also be performed via a sliding genioplasty technique. Hinds and Kent (1969) were the first to describe setback genioplasty in a scientific article. Vertical chin height reduction, also called intrusion or impaction genioplasty, was first described by Reichenbach et al. (1965) by removing a wedge of bone in the middle of the symphysis. Chin extrusion ("downgrafting" or vertical height augmentation genioplasty) was first described by Converse and Wood-Smith (1964) with the insertion of a bone graft into the horizontal osteotomy site. From a frontal view, the chin can also be widened or narrowed. Several procedures have been proposed to treat an asymmetric chin, either by using alloplastic material (Bell and Gallagher, 1983) or by performing specific osteotomies (Raffaini and Sesenna, 1995). Park and Noh (2008) were the first authors to publish on bilateral narrowing of the chin for aesthetic purposes, by means of a horizontal osteotomy and resection of a central bone fragment. Narrowing genioplasty, in combination with angle and body of the mandible osteotomy, is indicated to slender a square face type, and has gained interest among patients who require facial feminization and also patients of Asian descent (Khadka et al., 2011; Chen et al., 2011, 2013; Mommaerts, 2013a). Widening genioplasty is less common. Symphyseal widening with a distraction device is used in absolute transverse mandibular deficiency (Guerrero, 1990; Mommaerts, 2001). Chin proper widening osteotomy was proposed by Epker et al. (1995) by dividing the chin segment and interpositioning a bone graft. Reyneke and Sullivan (2001) proposed a simplified technique by midline osteotomy of the chin segment and anterior rotation of the fragments.

Apart from chin osteotomy, different implants have been used to give volume to the chin. Silicone (Friedland et al., 1976), polytetrafluoroethylene (PTFE) (Parkes et al., 1976), polyester (Gross et al., 1999) polyethylene (PE) (Shaber, 1987), and polymethylmethacrylate (Karras and Wolford, 1998) have been the most common materials used for making implants for chin augmentation.

When a chin implant is placed or when a chin osteotomy is performed and the implant or segment is fixed in a new position, the soft tissues will follow in a degree that is measured using soft-to-hard tissue ratios. Each ratio explains how much a certain soft-tissue landmark will move in relationship to a certain hard-tissue landmark. For example, a ratio of 0.9:1 between soft Pogonion (sPg) and hard Pogonion (Pg) means that for each 10 mm of anterior movement of Pg, sPg will follow 9 mm. The rationale for the research was that precise soft-to-hard tissue ratios in orthofacial chin procedures are not well established. Knowledge of how soft tissue moves in relation to hard tissue will provide better outcome predictions when using the facial profile line for planning (Mommaerts, 2013b) and Photoshopping simulations are performed (Mommaerts, 2013c; Büttner and Mommaerts, 2015), which in turn can help the patient tune his/her sliding genioplasty. Our objective was to determine useful soft-to-hard tissue ratios for planning the magnitude of a sliding chin osteotomy, osseous recontouring, and alloplastic augmentation.

2. Material and methods

2.1. PICOS

The study population included all patients who had received a genioplasty. The intervention was a chin osteotomy with repositioning of the segment in all directions, or a chin augmentation procedure with alloplastic or autologous materials. There was no comparator. Outcomes were based on the soft-to-hard tissue ratios in the mid–sagittal plane. Study designs included randomized and observational studies, cohort studies and case reports.

2.2. Literature search

The systematic literature search (shown as a QUOROM-flow diagram (Moher et al., 1999)) (Fig. 1) was started with the assistance of Unika Library Service from the University of Navarre (Clínica Universitaria de Navarra, Pamplona, Spain). This Service allowed the authors to use PubMed central, ProQuest Dissertations and Theses, Science Citation Index, Elsevier Science Direct Complete, Highwire Press, Springer Standard Collection, SAGE premier 2011, DOAJ Directory of Open Access Journals, Sweetswise, Free E-Journals, Ovid Lippincott Williams & Wilkins total Access Collection, Wiley Online Library Journals, and Cochrane Plus databases. The heading sequence ("Soft Tissue" OR "Ratios") AND ("Genioplasty" OR "Mentoplasty" OR "Chin" OR "Genial") AND ("Advancement" OR "Augmentation" OR "Setback" OR "Retrusion" OR "Impaction" OR "Reduction" OR "Vertical Deficit" OR "Widening" OR "Narrowing" OR "Expansion") was selected. Our initial search returned 4008 published articles till July 2014. Inclusion criteria mandated only academic publications, and the number of articles decreased to 980. No language restriction was used. Articles discussing non-human animals, cadavers, or a different topic were excluded, after which 305 potential articles were found. Articles about syndromic cases, pathologic cases, meta-analyses, Level of Evidence V, and mandibular alveolar subapical osteotomies, were excluded; remaining 50 articles. Of these, 22 fulfilled inclusion criteria 8, 9, and 10 (see Selection criteria). To complete the search, the references of each selected publication were searched by hand, and abstracts of congress/convention proceedings online were searched on line. A total of 25 additional articles were found, 11 of which fulfilled the selection criteria. With the addition of these 11 articles, a total of 33 articles were included in this systematic review.

2.3. Selection criteria

Selection criteria (inclusion and exclusion criteria) were chosen to select potential articles from the published abstract results: 1) only academic publications; 2) human patients; 3) no reviews, systematic reviews or meta-analyses; 4) no cadavers; 5) no syndromic patients (i.e., Pierre Robin syndrome); 6) no pathology at the chin or mandible region; 7) only articles of level of evidence from I to IV (level V are excluded); 8) number of patients must be cited in the articles; 9) hard-to-soft tissue ratios have to be cited in the articles or, at least, they are able to be calculated with the quantitative data available in the article; 10) if all patients in one article have had bilateral sagittal split osteotomy (BSSO) performed

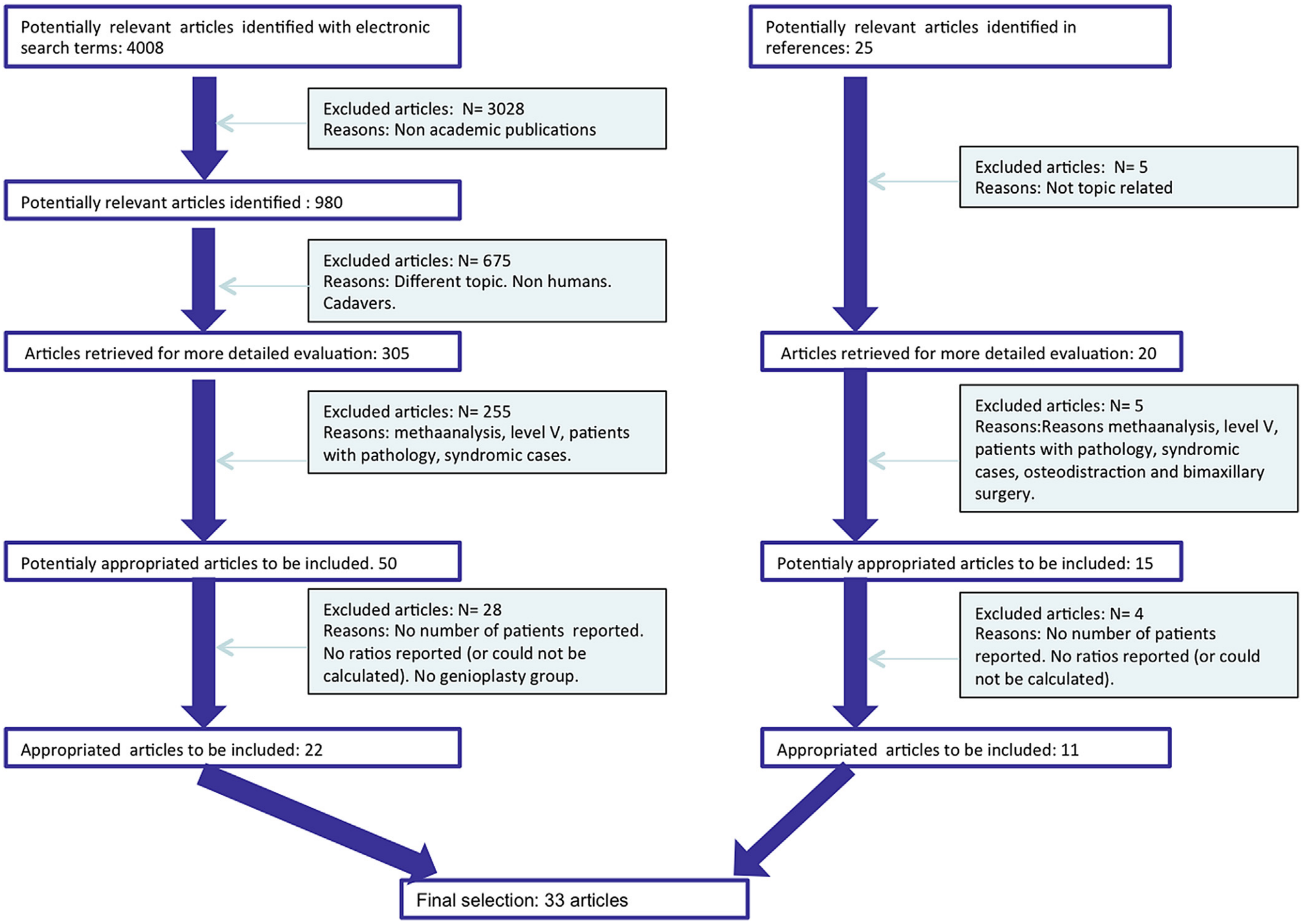

Fig. 1. QUOROM-flow diagram (Moher et al., 1999). The column on the left indicates the search of articles identified electronically; the column on the right indicates the search of articles identified using the references in the articles previously chosen and shown in the left column. The final selection includes the sum of the articles chosen and shown at the bottom of the right and left column. N = number of studies.

along with chin osteotomy, there should be an independent group evaluation of the data concerning to the chin.

There was no restriction regarding the size of the group. This is because for some of the movements assessed in this review, the number of patients evaluated was very low, probably due to the lesser indications for undergoing these types of surgeries. No language restriction was used.

The articles that met the inclusion criteria were divided into four groups according to the type of chin surgery performed: chin advancement/augmentation, chin retrusion, chin impaction/recontouring, and chin extrusion. No articles could be included with chin expansion and chin narrowing surgeries (Fig. 2).

2.4. Data extraction

To assess the methodological soundness of each article, a quality evaluation was performed using the Level of Evidence (LOE) scale according to the 2011 Oxford CEBM levels of evidence recommendations (Howick et al., 2011). The quality was categorized from level I to level IV.

The following data were extracted by two authors (J.S.M.M. and M.M.) or calculated (J.S.M.M.) from the full-text articles: authors, year of publication, number of patients, follow-up (in months), study design (prospective vs. retrospective), Level of Evidence (LOE) as study quality indicator, surgical techniques, additional procedures performed on the maxillo-mandibular complex, type of fixation, degree of relapse, whether detachment of suprahyoid musculature was performed, magnitude of the movement (in case of prostheses, size of the implant), gender of patients, age of patients, ethnicity, and horizontal line or plane used in cephalometric analyses. The data extracted were related to movements of Stomion

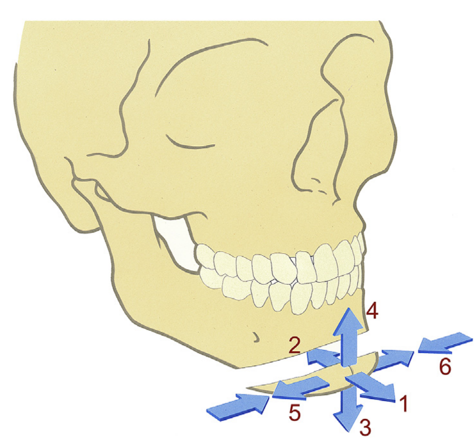

Fig. 2. Possible movements of the chin segment. 1) Advancement, 2) setback, 3) extrusion, 4) intrusion, 5) expansion, and 6) narrowing.

inferius (Stoi), Labrale inferius (Li), mentolabial fold (sB), soft pogonion (sPg), soft gnathion (sGn), and soft menton (sMe), either horizontally or vertically. All quantitative data regarding sPg and Pg were recalculated to a ratio.

3. Results

A total of 33 articles was obtained, of which 6 were LOE IIIB, 3 were LOE IIB, and the rest were LOE IV. Three studies were prospective in nature (Tables 1–4).

Soft-to-hard tissue ratios were recorded for chin advancement/augmentation and setback, inferior repositioning, and superior repositioning of the chin (Tables 5–8). Articles alluding to soft-to-hard tissue ratios for chin expansion and narrowing were not found.

3.1. Sliding advancement genioplasty/alloplastic augmentation

A total of 21 studies was found reporting soft-to-hard tissue ratios related to chin advancement surgery and anterior alloplastic augmentation (Table 1). Two articles were on prospective studies, 2 articles were LOE IIB, 2 articles were LOE IIIB, and the rest of the articles were LOE IV. A total of 463 patients were analyzed for chin advancement/augmentation. The amount of advancement/augmentation ranged from 4 mm to 13.1 mm (mean 8.47 mm). sPg was the most commonly used soft tissue landmark for the evaluation of soft tissue changes after chin advancement, and was correlated with Pg movement in 21 studies. The follow-up of the patients ranged from a minimum of 6 months (9 of 21 articles) to a maximum of 72 months (Shaughnessy et al., 2006).

Even with all of the controversies concerning Pg, it is still the most important landmark to be assessed in any genioplasty study, since it represents chin prominence. sPg:Pg ranged from 0.53:1 to 0.99:1, with a mean of 0.85:1. The correlations associated with these ratios were poor, with most correlation coefficients ranging from 0.38 to 0.72, indicating significant variance. Of the articles, 57% reported chin advancement along with other orthognathic procedures such as BSSO and/or Le Fort I osteotomy surgery. In all, 43% of the articles analyzed the effect of sole genioplasty (no other surgical procedures performed), with ratios ranging from 0.78:1 to 0.99:1 (mean of 0.89:1). These results suggest that a ratio of 0.9:1 could be used to predict soft tissue movement. Erbe et al. (2011) explain that their 0.97:1 ratio may be due to the homogeneity of the patient group, as they all showed a neutroclusion and hypoplastic mandible. When long-term (3 years) changes were accounted for, the ratio dropped from 0.92:1 to 0.86:1 (Shaughnessy et al., 2006).

The net anterior movement at the mentolabial fold (sB) is most likely the result of a remodelling process, with bone deposition occurring in this area (Shaughnessy et al., 2006). Most of these changes occur during the first 6 postoperative months. Usually attention is paid to maintain as much soft tissue attachment as possible to the repositioned bony segment, to obtain predictable soft-tissue changes (Bell et al., 1981). The mentolabial fold depth increased as a result of advancement genioplasty in some studies (Shaughnessy et al., 2006; Erbe et al., 2011; Reddy et al., 2011; Seifeldin et al., 2014). Gallagher et al. (1984) found, in contrast, that mentolabial fold depth did not significantly change in any patient, regardless of the amount of chin advancement. In that study, advancement genioplasty was combined with Le Fort I–type osteotomy, and the sample size was small (10 patients). A Le Fort I–type osteotomy can cause a forward movement of the lower lip and thereby increase mentolabial fold depth. Seifeldin et al. (2014) compared two groups of patients who underwent sliding advancement genioplasty with different techniques: chin shield genioplasty (four patients) and a conventional horizontal sliding genioplasty (four patients). They found that in the chin shield genioplasty technique, the increase in mentolabial fold depth was less than in the sliding genioplasty (20% compared to 90%). Moreover, sPg:Pg was greater in the chin shield group (0.99 in chin shield versus 0.83 in the horizontal sliding genioplasty).

A few studies investigated changes in Li after advancement genioplasty (Busquets and Sassouni, 1981; and Ross, 1992; Shaughnessy et al., 2006). Busquets and Sassouni (1981) and Ewing and Ross (1992) show horizontal changes in Li ranging from 44% to 50% of the movement of Ili (lower incisor tip), respectively. Shaughnessy et al. (2006) did not find a statistically significant horizontal change in Li or Ls (Labrale superius).

As for soft menton (sMe), Shaughnessy et al. (2006) and Reddy et al. (2011) reported that the vertical position of menton did not show statistically significant changes.

The change in the cervicomental angle after chin advancement was reported in two studies, and showed a decrease of 17° (Reddy et al., 2011) and 22.7° (Gallagher et al., 1984). This is in concordance with the idea that advancement genioplasty stretches the submental tissue and improves the appearance of a double chin.

Four articles report on soft-to-hard tissue changes after alloplastic chin augmentation and two studies compare their results with another group of patients with sliding genioplasty. sPg:Pg ranged from 0.57 to 0.99. The thickness of the implants ranged from 5.4 to 8.5 mm. Bell and Dann (1973) placed silicone implants in 3 patients and found that sPg followed the implant by 0.57. Dann and Epker (1977) placed PTFE implants in 31 patients, and found a ratio of 0.9. Mohammad et al. (2010) and Park et al. (2010) compared soft tissue response after the placement of PE implants and sliding genioplasty in two groups. Mohammad et al. (2010) found a ratio of 0.78 in the group of PE implants (8 patients), whereas in the group of horizontal osteotomy (8 patients) the ratio was 0.87. According to Mohammad et al. (2010), this shows that osseous sliding genioplasty provides better soft tissue predictability than alloplastic augmentation. In contrast, Park et al. (2010) found there was no difference between the amount of change in the soft tissues to that in the hard tissues when osseous sliding genioplasty (ratio of 0.93 in 14 patients) was compared to PE genial implants (ratio of 0.99 in 19 patients).

3.2. Chin setback

Six studies reported data concerning hard-to-soft tissue ratios after chin setback (Table 2). A total of 96 patients were analyzed for chin retrusion surgery. The amount of retrusion ranged from −2.9 mm to −7 mm (mean −4.35 mm). sPg:Pg ranged from −0.27:1 to −0.70:1, with a mean of −0.52:1. Thus, the results are not highly predictable and vary greatly, maybe because correlation analysis tests were not performed in every study or because some of the articles used a small number of patients.

Hohl and Epker (1976) reported a ratio of −0.27:1 (sPg/Pg) after a 1-year follow-up in 11 patients who underwent chin setback and impaction. Two patients in this group had anterior and inferior chin recontouring, and 9 patients underwent a sliding chin osteotomy. Bell et al. (1981) reported a ratio from sPg:Pg of −0.58:1 in 7 patients who underwent chin setback along with other procedures (Table 2). Dann (1987) reported that sPg followed Pg at a ratio of −0.70:1 ($r = 0.78$) in 32 patients who underwent rotation reduction genioplasty (pivot point located at the anterior osteotomy point in sagittal view). Krekmanov and Kahnberg (1992) reported a ratio of −0.53:1 (mean amount of setback at Pg of −4.9 mm). Yang et al. (2012) reported a ratio of −0.36 after a 3-month follow-up. Park et al. (2013) performed BSSO setback with

Table 1
Studies selected for chin advancement osteotomy.

Chin advancement														
Authors	Year	N	F–U (m)	Study	LOE	Technique	Additional procedures	Fixation	Relapse	Pedicled	Magn (mm) at Pg	Gender	Age (y)	Race	Horizontal Reference line
Bell and Dann	1973	8	20.8	Retro	IV	Sliding genioplasty	8/11 Le Fort	Wire	5% BR	Yes	6.6 (SD 3.4)	NR	NR	NR	FH
		3				Silicone implants		Not fixed	NR	Yes	NR				
Dann and Epker	1977	31	15.5	Retro	IV	PTFE implants	18 SAMO	Wire or suture	2 removals 22/31 BR, mean (4.6 mm)	NR	5.4	13	19 (13–35)	NR	Mandibular plane
McDonnell et al.	1977	15	12	Retro	IV	Horizontal osteotomy	9 BSSO, 6 bimaxillary	Wire	2.8 mm	NR	9.3	NR	NR	NR	NR
Busquets and Sassouni	1981	14	4.5	Retro	IV	Horizontal osteotomy Some with ostectomy	Only genioplasty	Wire	NR	NR	13.1	NR	NR	NR	NR
Gallagher et al.	1984	10	9	Retro	IV	Horizontal osteotomy	Le Fort I impac 10/10	Wire	Only in 1 pt	NR	7.2	NR	NR	NR	Basion-Nasion-Sella
Tulasne	1987	46	6	Retro	IV	Jumping bone flap	40 other surgeries (Le Fort I, segmental)	Wire	40% BR	Yes	10.6[a], 12[b]	8	23	NR	FH
Wittbjer and Rune	1989	17	72	Retro	IV	Sliding genioplasty + autologous bone graft	3 other surgeries (1 chin implant replacement, 1 mb adv, 1 mb setback)	Wire	NR	Yes	8 (4.0–15.5)	6	25 (18–40)	NR	FH
Park et al.	1989	23	6	Retro	IV	Horizontal osteotomy	17 bimaxillary	NR	<1 mm	Yes	6.6 (SD 1.2)	8	22.2 (13–36)	Caucasian	OP
Polido et al.	1991	10	6	Retro	IV	Horizontal osteotomy	Only genioplasty	4 wire, 6 rigid	2.9 mm	Yes	11.7	3	21	NR	FH
Vedtofte et al.	1991	14	12	Retro	IIIB	Sliding genioplasty	1 Le Fort I	NR	30.9% BR	No	8.2	5	20.2	NR	OP
		11	12			Sliding genioplasty	6 Le Fort I	NR	11 pt BR	Yes	7.7	4	23.5	NR	OP
Ewing and Ross	1992	17	72	Retro	IV	Sliding genioplasty + 2 chin impaction	11 BSSO, 6 Le Fort I	NR	Slight thinning of soft tissue	NR	NR	NR	19.5	NR	Facial plane (Nasion-Pg)
Krekmanov and Kahnberg	1992	65	12	Retro	IV	Sliding genioplasty	Only genioplasty	Wire/rigid	NR	NR	NR	28	26.5	NR	NR
De Freitas et al.	1992	39	6	Retro	IV	Sliding genioplasty	Only genioplasty	Rigid	No change	NR	5.7 (SD 2.33)	6	22.7	NR	NR
Van Sickels et al.	1994	18	6	Retro	IV	Horizontal osteotomy	1 Mx retrusion	Rigid	0.92 mm	NR	7.4 (SD 0.56)	NR	NR	NR	OP
Talebzadeh and Pogrel	2001	20	12	Retro	IV	NR	9 BSSO	Rigid	0.38 mm	NR	11.9	9	NR	NR	SN
Shaughnessy et al.	2006	21	72	Retro	IV	Horizontal osteotomy + iliac crest bone graft	Only genioplasty	11 wire, 10 rigid	8.20% BR	NR	8.4	7	NR	NR	NR
Mohammad et al.	2010	8	6	Prosp	IIB	Sliding genioplasty	Only genioplasty	Rigid	No change	NR	10.75	1	(15–35)	Indian	X axis 7° inf to SN
		8				PE Implant		Rigid – Ti screws	1.33 mm	NR	8.5	5	NR		
Park et al.	2010	14	6	Retro	IIIB	Sliding genioplasty	BSSO and Le Fort I (numbers not reported)	Rigid	18.59% BR	NR	4.49	15[c]	22 (18–37)[c]	NR	X axis 7° inf to SN
		19				PE implant		Rigid – Ti screws	14.56% BR		7.05				
Erbe et al.	2011	14	12	Retro	IV	Only advancement genioplasty	Only genioplasty	11 wire, 3 rigid	0.1 (SD 0.95) mm	NR	7.9	3	26.2 (SD 8.4)	NR	OP
Reddy et al.	2011	10	9.2	Retro	IV	Horizontal osteotomy	Only genioplasty	Rigid	10.7% surg adv	Yes	7.92	4	22 (21–25)	NR	OP
Seifeldin et al.	2014	4	6	Prosp	IIB	Sliding genioplasty	Only genioplasty	Rigid	No change	NR	4.7 (SD 0.3)	2	25 (20–30)	NR	FH
		4				Chin shield osteotomy	Only genioplasty			NR	6.2 (SD 4.8)				

The column "Pedicled" indicates whether suprahyoid muscles were preserved (yes) or reflected/detached from the bony chin (no).
The column "Gender" indicates number of male patients of each study.
Numbers inside parenthesis (–) indicate a range of values.
Abbreviations: N (number of patients), F–U (follow-up), m (months), LOE (level of evidence), Magn (magnitude of movement), y (years), Retro (retrospective), Prosp (prospective), PTFE (polytetrafluoroethylene), PE (polyethylene), NR (not reported), SAMO (subapical anterior mandibular osteotomy), BSSO (bilateral sagittal split osteotomy), Mx (maxilla), Mb (mandible), ti (titanium), pt (patient), BR (bone resorption), mm (millimeters), Pg (pogonion), SD (Standard Deviation), OP (occlusal plane), FH (Frankfort Horizontal), SN (Sella-Nasion), inf (inferior).
[a] Adults.
[b] Teenagers.
[c] Data not stratified between the two groups of the article.

Table 2
Studies selected for chin setback surgery.

Chin setback															
Authors	Year	N	F–U (m)	Study	LOE	Technique	Additional procedures	Fixation	Relapse	Pedicled	Magn (mm) at Pg	Gender	Age (y)	Race	Horizontal Reference line
Hohl and Epker	1976	11	12	Retro	IV	(9 ostectomy/2 anterior recontouring) + impaction	Only genioplasty	NR	NR	NR	−2.9	NR	NR	NR	Line passing through N, perpendicular to line N-Pg
Bell et al.	1981	7	10.5	Retro	IV	Modified horizontal osteotomy	1 BSSO, 2 Le Fort downgrafting, 2 Le Fort I advancement	Wire	2.2 mm	Yes	−5	1	30.2	NR	FH
Dann	1987	32	30	Retro	IV	Sliding setback + impaction	Only genioplasty	NR	NR	NR	NR	NR	NR	NR	NR
Krekmanov and Kahnberg	1992	12	12	Retro	IV	Sliding setback horizontal	Genioplasty/BSSO/Le Fort I (no numbers reported)	Wire/rigid	NR	No	−4.9 (3–7)	NR	NR	NR	NR
Yang et al.	2012	12	3	Retro	IV	Sliding with slope	3 BSSO	Rigid	NR	NR	−5.07	6	21 (18–26)	Kor	NR
Park et al.	2013	22	12	Retro	IV	Sliding setback horizontal	BSSO setback (no numbers reported)	Rigid	NR	NR	−3.89 (SD 3.10)	10	25.2 (21–33)	NR	X axis 7° inf to SN

The column "Pedicled" indicates whether suprahioid muscles were preserved (yes) or reflected/detached from the bony chin (no).
The column "Gender" indicates number of male patients of each study.
Numbers inside parenthesis (–) indicate a range of values.
Negative numbers indicate setback movement along the x axis.
Abbreviations: N (number of patients), F–U (follow-up), m (months), LOE (level of evidence), Magn (magnitude of movement), y (years), Retro (retrospective), NR (not reported), BSSO (bilateral sagital split osteotomy), mm (millimeters), Pg (pogonion), SD (Standard Deviation), Kor (Korean), FH (Frankfort Horizontal), SN (Sella-Nasion), N (Nasion), inf (inferior).

Table 3
Studies selected for Chin downgrafting.

Chin extrusion (downgrafting)															
Authors	Year	N	F–U (m)	Study	LOE	Technique	Additional procedures	Fixation	Relapse	Pedicled	Magn (mm) at menton	Gender	Age (y)	Race	Horizontal Reference line
Wessberg et al.	1980	1	6	Retro	IV	VHA with iliac bone graft	Only genio	Wire	No change	NR	NR	NR	NR	NR	NR
Rosen	1988	8	11.1	Retro	IV	Transversal segmented osteotomy + HA block	7 BSSO advancement 1 BSSO setback	Wire	No change	NR	5.3 (4.5–7)	1	38 (16–52)	NR	Legan and Burstone analysis
Kim et al.	2005	23	12	Retro	IV	Extrusion with iliac bone graft 8/23 Extrusion + adv genioplasty.	8 Mx impaction + mb setback, 6 mx impaction + mb advancement, 3 mb setback, 4 mb advancement, 2 angle reduction.	Rigid	NR	NR	4.52 (3–8)	8	24.4	Korean	NR

The column "Pedicled" indicates whether suprayioid muscles were preserved (yes) or reflected/detached from the bony chin (no).
The column "Gender" indicates number of male patients of each study.
Numbers inside parenthesis (–) indicate a range of values.
Legan and Burstone analysis as explained in the References (Legan and Burstone, 1980).
Abbreviations: N (number of patients), F–U (follow-up), m (months), LOE (level of evidence), Magn (magnitude of movement), y (years), Retro (retrospective), NR (not reported), HA (hydroxyapatite), BSSO (bilateral sagital split osteotomy), Mx (maxilla), Mb (mandible), mm (millimeters).

Table 4
Studies selected for impaction genioplasty.

Chin intrusion (impaction)															
Authors	Year	N	F–U (m)	Study	LOE	Technique	Additional	Fixation	Relapse	Pedicled	Magn (mm) to Me, vertically	Gender	Age (y)	Race	Measurement
Hohl and Epker	1976	11	12	Retro	IV	9 Horizontal ostectomy 2 Anterior recontouring	Only genioplasty	NR	NR	NR	−7.9	NR	NR	NR	Line passing through N, perpendicular to line N-Pg
Dann	1987	32	30	Retro	IV	Genio setback + impaction	Only genioplasty	NR	NR	NR	NR	NR	NR	NR	NR
Krekmanov and Kahnberg	1992	19	12	Retro	IV	Horizontal ostectomy	NR	Rigid	NR	No	−5.9 (4–6)	NR	NR	NR	NR
Van Butsele et al.	1995	9	6	Retro	IV	Genio impaction and advancement	Only genioplasty	Rigid	NR	NR	Vert: 0.9 (SD 4.4) Hor: 2.7 (SD 5.3)	NR	NR	NR	FH
		15					Mx impaction	Rigid			Vert: 6.8 (SD 3.8) Hor: 7.3 (SD 4.6)				
Díaz Fernández et al.	2003	24	18–96	Prosp	IIB	Genio impaction and setback	16 BSSO	Rigid	NR	NR	Vert: 5.5 (SD 0.9) Hor: 6.0 (SD 1.9)	14	20.2 (19–25)	75% mest	X axis 7° inf to SN
Ho et al.	2012	16	11	Retro	IV	Genio impaction only	16 BSSO setback	Rigid	NR	NR	−5.1	6	22.6	orien	FH
Kim et al.	2014	97	9	Retro	IV	Vertical reduction and narrowing (inverted V-shape osteotomy)	Only genioplasty	Rigid	NR	Yes	−6 (4–8)	15	26.7 (20–36)	NR	Frontal photos. Lateral and frontal radiographs

The column “Pedicled” indicates whether suprahioid muscles were preserved (yes) or reflected/detached from the bony chin (no).
The column “Gender” indicates number of male patients of each study.
Numbers inside parenthesis (–) indicate a range of values.
Negative numbers indicate setback movement along the y axis.
Abbreviations: N (number of patients), F–U (follow-up), m (months), LOE (level of evidence), Magn (magnitude of movement), y (years), Retro (retrospective), Prosp (prospective), NR (not reported), BSSO (bilateral sagital split osteotomy), Mx (maxilla), mm (millimeters), SD (Standard Deviation), mest (mestizo), orien (oriental), FH (Frankfort Horizontal), inf (inferior).

setback genioplasty in 22 Korean patients. The effect of the genioplasty was analyzed independently. They found a ratio of −0.68:1.

With respect to the mentolabial fold, Hohl and Epker (1976) reported a slight flattening. B varied slightly. sB moved anteriorly (mean 1.4 mm). Park et al. (2013) reported a soft tissue increase in the mentolabial fold of 102% 1 year postoperatively.

The lower lip appeared to become slightly more prominent by 1 mm at labrale inferius anterior (Lia), although there was barely no change in incisor position (Hohl and Epker, 1976). Park et al. (2013) found that Li followed the tip of the lower incisor (IIi) at a ratio of 0.86:1.

Park et al. (2013) found that changes in the vertical position of sMe were statistically nonsignificant, but the horizontal movement of sMe showed a moderate correlation, with a ratio of 1.1:1 (sMe:Me), which means that sMe advanced more than Me.

3.3. *Chin extrusion (“downgrafting”)*

Three publications report data concerning soft-to-hard tissue ratios after chin extrusion (Table 3). A total of 32 patients were analyzed for chin extrusion. The amount of extrusion ranged from 3 mm to 8 mm (mean 4.75 mm). Ratios of soft tissue to bony movement ranged from 0.89:1 to 1:1, with a mean of 0.95:1 (sMe:Me) in the *y* axis. The mean vertical sPg:Pg was 0.83:1. Rosen (1988) interposed an alloplastic material (a block of porous hydroxyapatite) for vertical height augmentation, and found a 0.89:1 ratio (sMe:Me). Autologous iliac bone grafting was used by Wessberg et al. (1980) and Kim et al. (2005). Although Wessberg et al. (1980) was the first author to report a soft-to-hard tissue ratio after “downgrafting” surgery (1:1), he analyzed only one patient. Kim et al. (2005) reported on extrusion surgery results in 23 patients. However, maxillary impaction or mandibular setback/advancement surgery or angle reduction were performed concomitantly. To avoid interferences of maxillary impaction movements with the calculation of sMe:Me, the occlusal plane was used as a reference. These authors found a 0.96:1 vertical sMe:Me ratio at postoperative 6 months with a high correlation ($r = 0.74$, $p < 0.01$).

3.4. *Chin intrusion (“impaction”)*

Seven studies up-to-date report data regarding soft to hard tissue ratios after chin intrusion surgery (Table 4). A total of 191 patients were analyzed for chin intrusion. The amount of vertical movement ranged from 0.9 mm to 7.9 mm (mean 5.35 mm). Six studies took Me as the reference hard tissue landmark to assess chin intrusion, and 1 study took Gnathion (Gn) as a reference landmark. sMe followed the vertical movement of Me in a ratio ranging from −0.22:1 to −0.80:1 (mean −0.43:1), and stomion inferius (Stoi) followed Me at a ratio of −0.41:1 (Van Butsele et al., 1995). sPg followed Pg vertically at a mean ratio of −0.78:1. sGn followed Gn vertically with a ratio of −0.48:1 (Kim et al., 2014).

Hohl and Epker (1976), Dann (1987) and Díaz Fernández et al. (2003) studied patients who underwent both chin impaction and retrusion surgery. Hohl and Epker (1976) reported a sMe:Me ratio of −0.22:1. Dann (1987) reported a ratio of 0.8:1 ($r = 0.77$; $p < 0.005$) in 32 patients who underwent rotation reduction genioplasty. The mean amount of reduction was not mentioned. Krekmanov and Kahnberg (1992) reported a ratio of −0.67:1 vertical change of sPg:Pg, with a vertical reduction of the chin of 4–6 mm (mean 5.9 mm) and a ratio of −0.35:1 vertical change of sMe:Me; the horizontal sPg:Pg did not change. Van Butsele et al. (1995) reported a ratio of −0.4:1 (Stoi/Me), after vertical height reduction (concomitant to chin advancement), with a mean 0.9 mm vertical bone reduction. This means that Stoi followed the upward

Table 5
Soft-to-hard tissue ratios for advancement/augmentation genioplasty.

Advancement genioplasty ratios								
Authors	Year	Technique	Li/Ili (x)	sB (x)[a]	sPg:Pg (x)	sPg:Pg (y)	sMe:/Me (y)	Submental angle[b]
Bell and Dann	1973	Sliding genioplasty			0.6			
		Silicone implants			0.57			
Dann and Epker	1977	PTFE implants			0.9			
McDonnell et al.	1977	Horizontal osteotomy			0.75			
Busquets and Sassouni	1981	Horizontal osteotomy	44		0.8			
Gallagher et al.	1984	Horizontal osteotomy		−2.5 (SD 1.7)	0.87			−22.7
Tulasne	1987	Overlapping bone graft			0.75			
Wittbjer and Rune	1989	Sliding genioplasty + bone graft			0.94			
Park et al.	1989	Horizontal osteotomy			0.97			
Polido et al.	1991	Horizontal osteotomy			0.88			
Vedtofte et al.	1991	Sliding genioplasty			0.53			
		Sliding genioplasty			0.92			
Ewing and Ross	1992	Sliding genioplasty +2 chin impaction	50		0.9			
Krekmanov and Kahnberg	1992	Sliding genioplasty			0.93			
De Freitas et al.	1992	Sliding genioplasty			0.9	0.90		
Van Sickels et al.	1994	Horizontal osteotomy			0.92			
Talebzadeh and Pogrel	2001	NR			0.75			
Shaughnessy et al.	2006	Horizontal osteotomy + bone graft		−1.8	0.9		0	
Mohammad et al.	2010	Sliding genioplasty			0.87			
		PE Implant			0.78			
Park et al.	2010	Sliding genioplasty			0.93			
		PE implant			0.99			
Erbe et al.	2011	Sliding genioplasty		−0.7(SD 1.08)	0.97			
Reddy et al.	2011	Horizontal osteotomy		−1.14	0.89		0	−17
Seifeldin et al.	2014	Sliding genioplasty		−0.9 (SD 0.3)	0.83			
		Chin shield osteotomy		−0.2 (SD 0.5)	0.99			

Numbers are in % mode.
x: x axis (horizontal axis in sagital view).
y: y axis (vertical axis in sagital view).
Abbreviations: SD (Standard Deviation).
[a] mm of mentolabial fold deepening (negative sign indicates deepening).
[b] Degree (°) of submental angle (negative sign indicates decrease of the value).

Table 6
Soft-to-hard tissue ratios for setback genioplasty.

Setback genioplasty ratios										
Author	Year	Technique	Li/Ili(x)	sB/Ili (x)	sB:B (x)	sB:B (y)	sPg:Pg (x)	sPg:Pg (y)	sMe:Me (x)	sMe:Me (y)
Hohl and Epker	1976	(9 ostectomy/2 anterior recontouring) + impaction	+1[a]		+1.4[a]		−0.27			
Bell et al.	1981	Modified horizontal osteotomy			+0.0[a]	−1.5[a]	−0.58			+0.1[a]
Dann	1987	Sliding setback + impaction					−0.7			0.8
Krekmanov and Kahnberg	1992	Sliding setback horizontally					−0.53			
Yang et al.	2012	Sliding with slope					−0.36	0.62	0.67	1.04
Park et al.	2013	Sliding setback horizontally	0.86	0.9	0.83	0.7	−0.68		0.98	1.12

x: x axis (horizontal axis in sagital view).
y: y axis (vertical axis in sagital view).
Negative sign indicate setback movement onto the x axis.
[a] mm of movement (positive sign indicates movement opposed to the setback).

movement of the Me by a ratio of −0.4:1. Díaz Fernández et al. (2003) analyzed 23 impaction and retrusion genioplasties and found a sMe:Me rof 0.80:1, higher than previous studies. Sixteen patients also underwent BSSO. Only one author group (Ho et al., 2012) studied thoroughly sMe:Me after vertical height reduction. They found −0.35:1 with a mean of 5.1 mm vertical osseous chin reduction. However, as the correlation coefficient was 0.11 and did not reach statistical significance, it was not possible to see any

Table 7
Soft-to-hard tissue ratios for extrusion genioplasty.

Extrusion genioplasty ratios				
Author	Year	Technique	sPg:Pg (x)	sMe:Me (y)
Wessberg et al.	1980	Downgrafting with Iliac bone graft	0.75	1.00
Rosen	1988	Downgrafting with HA block		0.89
Kim et al.	2005	Downgrafting with iliac bone graft 8/23 downgrafting + advancement genioplasty	0.91	0.96

x: x axis (horizontal axis in sagital view).
y: y axis (vertical axis in sagital view).

Table 8
Soft-to-hard tissue ratios for impaction genioplasty.

Impaction genioplasty ratios										
Authors	Year	Techniques	Mentolabial angle[c]	sB:B (x)[a]	sB:B (y)	sPg:Pg (x)	sPg:Pg (y)	sGn:Gn (y)	sMe:Me (y)	sMe:Stoi (y)
Hohl and Epker	1976	9 Horizontal ostectomy 2 Anterior recontouring							−0.22	
Dann	1987	Genio setback + impaction				−0.70			−0.8	
Krekmanov and Kahnberg	1992	Horizontal ostectomy					−0.67		−0.35	
Van Butsele et al.	1995	Genio impaction and advancement								0.4
		Genio impaction and advancement + mx impaction								0.42[d]
Díaz Fernández et al.	2003	Genioplasty impaction and setback		1 mm		−0.97	−0.89		−0.8	
Ho et al.	2012	Genio impaction only	−16.9	−1.2 mm	0.38		−0.79		−0.36	
Kim et al.	2014	Vertical reduction and narrowing (inverted V-shape osteotomy)						0.48[b]		

Negative sign indicate upper movement onto the y axis.
x: x axis (horizontal axis in sagital view).
y: y axis (vertical axis in sagital view).
[a] mm of movement.
[b] Subnasale to bony gnathion.
[c] Magnitude expressed in degrees (negative sign indicates decrease of the value of the angle).
[d] Regression equation.

correlation between the changes in sMe and the superior movement of Me. The same authors found that sPg followed vertically Me in 0.79:1, but there was a nonsignificant correlation. Kim et al. (2014) studied 97 patients in whom mandibular contouring surgery was performed. The contouring consisted in narrowing and impaction of the chin, by using an inverted V-shaped osteotomy. They found a −0.48:1 ratio (sGn:Gn).

The depth of the mentolabial fold after chin impaction showed an increase by 1.28 mm when only impaction was performed (Ho et al., 2012). When impaction was performed along with chin setback, however, there was a flattening of the mentolabial fold (Díaz Fernández et al., 2003).

Díaz Fernández et al. (2003) reported that lower lip length was reduced by 4.3 mm, which created a more protrusive and thickened lower lip, which in turn prevented it from moving backwards. The upper lip turned out to be more prominent also. Ho et al. (2012) also found an increase in lower lip thickness, by a net amount of 1.6 mm. Hohl and Epker (1976) reported a mean anterior and inferior movement of the lower lip of 3.4 mm and 1 mm, respectively.

4. Discussion

Soft tissue changes following sliding advancement genioplasty depend on several factors, which include the type of incision, the detachment of the musculo-periosteal pedicle, the amount of advancement, the presence of other maxillo-mandibular surgeries, the type of fixation, the phenomenon of bone remodelling, the use of bone grafting (Wittbjer and Rune, 1989; Shaughnessy et al., 2006), any vertical movement (Van Sickels et al., 1994; Van Butsele et al., 1995), and probably other factors.

In the early days, the symphysis was completely degloved. Currently the incision is performed midway between the depth of the labial vestibule and the vermillion border to avoid scar contracture, which could induce resorption of the repositioned chin segment (Polido et al., 1991; Bell et al., 1981).

The mentalis muscle is the sole elevator of the lower lip and chin, and it provides the major vertical support for the lower lip. If the muscle is stripped or not reconstructed after transection, chin ptosis and labial incompetence may result (Strauss and Aubaker, 2000; Mommaerts, 2013a). Polido et al. (1991) asserted that scar contracture might cause decreased soft-tissue thickness when complete stripping is done.

Several authors showed that when the suprahyoid muscle pedicle was not detached during sliding genioplasty, the soft tissues followed the hard tissues closely (Wittbjer and Rune, 1989; Polido et al., 1991; Reddy et al., 2011; Park et al., 1989). Vedtofte et al. (1991) compared two groups of patients who underwent sliding genioplasty. One group of 14 patients had a detachment of suprahyoid muscles, and another group of 11 patients had the pedicle preserved. There was a greater bone resorption in the first group (30.9% bone resorption) compared to the second group (11% bone resorption). The sPg/Pg was 0.53:1 in the group with the detached suprahyoid pedicle and 0.92:1 in the group with preserved pedicle.

When soft tissue response to movements of the hard tissue greater than 8 mm and less than 8 mm were compared, a significant difference was found (Van Sickels et al., 1994), in the sense that the more the hard tissues were sagitally advanced, the less the soft tissue moved proportionally with it. This could also explain the low sPg:Pg of 0.7:1 found by Tulasne (1987), who performed an overlapping ("jumping") genioplasty, which meant an advancement of 10–12 mm. In contrast, Talebzadeh and Pogrel (2001) showed no significant difference in bony resorption between the groups with a small or a large advancement.

Studies have shown that interosseous wire fixation usually affords good stability (Mc Donnell et al., 1977; Scheideman et al., 1981; Aravind and Venkataraman, 2011), but the possibility of posterior and inferior displacement of the advanced chin segment has been postulated by several authors (Scheideman et al., 1981; Wittbjer and Rune, 1989; Tulasne, 1987; DeFreitas et al., 1992). It has been postulated that the use of wire osteosynthesis can result in less accurate advancement (Wolford and Bates, 1989). Shaughnessy et al. (2006) reported that the patients fixated with wires had a tendency toward greater relapse than those fixed with plates, although the differences were not statistically significant. Reyneke et al. (1997) and Talebzadeh and Pogrel (2001) found no difference in relapse rate for advancement genioplasty with various amounts of advancement. Aravind and Venkataraman (2011) compared wire fixation (five patients) with rigid fixation (five patients) and found that the difference between the groups was statistically insignificant. The issue of whether the type of fixation, wire, or plates/screws can directly affect soft-to-hard tissue ratios has not been clarified. Apart from bony changes due to segmental instability, changes caused by bone remodelling can also be found. The sites of bone deposition are the anterior surface of the mandible above the osteotomy site and the posterior part of the segment between the mandible and the advanced chin. This bone remodelling contributes to the smoothening of the osteotomy edges. Remodelling patterns of the advanced segment never showed any evidence of inferior rotation or displacement of the body of the chin in the postoperative evaluation (Reddy et al., 2011; Mc Donnell et al., 1977; Park et al., 1989; Bell and Dann, 1973; Shaughnessy et al., 2006).

As a more accurate predictor of soft tissue changes in orthognathic surgery, multiple regression analysis has been used. Van Sickels et al. (1994) and Van Butsele et al. (1995) showed that when the combination of initial bony vertical and horizontal movement was used as a predictor of soft tissue movement in a multiple regression analysis, the correlation between bony and soft tissue movement increased significantly.

The benefits of osseous genioplasty over alloplastic augmentation are preservation of the normal chin contour, increased predictability of the soft tissue response (Mohammad et al., 2010), increased stability, and versatility (e.g., intrusion surgery). Bone resorption underneath silicone implants can occur, probably due to micro-movements of the implant in the postoperative period (Robinson and Shuken, 1969). Mohammad et al. (2010) found no bony resorption in their group with PE implants, whereas in the sliding genioplasty group, bone resorption averaged 1.33 mm after 6 months. PE implants are fixed with titanium screws, whereas silicone implants are usually placed in a pocket between bone (or periosteum) and the soft tissues, without any rigid fixation. In line with the previous study, Park et al. (2010) concluded that the patients to whom PE implants were placed showed also smaller soft tissue relapse. They found that compared with the patients who underwent genioplasty with PE the relapse rate of soft tissues was smaller (14% versus 18%, respectively).

Chin retrusion alone usually does not provide good cosmetic results, because there is flattening of the mentolabial fold, increase of submental ptosis and a fleshy appearance with loss of definition (Hohl and Epker, 1976; Hoffmann and Moloney, 1996; Park et al., 2013; Mommaerts, 2013a). This procedure should be performed with caution in patients with a small mentolabial fold depth and could indicate a strategy of clockwise rotation of the mandible or bimaxillary complex (Mommaerts et al., 2004, 2010). To avoid this drawback, the posterolateral portions of the mobilized segment can be shortened, or a rotational or angular osteotomy divergent toward the base of the mandible can be performed (Park et al., 2013), and redraping by liposuction can be considered.

According to Bell et al. (1981), the low soft-to-hard tissue ratio obtained after chin setback surgery (a mean of −0.52:1 in this review) could be explained by several factors, such as vestibular scarring, excessive detachment of the soft tissue from the chin, myotomy, improper closure of the soft-tissue incision or application of pressure dressings, and concomitant maxillary and mandibular surgical procedures.

Only three articles on chin extrusion surgery with data regarding soft-to-hard tissue ratios could be found. The soft tissue seemed to follow the hard tissue, with results similar to those for chin advancement. Since the mobilized segment has to be positioned downward, a gap between the two bony fragments must be filled if contact is lost. Although iliac bone graft is said to be prone to resorption, the high ratios found by Kim et al. (2005) suggest that resorption rate is low. The use of autologous iliac bone graft appeared to give higher ratios (0.96:1 and 1:1) (Kim et al., 2005; Wessberg et al., 1980) compared to nonautologous graft placement (0.89:1) (Rosen, 1988). Prospective studies are needed to assess this statement.

As for chin impaction, ratios remain low compared to chin advancement or chin extrusion, although it follows the line of the results obtained for chin setback. Since the bony chin moves up, soft tissue can be stretched by gravity and can follow the bone to a lesser degree. Strained orbicularis oris and mentalis muscle can relax, causing soft tissue drop.

5. Conclusion

Articles dealing with soft tissues changes after chin narrowing and expansion are lacking. There is spares documentation of intrusion and extrusion surgery. Advancement and extrusion movements of the chin segment show respectively a 0.9:1 of sPg:Pg horizontally and 0.95:1 of sMe:Me vertically. Setback and impaction movements show respectively a −0.52:1 of sPg:Pg horizontally and −0.43:1 of sMe:Me vertically. Several factors reported in this article are linked to a better predictability.

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