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Cleft-related nose deformation evaluation and measurement methods. Literature review

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SUMMARY

Introduction. Rhinoplasty for the cleft lip and palate patient is very challenging and surgical outcome of the nose is difficult to evaluate. Discussions of aesthetic evaluation of the nose in cleft lip and palate patients remain problematical. Many different nose aesthetic evaluation methods have been described in the literature; they differ even among articles published in a single year.

Aim. To analyse the literature concerning aesthetic evaluation of the nose in cleft lip and palate patients and to identify the most objective method for such evaluation postoperatively.

Material and methods. The literature was reviewed using MedLine and PubMed sources dated between January 1996 and December 2014. In total, 118 full text articles in English language were selected. Exclusion criteria were: case reports, surgical reviews, literature review, and single evaluations of nasal function.

Results. Measurements were obtained from two-dimensional images in 73 articles. Noses were evaluated from 3D images in 22 and by clinical examination in 15. Other methods were evaluation from dental/facial casts, cephalometric evaluation, computer tomography and video recording. In 26 articles some combination of methods was used.

Conclusions. The most popular evaluation method is still two-dimensional photography and measurements using anthropometric facial landmarks. Measurements from three-dimensional images seem to be the most objective method and automated facial anthropometric landmark protraction seems to hold promise for the future.

Key words: cleft nose/nasal aesthetic assessment, evaluation and measurement methods.

INTRODUCTION

Cleft lip and palate is the most frequent congenital craniofacial deformity with a mean prevalence in Europe of between 1:500 and 1:700 (1). Cleft lip and palate irregularities vary greatly in terms of cleft width and other characteristics. Treatment modalities also differ, depending on the timing of surgery and the technique of reconstruction (2).

As the central feature of the face, the nose has a profound effect on facial aesthetics (3). It is known to be aberrant in appearance and function in patients with cleft lip or a cleft lip and palate. Distortions of the nose range from almost invisible to catastrophic (4). Rhinoplasty for cleft lip and palate patients is very challenging owing to its complex pathology, and also frustrating because the final postoperative outcome is limited (5). Also, the timing and methods of nasal correction differ among clinics.

The surgical outcome regarding nose shape is difficult to evaluate because the shape is complex (6). A literature review by Al Omari (2005) demonstrated no single reliable method for aesthetic evaluation of the nose (7). However, evaluation from three-dimensional photographs seemed promising.

Aim

To analyse the literature concerning aesthetic evaluation of the nose in cleft lip and palate patients and to identify the most objective method for such evaluation postoperatively.

MATERIAL AND METHODS

The literature was reviewed using MedLine and PubMed sources dated between January 1996 and December 2014 using the keywords: cleft nose/

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nasal aesthetic assessment, evaluation and measurement methods. Afterwards, 118 full text articles in English language were selected according to the following exclusion criteria: case reports, surgical reviews, literature reviews and single evaluations of nasal function.

RESULTS AND DISCUSSION

The methods used in articles were: two-dimensional and three-dimensional images, clinical examination, lateral cephalograms, computer tomography, video recording, dental or facial casts (Table 1).

The numbers in the groups examined ranged from 10 to 796. Groups of 10–40 patients were used in 71 cases, 41-100 patients in 35, and over 100 in 12; there was one literature review. A control group was used in 41 articles mostly to compare the patients with healthy individuals or to compare two surgical methods. In 60 articles the number of evaluators was revealed; 47 of these had more than one evaluator.

The statistical methods used in the articles were also noted. In 14 articles no statistical methods were described.

Clinical examination

Clinical examination was used in 15 articles (Table 1), in eight of which they were used together with other methods such as two-dimensional images (3, 8-14) or three-dimensional images (8). Nagy and Mommaerts (2007) proposed that direct anthropometric measurement is most accurate and well accepted by anthropologists, but it is problematical to reproduce, especially in large numbers of patients (9). Also, recall is complicated and could be ineffective and, of course, patients grow during the period between recalls. Furthermore, it is almost impossible to compare the results from different centres (9). The investigation by Al Omari et al (2003) demonstrated differences between assessments of facial deformity clinically and by either two- or three-dimensional imaging (8). Both imaging systems provided more reproducible and reliable methods of assessment than clinical assessment (8). Becker et al. (1998) concluded that clinical evaluation could probably be limited to judging functional aspects and forming a subjective opinion about the nose, the lips, and the whole face (11). This subjective evaluation can then be repeated, using digital photographs if necessary, as all information is stored permanently. They proposed that methods could be complementary (11).

Two-dimensional images

The most popular method for evaluating the nose aesthetically is still two-dimensional imaging; such images were used in 73 articles (Table 1). They were popular even in articles as recent as 2013 and 2014. Among the 73 two-dimensional articles, 20 used combinations of methods. The combinations were various – rhinomanometry (15, 16), computer tomography (17-19) cephalograms (15, 18, 20-22), dental/facial casts (20-25), three-dimensional images (8, 26), and clinical examination (3, 8-14).

Two–dimensional images enable patients to be evaluated consistently after operations involving different techniques. They also have the advantage that digital photographs are stored permanently, so new ideas can be tested on the same series. Now that data communication is worldwide it has the capacity to provide an important tool for multicentre studies that require uniform evaluations on different occasions, in different places, and by independent observers (11).

Three–dimensional images

Three-dimensional evaluation was used in 22 articles of selected (Table 1). In the literature review by Al Omari et al (2005), three-dimensional images were already most highly rated (7) and so they remain. Three-dimensional stereophotogrametry (4, 27-34) and three-dimensional optical scanning (35-39) have been used. Also, three-dimensional coordinates of soft tissue facial landmarks have been obtained using an electromagnetic digitizer (40), a non-contact type semiconductor laser three-dimensional measurement system (41, 42), three-dimensional vision-based capture (43), and a three-dimensional video-based tracking system (44). Three-dimensional symmetry analysis has also been used on nasal plaster casts scanned with an electromagnetic scanner (45).

The main conclusions were that the three-dimensional methods are better for assessing cleft lip and nose surgery (41). Devlin et al (2007) concluded that 3D stereophotogrametry is a non-invasive, accurate and achievable method for assessing facial form and surgical change (30). Nasal symmetry can be quantified and measured reliably with this tool (30). Many authors have indicated that further three-dimensional analysis with more patients will allow surgical techniques for improving face symmetry to be evaluated by wider and more systematic analysis (46).

Cephalograms and computer tomography

Cephalograms and computer tomography were used to evaluate nasal aesthetics in 20 articles. Cephalograms were used in twelve articles (13, 15, 18, 20-22, 39, 47-51) and computer tomography in eight (17-

19, 52-56). In many cases they were combined with other methods. Cephalograms were mostly combined with two-dimensional images (15, 20-22). Ridgway et al (2011) evaluated nasal septum deviation in cleft patients using posterior-anterior cephalography (51). They concluded that this is a simple method and patients are subjected to less radiation than with computed tomography. However, posterior-anterior cephalography gives only a two-dimensional image of the three-dimensional septal deviation. These authors believe that cost and potential risk override the benefits of using computed tomography in children just to determine septal position (51). However, the validity of soft tissue profile measurements from lateral cephalometric radiographs remains unproved (49).

Computer tomography is an excellent method for quantifying and analysing surface and deep craniofacial structures (56). Li et al (2012) compared measurements taken from photographs and cone-beam computerized tomography (CBCT) and concluded that the photograph-CBCT pairing measurement strategy they adopted appeared reliable for evaluating hard-soft tissue relationships in the nasolabial area (17). They noticed that the soft tissue could be camouflaged to some extent by the bone deformities. This is very important for secondary nose corrections (17). Fisher et al (1999) proposed that three-dimensional CT data analysis of the cleft lip nasal deformity offers many advantages over other techniques (54). They imaged infants sedated in a resting state, so there were no muscle movements or extrinsic deforming factors. The images were then viewed in multiple positions and both soft tissue and skeletal landmarks were evaluated. Measurements obtained by this method can be repeated and verified but the accuracy of CT soft tissue measurements remains to be verified (54).

Computer tomography is the only examination method for objective evaluation of nasal septum deviation. Cepahalograms are widely available and used in orthodontics, so the method has long been established.

Video recording

Video recording was used in three articles (44, 57, 58). Trotman et al (2007) used the video-based tracking system to measure the circumoral movements of each participant (44). This system tracks retro-reflective markers secured to specific facial landmarks. In this study, circumoral movements were compared among three groups of participants: a group with repaired cleft lip slated to have revision surgery but who had not yet undergone the surgery; a second group with repaired cleft lip who did not have surgery; and a group of non-cleft participants. These authors concluded that to distinguish reliably between a participant with a repaired cleft of the upper lip and a control participant, many repeated movements are required (44). Morrant and Shaw (1996) used video taping to record 30 cleft patients (57). Recordings were taken from six different angles, during each of which the subject was asked to repeat three phrases and make a series of lip movements. The reliability of the panel ranged from poor to excellent for different features of the lip and nose. These authors concluded that this technique could be useful for quality assurance, inter-centre comparisons or outcome studies of surgical techniques. However, patients must be old enough to cooperate fully and appropriate trained operators are needed to ensure reproducible recording (57). Russell et al (2000) filmed nose casts and analysed nostril structure at the angle of maximum area (58). They concluded they had developed and validated an objective and quantitative method for assessing nostril and nasal morphology in cleft patients (58).

Dental/ facial casts

This method was used in 11 articles of selected (20, 21, 23-25, 45, 58-62), being combined with two-dimensional images in (20, 21, 23-25). Duskova et al (2006) took plaster impressions of the face and evaluated nasal morphology by direct anthropometry on the gypsum casts (60). They noted that this method is objective, measurements of selected parameters are more precise as soft tissues are not deformed, measurements can be repeated and extended as needed, they reflect the three-dimensional contour, and the method is easily available and of low cost (60). In three articles, scanned nose casts were used to evaluate nasal aesthetics (25, 45, 59). There were direct measurements on gypsum casts in other articles (20, 61, 62). Dental arch relationships were also evaluated together with two-dimensional photogrametry or other methods (21, 23, 24).

Combinations

Since none of the methods is perfect, different combinations of methods were used in 23 articles (Table 1). Two articles compared two-dimensional and three-dimensional methods and the results were not clear (8, 61). Four articles compared clinical examination with two-dimensional images (9, 11, 12, 14).

Pitak-Arnnop et al (2011) evaluated the patients' own satisfaction with their nose aesthetics using a questionnaire and evaluation of nose aesthetics

Table. Evaluation methods in articles

Methods	Positive characteristics of methods	Negative characteristics of methods	Authors
Clinical examination	• Accurate • Well accepted by anthropologists	• Subjective • Less reliable • Difficult to reproduce • Impossible to compare results between various centres • Time-consuming for patient and surgeon	Sinko et al. 2005 (2), Z.-J. He et al. 2009 (3), Al-Omari et al. 2003 (8), Nagy & Mommaerts 2007 (9), Reddy et al. 2008 (10), Becker et al. 1998 (11), Hurwitz et al. 1999 (12), Chaithanyaa et al. 2011 (13), Kim et al. 2004 (14), Oosterkamp et al. 2007 (68), Nolst Trenité 2002 (69), Nolst Trenité 2006 (70), Rossell-Perry & Gavino-Gutierrez 2011 (71), Anastassov & Chipkov 2003 (72), Oti et al. 2014 (73)
2D images	• Simple • Economical • Non-invasive • Convenient • Non-ionizing • Widely available • Reliable and reproducible • Long term results stored permanently • Possible to compare two surgical methods separated in place and time • Less patient cooperation and assessment time required • No need for highly trained personnel	• Important proper position • Head orientation • Distortion errors • Lip dynamics cannot be judged • Lighting • Unsuitable for absolute measurements because of magnification • Point chosen can be quite inaccurate • Single two-dimensional slide cannot accurately reflect the whole feature	Z.-J. He et al. 2009 (3), Nolst Trenité et al. 1997 (5), Karube et al. 2012 (6), Al-Omari et al. 2003 (8), Nagy & Mommaerts 2007 (9), Reddy et al. 2008 (10), Becker et al. 1998 (11), Hurwitz et al. 1999 (12), Chaithanyaa et al. 2011 (13), Kim et al. 2004 (14), Anastassov et al. 1998 (15), Huempfner-Hierl et al. 2009 (16), Li et al. 2012 (17), Scopelliti et al. 2013 (18), Alonso et al. 2014 (19), Russell et al. 2009 (20), Tindlund et al. 2009 (21), Brattström et al. 2005 (22), Bongaarts et al. 2008 (23), Kaiser et al. 1996 (24), Russell et al. 2001 (25), Nakamura et al. 2010 (26), Papamanou et al. 2012 (47), Pitak-Arnnop et al. 2011 (63), Roosenboom et al. 2014 (64), Byrne et al. 2014 (65), Pigott & Pigott 2010 (66), Russell et al. 2014 (67), Timoney et al. 2001 (74), Kim et al. 2011 (75), Flores et al. 2009 (76), Mommaerts & Nagy 2008, (77), Lo et al. 2002 (78), Noor & Musa 2007 (79), Gosain & Fathi 2009 (80), Kim et al. 2009 (81), X. He et al. 2009 (82), Li et al. 2010 (83), Chang et al. 2010 (84), Cheon & Park 2010 (85), Gurley et al. 2001 (86), Vegter et al. 1997 (87), Nollet et al. 2007 (88), Fudalej et al. 2009 (89), Daelemans et al. 2006 (90), Fisher et al. 2008 (91), Bearn et al. 2002b (92), Meazzini et al. 2010 (93), Chowchuen, et al. 2010 (94), McComb & Coghlan 1996 (95), Kuijpers-Jagtman et al. 2009 (96), Wong et al. 2002 (97), Kim et al. 2006 (98), Brussé et al. 1999 (99), Mercado et al. 2011 (100), Mulliken & Martínez-Pérez 1999 (101), Reddy et al. 2013 (102), Zaleckas et al. 2011 (103), Ohannessian et al. 2011 (104), Li et al. 2011 (105), Chetpakdeechit et al. 2011 (106), Pai et al. 2005 (107), Smolka et al. 2008 (108), Kyrkanides et al. 1996 (109), Fudalej et al. 2012 (110), Hafezi et al. 2013 (111), Offert et al. 2013 (112), Luyten et al. 2013 (113) Chowchuen et al. 2010 (114), Paiva et al. 2014 (115), Iliopoulos et al. 2014 (116), Chang et al. 2014 (117), Mosmuller et al. 2014 (118)
3D images	• Reliable • Accurate • Safe • Non–invasive • Qualitative • Quantitative • Reproducible • Quick • Non-ionizing • Can be employed on child patients • Enhances the potential for data manipulation • Facilitating record storage and retrieval long term • Digital patient model can be used immediately in a clinical setting	• Expensive equipment and related software • Long time required to prepare the subject and obtain data • Lighting conditions • Non-portable system, • Errors can appear when 3D photographs are reconstructed • The 3D hardware and software have limitations in the reconstruction • The nostrils are regions of error • Inability to measure bony or interactive landmarks	van Loon et al. 2010 (4), Al-Omari et al. 2003 (8), Nakamura et al. 2010 (26), Weinberg et al. 2009 (27), Hood et al. 2003 (28), Hood et al. 2004 (29), Devlin et al. 2007 (30), Zreaqat et al. 2012 (31), Singh et al. 2005 (32), Othman et al. 2014 (33), Bell et al. 2014 (34), Yamada et al. 1999 (35), Duffy et al. 2000 (36), Yamada et al. 2002 (37), Bilwatsch et al. 2006 (38), Verze et al. 2014 (39), Ferrario et al. 2003 (40), Mori et al. 2005 (41), Okawachi et al. 2011 (42), Ayoub et al. 2011 (43), Trotman et al. 2007 (44), Russell et al. 2011 (45)

Table. Evaluation methods in articles (continued)

Methods	Positive characteristics of methods	Negative characteristics of methods	Authors
	• Small errors in placing facial landmarks does not lead to statistically significant differences	• Lack of normative database values for digitized images	
Dental / facial casts	• Easily • Available • Low costs • Objective • Quantitative • Reliable • Precise • Can be repeated and extended • Reflects three dimensional contour • Eliminates soft tissue distortion • No burden for patient	• Time consuming • Difficult to apply in clinical practice	Russell et al. 2009 (20), Tindlund et al. 2009 (21), Bongaarts et al. 2008 (23), Kaiser et al. 1996 (24), Russell et al. 2001 (25), Russell et al. 2011 (45), Russell et al. 2000 (58), Mishima et al. 2002 (59), Dusková et al. 2006 (60), Reiser et al. 2011 (61), Barillas et al. 2009 (62)
Cephalometric radiographs	• Acceptable reliability • Simple alternative to CT with less radiation	• The validity of soft tissue profile measurements is unproven	Chaithanyaa et al. 2011 (13), Anastassov et al. 1998 (15), Scopelliti et al. 2013 (18), Russell et al. 2009 (20), Tindlund et al. 2009 (21), Brattström et al. 2005 (22), Verze et al. 2014 (39), Papamanou et al. 2012 (47), Yoon et al. 2003 (48), Bearn et al. 2002a (49), Smahel & Müllerova 1996 (50), Ridgway et al. 2011 (51)
Computer tomography	• Measurements can be repeated and verified • Records are permanent • Provides information about hard tissue, • Excellent method for quantifying surface and deep craniofacial structures • Evaluates septum quantitatively • Images can be viewed in multiple positions • Soft tissue and skeletal landmarks can be evaluated • No muscle movements or extrinsic deforming factors (if under sedation)	• Radiation exposure • Sedation for young children • Surface texture is poorly defined	Li et al. 2012 (17), Scopelliti et al. 2013 (18), Alonso et al. 2014 (19), Nagasao et al. 2008 (52), Miyamoto & Nakajima 2010 (53), Fisher et al. 1999 (54), Miyamoto et al. 2012 (55), Suri et al. 2008 (56)
Video recording	• Allows movements to be assessed • Photographs can be generated from video records • No need for clinical photographs	• Time consuming • Considerable cooperation is required • Multiple editing stages lead to loss of definition of the image • Needs trained operators	Trotman et al. 2007 (44), Morrant & Shaw 1996 (57), Russell et al. 2000 (58)
Rhinomanometry, nasal function			Chaithanyaa et al. 2011 (13), Anastassov et al. 1998 (15), Huempfner-Hierl et al. 2009 (16), Reiser et al. 2011 (61)
Combined methods			Z.-J. He et al. 2009 (3), Al-Omari et al. 2003 (8), Nagy & Mommaerts 2007 (9), Reddy et al. 2008 (10), Becker et al. 1998 (11), Hurwitz et al. 1999 (12), Chaithanyaa et al. 2011 (13), Kim et al. 2004 (14), Anastassov et al. 1998 (15), Huempfner-Hierl et al. 2009 (16), Li et al. 2012 (17), Scopelliti et al. 2013 (18), Alonso et al. 2014 (19), Russell et al. 2009 (20), Tindlund et al. 2009 (21), Brattström et al. 2005 (22), Bongaarts et al. 2008 (23), Kaiser et al. 1996 (24), Russell et al. 2001 (25), Nakamura et al. 2010 (26), Verze et al. 2014 (39), Papamanou et al. 2012 (47), Russell et al. 2000 (58), Reiser et al. 2011 (61), Roosenboom et al. 2014 (64), Luyten et al. 2013 (113)
Other / not shown			Cho & Baik 2001 (119), Tanikawa et al. 2010 (120)

from two-dimensional photographs by professionals and laypersons (63). Tindlund et al (2009) used two-dimensional photographs, roentgenograms, lateral cephalograms, plaster casts, speech records and hearing (21). Evaluation included descriptive craniofacial cephalometric analysis, dentoalveolar morphology, dentofacial aesthetics, speech concerning articulation and nasality, and hearing status (21). Russell et al. (2009) used two-dimensional and three-dimensional measurements of frontal photographs, lateral cephalometric radiographs and plaster nose casts (20). For the plaster nose casts a visual analogue scale was used. The authors concluded that although there were slight morphological differences, these were not sufficient to explain the subjective aesthetic evaluation by the panel (20). Generally, all methods complemented each other (3, 10, 13, 15, 16, 19, 21-24, 26, 39, 58, 61, 64, 65) as lip dynamics cannot be judged from photographs, but other areas can be measured with a degree of accuracy on digital photographs; this is difficult to achieve by clinical examination (11).

Of course, function is very important besides nasal aesthetics. Nasal function together with aesthetic evaluation was considered in only four articles (13, 15, 16, 61).

Likewise, new automated methods have been introduced, but as yet their application in practice has been experimental. For example, Mishima et al (1996) used an accurate, quantitative method for measuring external nasal forms to identify facial landmarks semiautomatically from plaster facial casts (59). This highly accurate contact-type three-dimensional coordinate measurement apparatus was used on five patients. Pigott and Pigott (2010) and Russell et al (2014) evaluated the SymNose programme for the efficacy of nose symmetry evaluation; this programme was used on two-dimensional photographs (66, 67). The methods seem to be promising but are not popular in articles.

Measurements

There is no consensus about measurements, either. Facial landmarks were used in 57 articles of selected but they differed from study to study. Mostly, Farkas anthropometric landmarks with modifications were used. However, some landmarks such as the nasal tip, alar points and height of nares were used in all almost measurements.

Graded scales were the second most widely used measurement; 33 articles considered 5-point, 4-point and 3-point graded scales, again differing from study to study. In some articles, combinations of graded scales were used. The intra- and inter-rater agreements were good in most of these studies.

We propose that every publication should describe the precise cleft type, number of patients and groups, number of evaluators, methods, measurements, and statistical methods used. This is important for interpreting the data and the reliability of the study.

CONCLUSION

1. In the literature concerning aesthetic evaluation of the nose, multiple methods and combinations of them were used.

2. The most popular evaluation method remains two-dimensional photography and measurements using anthropometric facial landmarks. This method is simple, reproducible and long-used, so many records have been collected and are available for analysis.

3. Measurements from three-dimensional images seem to be most objective method available to date. Automated facial anthropometric landmark protraction seems to hold promise for the future.

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