

Lip Morphology and Aesthetics: Study Review and Prospects in Plastic Surgery

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Abstract The lip profile plays an important role in the perception of facial aesthetics; lip morphology and aesthetics research is receiving increasing attention. The advancement of research tools such as three-dimensional imaging technology has led to the clarification of lip morphologic and aesthetic characteristics. After studies of lip characteristics according to gender, ethnicity and age provided basic data, studies on lip aesthetics have been conducted by scholars worldwide. These studies could provide a basic theory to support diagnosis and treatment options, as well as the basis for evaluative criteria for precise treatment and technical improvements. According to the conclusions of the above studies, new ideas for cosmetic surgery design, including lip, perioral and labial–facial relationships, have been discovered.

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Keywords Lip morphology · Lip aesthetics · Lip measurement · Gender · Ethnicity · Age · Preoperative planning

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Introduction

The lip profile plays an important role in the perception of facial aesthetics [1, 2]. Conditions such as congenital deformities, trauma and tumors can not only impair patients' normal appearance but also affect normal functions, including vocalization, mastication and emotional expression [3]. For patients with disfigurements, an appropriate surgical treatment plan should take function and morphology into account and alleviate both physical and psychological damage [4]. Some patients' facial aesthetics could also be improved through lip cosmetic surgery or minimally invasive surgery (injection) [5]. Research on lip morphology and aesthetics, including lip, perioral and labial–facial relationships, could provide a basic theory to support diagnosis and treatment options, as well as a basis for evaluative criteria for precise treatment and technical improvements.

Lip Measurement Tools

Early research on lip morphology and aesthetics was mainly based on two-dimensional (2D) imaging tools, such as standardized photographs and X-ray cephalometric analysis. However, 2D imaging methods cannot identify curves and surfaces or the protrusion and depression of the lip. These limitations made it difficult for people to evaluate the surgical outcomes precisely, especially with regard to volume calculations [6]. Although computed tomography (CT) and magnetic resonance imaging (MRI) can easily acquire 3D lip data, soft tissue deformation between the standing/sitting and lying position could cause errors in lip morphology measurements. In recent years, 3D surface imaging systems have gained popularity worldwide. Their

ability to capture 3D images, including both shape and texture information with multiple environments and arbitrary body posture, has made them some of the most important tools for plastic surgeons [7–9]. Moreover, some scholars have attempted to use a 3D motion capture system (Di4D) to build a time sequence of 3D models and explore dynamic lip characteristics [10].

This article summarizes the changing trends in the research methodology used to investigate lip morphology and aesthetics as they have transitioned from 2D to 3D and from static to dynamic. The advancement of research tools and methods has led to the clarification of lip morphologic and aesthetic characteristics, which further provides a theoretical basis for clinical practice.

Lip Anthropometric Measurements

As we mentioned above, lip characteristics have often been studied as part of the anthropometric features of the human face. Carey et al. [11] summarized the basic anatomical landmarks and defined the morphological terms that provide a standardized reference for relevant research. Farkas et al. [12] noted that to treat congenital or acquired facial disfigurements in members of various races/ethnic groups successfully, surgeons require access to craniofacial databases with accurate anthropometric measurements. Subsequently, Weinberg et al. established the 3D Facial Norms (3DFN) database, which consists of data of 2454 male and female participants ranging in age from 3 to 40 years. Sex- and age-specific summary statistics and growth curves for every anthropometric measurement in the 3DFN dataset are provided as a supplement, which aids clinicians in the assessment of craniofacial dysmorphology (Fig. 1) [13, 14]. In China, Li Yong-lan et al. [15] investigated 330 males and 357 females in Zhejiang Province and compared the data obtained with the measurements of other Chinese ethnic groups. Based on this analysis, they noted several unique anthropometric facial features of Zhejiang Han. Additionally, there have been attempts to establish a 3D facial database to help future studies [16]. As the sample size of the database grows, it will be increasingly helpful for plastic surgeons who seek to achieve a better understanding of lip characteristics.

Studies of Lip Characteristics

Lip characteristics are not only part of the anthropometric features of the human face but also have intrinsic features, which need comparative studies in different groups to be identified. Thus far, these studies have mainly focused on gender, ethnicity and age.

Gender Characteristics

Using cross-sectional data derived from the 3D Facial Norms data repository, Kesterke et al. [17] conducted a study on the sexual dimorphism of craniofacial soft tissue morphology, which showed that definitive adult male and female facial shapes are present following puberty and that the reduction in the relative height of the vermilion border of the lower lip was more pronounced in males. Sforza et al. [18] collected the 3D coordinates of seven landmarks of facial soft tissues from 654 healthy native Northern Sudanese subjects (327 males and 327 females, aged 4–30 years) and calculated five angles and two linear distances. The results demonstrated that sex had a significant effect on the mentolabial and maxillary prominence angles, and both those angles and the upper and lower lip distances from Ricketts' E-line were also significantly larger in male subjects. According to Weinberg et al., increased prenatal androgen exposure might be related to a more masculine facial phenotype, which is associated with increased upper and lower lip projection [19].

Ethnic Characteristics

Wong et al. [20] measured the lips of 197 male and female Caucasian, Chinese, and Korean subjects using surface imaging technology (Fig. 2). Caucasian upper lips were discovered to be thinner, and Chinese females had more curved cupid's bow lips with thicker lower lips, which was consistent with the prevalent image of Eastern people. Mouth width also displayed diversity according to ethnicity; mouths were significantly wider in Hungarian subjects and narrower in Vietnamese subjects than in those of other ethnicities included in the study. Ioi et al. [21] evaluated the influence of vermilion height on the assessment of lip attractiveness by Japanese and Korean orthodontists and orthodontic patients.

Age Characteristics

The change in the morphologic features of the lip is one of the most significant characteristics of facial aging. Rosati et al. [22] noted that with increasing age, the smile becomes elongated and less appealing due to the reduced labial appearance of flat lips in the older group. Similarly, a study by Gibelli et al. [23] demonstrated that young subjects always showed higher measurements than old subjects and that lower lip thickness was the metric that provided the highest percentage of correct age identification (Fig. 3). Moreover, studies by Chinese scholars demonstrated that changes in the aging lip could be identified as an increase in length, a decrease in thickness, vermilion atrophy and ptosis of the labial angle [24, 25].

Upper Lip Height

Landmarks Involved

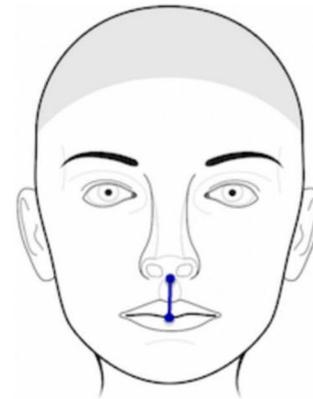
- **Subnasale (sn):** Midline point marking the junction between the inferior border of the nasal septum and the cutaneous upper lip. It is the apex of the nasolabial angle.
- **Stomion (sto):** Midpoint of the labial fissure.

Measurement Description

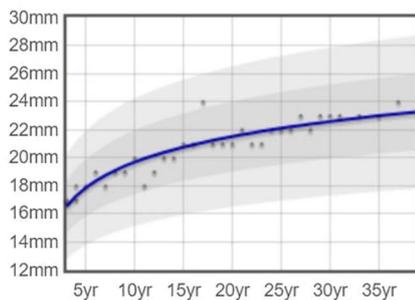
Vertical measurement designed to capture the length/height of the entire upper lip including the skin and vermilion segments. Other common names for this measurement include: total upper lip height/length.

Measurement Method

Inter-landmark distance calculated from 3D stereophotogrammetry.

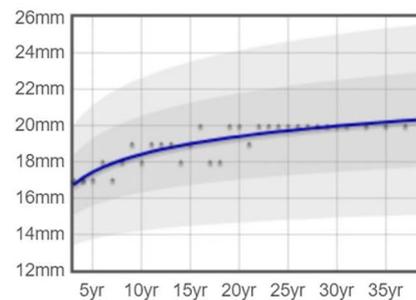


Males



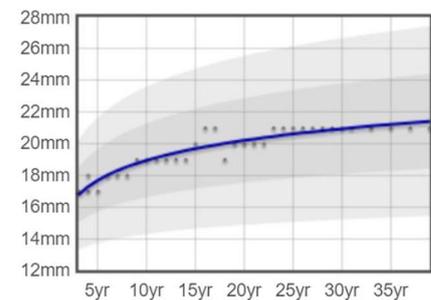
Age	N	Mean	S.D.
3	11	17.13	1.68
3.5	18	17.7	1.54
4	12	17.87	2.07
4.5	11	18.61	2.2
5	25	18.47	1.83

Females



Age	N	Mean	S.D.
3	13	17.37	2.03
3.5	18	17.64	1.78
4	13	17.94	1.48
4.5	7	17.79	1.3
5	21	17.26	1.73

Combined



Age	N	Mean	S.D.
3	24	17.26	1.84
3.5	36	17.67	1.64
4	25	17.91	1.75
4.5	18	18.29	1.9
5	46	17.92	1.87

Fig. 1 Partial screenshot from the 3D Facial Norms Web site interface (<https://www.facebase.org>) showing relationship between upper lip height and age. Users can download summary statistics tables for all measurements in the database as a .csv file

From the above information, we can conclude that most studies about the characteristics of the lip have been based on measurements of certain populations. Verifying different types of lip metrical characteristics could provide indications for reconstructive and aesthetic surgery.

Studies of Lip Aesthetics

Kim et al. [26] evaluated the facial dimensions of young adult women with a preferred facial appearance and compared the results with those from the general population.

They concluded that the Miss Korea group had longer and more retruded lower lips and chins, larger lip vermilion areas and smaller labiomental angles, while Jang et al. [27] obtained similar results through 3D imaging analysis. Galantucci et al. [28] measured the soft tissues of the faces of Caucasian women using noninvasive three-dimensional relief methods and determined that low face attractiveness was closely related to the mouth width and interlabial angle.

While the objective laws of lip aesthetics can be discovered through morphologic studies, the subjective standards may be different in certain groups of individuals for

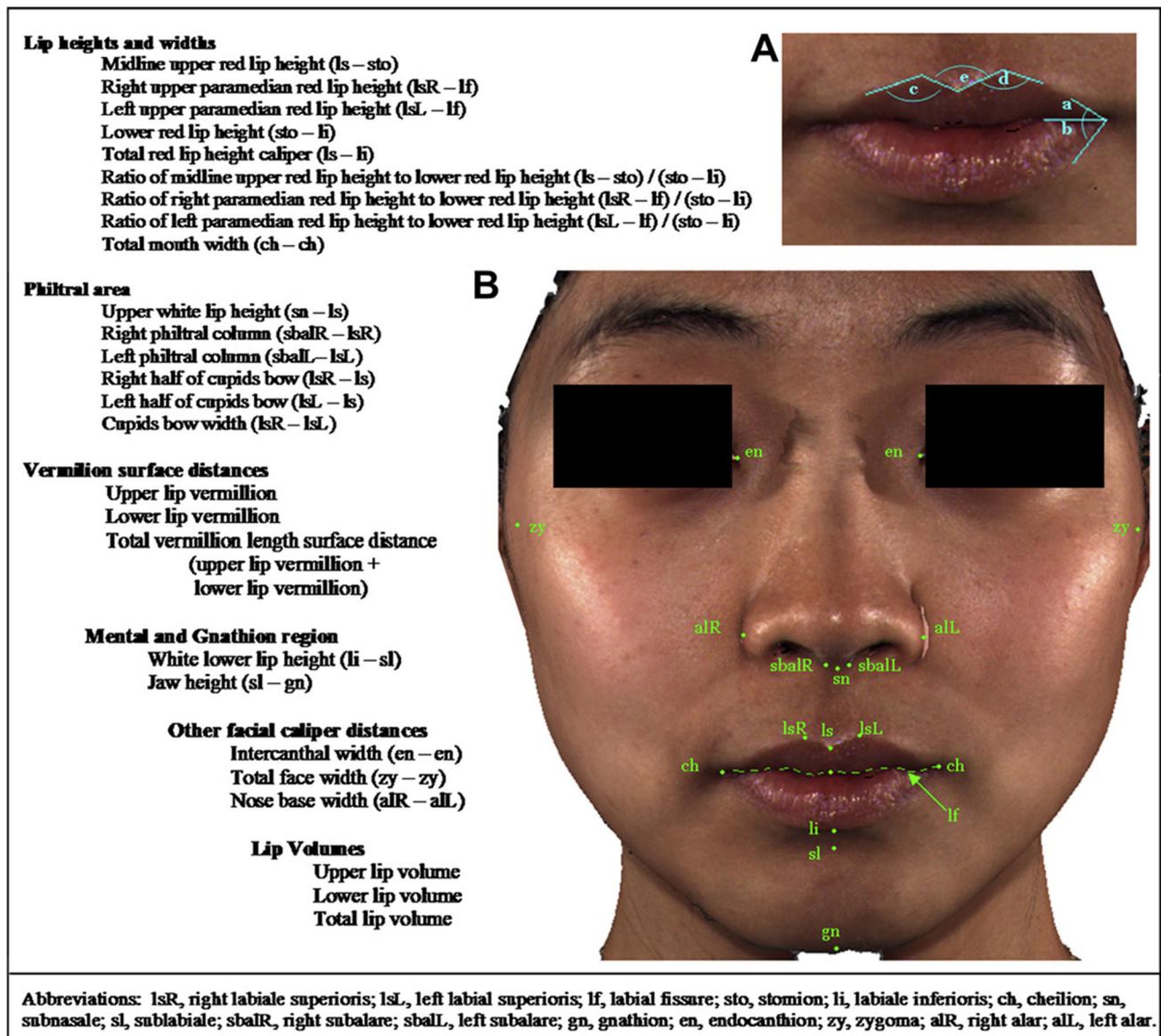


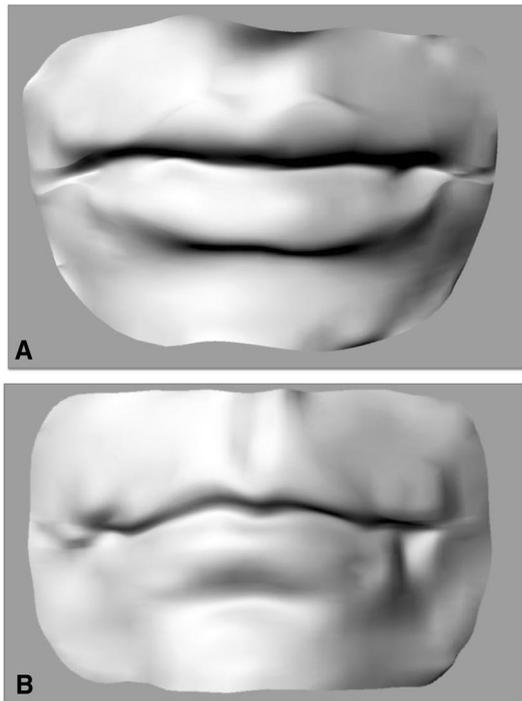
Fig. 2 a Lip angles measured: a upper lip angle; b lower lip angle; c right cupid's bow angle; d left cupid's bow angle; e central bow angle. b Facial and lip landmarks used for measurements. Reprinted from Wong et al. [20]

particular reasons [29]. For example, Shimomura et al. [30] found that orthodontic patients tended to prefer a slightly retruded lip position over the average facial profile. Interestingly, according to Dong et al., half of the patients in their study underwent a central lip lift for facial physiognomic improvement in Asia [31]. Hence, they concluded that in today's multiracial society, plastic surgeons planning a central lip lift in Asian patients should consider both aesthetic and physiognomic perspectives.

Moreover, Westerners are more interested in pursuing the fullness of lips than Asians. Unrealistic expectation of lip injection outcome could lead to "sausage" or "duck" lip [32]. By contrast, Asians prefer exquisite and curvaceous lips. Exaggerated lip characteristics are less accepted

in Asians than in Westerners. The ideal ratio of upper and lower lip is 1:1.6 [33], which is almost exactly in line with the phi ratio. Interestingly, the upper and lower lip ratio in attractive Asians is 1.43 [27], which fits in with the $\sqrt{2}$ rule [34].

There is no difficulty in observing that there is a diversity of morphologic features in certain groups of people from the information presented above. Moreover, the public evaluation of aesthetics could involve social factors and cultural background. A thorough understanding of those factors could be helpful for plastic surgeons seeking to achieve individualized treatment of certain patients [35].



	Young Mean (SD)	Old Mean (SD)	p-value Student's t
Upper area (mm ²)	487.5 (100.0)	438.5 (84.1)	0.102
Lower area (mm ²)	531.7 (99.2)	453.5 (98.3)	0.017
Upper volume (mm ³)	2101.3 (673.1)	1983.9 (586.8)	0.56
Lower volume (mm ³)	2357.0 (860.0)	1827.6 (695.5)	0.039
Upper thickness (mm)	10.5 (1.5)	9.0 (1.6)	0.003
Lower thickness (mm)	16.4 (4.2)	10.8 (1.7)	<0.001

Fig. 3 Above, two examples of a 3D model of lips from a young (a) and an old (b) subject; below, mean and standard deviation for each measurement performed in young and old subjects. Reprinted from Wong et al. [20]

Discussion: Clinical Applications

Lip Rejuvenation

Studies of aging characteristics have provided a theoretical basis for lip rejuvenation. In recent years, several modified procedures have been reported that could achieve better outcomes, such as the endonasal lip lift technique by Raphael et al. [36], the upper lip lift with a “T”-shaped resection of the orbicularis oris muscle [37] and the angulus oris lip lift by Pan et al. [38]. Moreover, as Dong et al. [31] mentioned in a retrospective chart review performed with 202 Asian patients, a long philtrum was primarily caused by bone retraction after an orthognathic surgery or orthodontic procedure, while in Westerners, it was mainly caused by the aging process. This difference

could partially explain the lower age of Asian people seeking lip rejuvenation. From the above information, we can conclude that the reasons behind the appearance of an aging lip vary in different patients. A systemic approach and standard procedure to solve this problem are still under exploration.

Smile Aesthetics and Gummy Smile Treatment

Smile aesthetics have received increasing attention in the practice of both dentistry and plastic surgery. A number of characteristic features have been described to formulate a standard smile, including smile type, gingival contour and buccal corridor [29]. While dentists are mainly focused on teeth and gingiva, much attention has been paid to lip morphologic characteristics by plastic surgeons because of their important functions [39]. The treatment of gummy smile can be taken as an example. As one of the common types of unattractive smiles [40], gummy smile has complex etiologic factors. While some patients can be treated through periodontal, orthodontic and orthognathic treatment [41], those with abnormal muscle strength and morphologic characteristics of the upper lip must undergo revision of the dynamic appearance of the soft tissue. In recent years, lip repositioning surgery and its modified procedures have been introduced to treat gummy smile [42–44]. Tawfik et al. have reviewed the literature on this topic. The result suggested that the technique could be used successfully to treat gummy smile, although more studies were necessary to properly evaluate the treatment approach and the stability of the technique [45]. Moreover, Sucupira et al. [46] treated 52 patients with botulinum toxin A injection and obtained satisfactory results. The above studies have demonstrated the important roles that lip morphologic characteristics play in smile aesthetics and related treatments. The intrinsic laws underlying smile aesthetics are being investigated, and the standard features of lip morphologic characteristics still need further evaluation.

Lip Aesthetics and Preoperative Planning

When planning lip surgery, in addition to the appearance of the lips, several other factors should also be taken into consideration, such as their relationship with the nose, chin, cheek and whole face. For example, when consulting with a patient who complains of “mandibular protrusion,” the surgeon may be confronted with a choice between osteotomy of the mandible or simply increasing the lip protrusion through soft tissue filler injection. Comparing the patient’s 3D photographs with the repository of “attractive faces” might be helpful in determining which is the better choice.

Conclusions

The lip profile plays an important role in the perception of facial aesthetics. Although people already have an essential understanding of lip morphology and aesthetics, there are still many questions to be answered in this field. The advancement of imaging tools and methods can be helpful in determining the answers to these questions and providing a theoretical basis for clinical practice.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflicts of interest to disclose.

References

- Eisenbarth H, Alpers GW (2011) Happy mouth and sad eyes: Scanning emotional facial expressions. *Emotion* 11(4):860–865
- Park JU, Hwang YS (2008) Evaluation of the soft and hard tissue changes after anterior segmental osteotomy on the maxilla and mandible. *J Oral Maxillofac Surg* 66(1):98
- Naini FB (2011) *Facial aesthetics: concepts and clinical diagnosis*. Wiley, London
- Nabili V, Knott PD (2008) Advanced lip reconstruction: functional and aesthetic considerations. *Facial Plast Surg* 24(1):92–104
- Xie YC, Fan JC (2005) Cosmetic surgery of vermilion deformities. *Chin J Aesthet Plast Surg* 16(6):357–359
- Li Y, Yang X, Li D (2016) The application of three-dimensional surface imaging system in plastic and reconstructive surgery. *Ann Plast Surg* 77:S76
- Zhou LX, Guo HM, Bai YX et al (2001) The stereophotogrammetry method for facial soft tissue morphometry. *Beijing J Stomatol* 9(3):132–133
- Kovacs L, Zimmermann A, Brockmann G et al (2006) Three-dimensional recording of the human face with a 3D laser scanner. *J Plast Reconstr Aesthet Surg* 59(11):1193–1202
- Kovacs L, Zimmermann A, Brockmann G et al (2006) Accuracy and precision of the three-dimensional assessment of the facial surface using a 3-D laser scanner. *IEEE Trans Med Imaging* 25(6):742
- Ju X, O’Leary E, Peng M et al (2014) Evaluation of the reproducibility of nonverbal facial expressions using a 3D motion capture system. *Cleft Palate Craniofac J* 53(1):22
- Carey JC Jr., Cohen MM, Curry CJ et al (2009) Elements of morphology: standard terminology for the lips, mouth, and oral region. *Am J Med Genet A* 149a(1):77–92
- Farkas LG, Katic MJ, Forrest CR et al (2005) International anthropometric study of facial morphology in various ethnic groups/races. *J Craniofac Surg* 16(4):615
- Weinberg SM, Raffensperger ZD, Kesterke MJ et al (2016) The 3D facial norms database: Part 1. A web-based craniofacial anthropometric and image repository for the clinical and research community. *Cleft Palate Craniofac J* 53(6):185
- 3D Facial Norms Database (2010) 3D facial norms summary statistics-upper lip height. https://www.facebase.org/facial_norms/summary/#uplipheight/. Updated August 24 2018. Accessed Sept 2018
- Lu SH, Zheng LB et al (2013) Physical characteristics of Zhejiang Han. *Acta Anat Sin* 44(5):707–716
- Yuan FL (2006) The application of 3-D face shape measurement system in medical measurement. Jinan University, Jinan
- Kesterke MJ, Raffensperger ZD, Heike CL et al (2016) Using the 3D Facial Norms Database to investigate craniofacial sexual dimorphism in healthy children, adolescents, and adults. *Biol Sex Differ* 7(1):23
- Sforza C, Dolci C, Gibelli DM et al (2016) Age-related and sex-related changes in the normal soft tissue profile of native Northern Sudanese subjects: a cross-sectional study. *Br J Oral Maxillofac Surg* 54(2):192
- Weinberg SM, Parsons TE, Raffensperger ZD et al (2015) Prenatal sex hormones, digit ratio, and face shape in adult males. *Orthod Craniofac Res* 18(1):21–26
- Wong WW, Davis DG, Camp MC et al (2010) Contribution of lip proportions to facial aesthetics in different ethnicities: A three-dimensional analysis. *J Plast Reconstr Aesthet Surg* 63(12):2032–2039
- Ioi H, Kang S, Shimomura T et al (2014) Effects of vermilion height on lip esthetics in Japanese and Korean orthodontists and orthodontic patients. *Angle Orthod* 84(2):239–245
- Rosati R, Codari M, Maffessanti F et al (2014) The labial aging process: a surface analysis-based three-dimensional evaluation. *Aesthetic Plast Surg* 38(1):236–241
- Gibelli D, Codari M, Rosati R et al (2015) A quantitative analysis of lip aesthetics: the influence of gender and aging. *Aesthetic Plast Surg* 39(5):771–776
- Wang ZF (2008) The study of evaluation criterion in quantity for adult labial aging and its clinical significance. Capital Medical University, Fengtai
- Wang ZF, Chen ZC, Gao S et al (2007) The initial research of evaluation criterion in quantity for adult labial aging. *Chin J Aesthet Med* 16(7):962–965
- Kim SY, Bayome M, Park JH et al (2015) Evaluation of the facial dimensions of young adult women with a preferred facial appearance. *Korean J Orthod* 45(5):253–260
- Jang KS, Bayome M, Park JH et al (2017) A three-dimensional photogrammetric analysis of the facial esthetics of the Miss Korea pageant contestants. *Korean J Orthod* 47(2):87–99
- Galantucci LM, Deli R, Laino A et al (2016) Three-dimensional anthropometric database of attractive caucasian women: standards and comparisons. *J Craniofac Surg* 27(7):1884
- Cui D, Li LJ, Zhou L et al (2017) Aesthetic characteristics of the smile aesthetic-related soft tissues. *Chin J Pract Stomatol* 10(1):1–5
- Shimomura T, Ioi H, Nakata S et al (2011) Evaluation of well-balanced lip position by Japanese orthodontic patients. *Am J Orthod Dentofacial Orthop* 139(4):291–297
- Dong EL, Su WH, Lee JH et al (2015) Central lip lift as aesthetic and physiognomic plastic surgery: the effect on lower facial profile. *Aesthet Surg J* 35(6):698
- Dejoseph LM, Agarwal A, Greco TM (2018) Lip augmentation. *Facial Plast Surg Clin N Am* 26:193–203
- Mandy S (2007) Art of the lip. *Dermatol Surg* 33:521
- Nakajima E, Maeda T, Yanagisawa M (1985) The Japanese sense of beauty and facial proportions. II. The beautiful face and the $\sqrt{2}$ rule. *Quint Int* 9:523
- Lv Y, Zhang XJ (2000) Analysis of facial profile preferences among the Chinese population. *Chin J Stomatol* 35(3):224
- Raphael P, Harris R, Harris SW (2014) The endonasal lip lift: personal technique. *Aesthet Surg J* 34(3):457
- Pan BL (2017) Upper lip lift with a “T”-shaped resection of the orbicularis oris muscle for Asian perioral rejuvenation: A report of 84 patients. *J Plast Reconstr Aesthet Surg* 70(3):392–400
- Pan BL (2016) The corner of the mouth lifting for perioral rejuvenation. *Chin J Plast Surg* 32(2):145–147

39. Ahrari F, Heravi F, Rashed R et al (2015) Which factors affect dental esthetics and smile attractiveness in orthodontically treated patients? *J Dent* 12(7):491
40. Hunt O, Johnston C, Hepper P et al (2002) The influence of maxillary gingival exposure on dental attractiveness ratings. *Eur J Orthod* 24(2):199–204
41. Zheng W, Li Y (2017) New development in the comprehensive multidisciplinary treatment of gummy smile. *Int J Stomatol* 44(5):560
42. Dayakar MM, Gupta S, Shivananda H (2014) Lip repositioning: an alternative cosmetic treatment for gummy smile. *J Indian Soc Periodontol* 18(4):520
43. Gaddale R, Desai SR, Mudda JA et al (2014) Lip repositioning. *J Indian Soc Periodontol* 18(2):254
44. Grover HS, Gupta A, Luthra S (2014) Lip repositioning surgery: a pioneering technique for perio-esthetics. *Contemp Clin Dent* 5(1):142
45. Tawfik OK, Elnahass HE, Shipman P et al (2017) Lip repositioning for the treatment of excess gingival display: a systematic review. *J Esthet Restor Dent* 5:38
46. Sucupira E, Abramovitz A (2012) A simplified method for smile enhancement: botulinum toxin injection for gummy smile. *Plast Reconstr Surg* 130(3):726–728