

Systematic Review Imaging

Assessment modalities of non-ionizing three-dimensional images for the quantification of facial morphology, symmetry, and appearance in cleft lip and palate: a systematic review

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Abstract. The use non-ionizing three-dimensional (3D) imaging in cleft lip and palate is an emerging field, but properly designed methods for the assessment of these images are not well established. Therefore, the aim of this study was to review the current literature on the modalities of assessment of non-ionizing 3D images for the quantification of facial morphology, symmetry, and appearance in cleft lip and palate, and to assess the method error of these modalities. A systematic literature search was conducted using MEDLINE (PubMed), Cochrane Central Register of Controlled Trials, Web of Science, and Embase. Cross-sectional studies with prospective or retrospective data collection, using non-ionizing 3D imaging, with a subjective or objective outcome assessment and including at least 10 cleft lip and/or palate patients were considered eligible. Overall, 1767 unique studies were identified and 33 met the inclusion criteria. The images were objectively assessed using elementary measurements and comprehensive statistical methods for superimposition, shape description, and structuring. Subjective assessment was performed using a Likert-type scale or visual analogue scale. It can be concluded that non-ionizing 3D images are widely used in cleft research, but 3D analysis of the images is often methodologically suboptimal. Researchers must fully utilize the content of 3D images to quantify morphology, symmetry, and appearance.

Key words: cleft lip and palate; three-dimensional; surface imaging; stereophotogrammetry; morphology; appearance.

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Orofacial clefts (OFCs) comprise a range of disorders affecting the facial bony structures and soft tissues during gestation. These malformations are located in the midfacial area, with the lips, nose, alveolar process, and palate primarily affected¹. Although rehabilitation is possible with good quality care, OFCs inevitably have a lifelong effect on speech, hearing, cognition, and facial morphology to a certain extent².

The face plays an important role in social recognition. Therefore, an unfavourable facial appearance in patients with OFCs can be a source of social and emotional distress³. The unfavourable morphology of these faces deviates to a certain degree from the norm (the non-affected ‘average’ face)⁴, and can primarily, but not solely, be explained by the residual asymmetry⁵.

Various methods of assessment have been described for the quantitative and qualitative evaluation of faces in patients with OFCs, such as direct clinical assessment^{6,7}, radiographic cephalometric assessment^{8,9}, clinical photographic assessment^{10–12}, and clinical videographic assessment^{13,14}. Over the last decade, non-ionizing three-dimensional (3D) imaging has gained considerable interest. This is due to the use of non-ionizing radiation, the fast capture time, the simplicity of application, and the reliable storage and archiving of data^{15–19}. Although the use of non-ionizing 3D images is well established, the processing and quantitative assessment of these images is often subject to operator bias. No systematic reviews reporting this topic have been published to date. Therefore, the aims of this study were (1) to review the current literature relating to the modalities of assessment of non-ionizing 3D images for the quantification of facial morphology, symmetry, and appearance in cleft lip and palate, and

(2) to assess the method errors of these modalities.

Materials and methods

The results of this review are reported in accordance with the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)²⁰. The search aimed to identify all original articles reporting diagnostic methods with a quantitative outcome.

Eligibility criteria

A systematic review was performed to investigate the modalities of assessment of non-ionizing 3D images for the quantitative assessment of facial morphology, symmetry, and appearance in cleft lip and palate. The population comprised patients with repaired or unrepaired cleft lip and/or palate without age restriction. Morphology, symmetry, or appearance had to have been evaluated in an objective or subjective manner on non-ionizing 3D images acquired with 3D surface scanning or 3D digital stereophotogrammetry. Eligible studies were required to present the following characteristics: (1) cross-sectional studies with prospective or retrospective data collection; (2) studies with at least 10 patients per study group; (3) studies reporting original data concerning humans; and (4) studies published in English. The exclusion criteria were (1) abstracts, conference summaries, case series, or case reports, (2) studies without a quantitative outcome, (3) reliability studies, and (4) method development studies.

Data sources and search methods

Studies were identified using the electronic databases MEDLINE (PubMed, 1966 to present), Web of Science (1955 to present),

Embase (1980 to present), and Cochrane Central Register of Controlled Trials (CENTRAL) (1988 to present). The following search terms were combined to create an appropriate search string: cleft lip, cleft palate, three-dimensional imaging, anthropometry, (stereo)photogrammetry, surface scanning, and morphometry. The electronic search strings used in the selected databases are shown in Table 1. Backward and forward citation tracking (snowballing) was also performed, using reference lists and the Science Citation Index of all the articles eligible for inclusion in this review.

Study selection, data extraction, and quality assessment

The search strategy was established a priori by all authors and the eligibility assessment was performed by two independent reviewers (L.T. and N.D.R.) in a non-blinded standardized manner. The titles and abstracts of retrieved studies were reviewed independently, and the full-text articles corresponding to the selected titles and abstracts were subsequently retrieved. Disagreements between the two reviewers concerning article selection were resolved by consensus after rereading and discussion with the other authors.

The methodological quality of the included studies was analyzed according to an adapted version of the MINORS checklist (Methodological Index for Non-Randomized Studies)²¹. The items ‘follow-up period appropriate to the aim of the study’ and ‘loss to follow-up less than 5%’ of the MINORS checklist were not used because they are not applicable to cross-sectional studies. Disagreements concerning the quality control between the two reviewers were resolved by consensus after rereading and discussion with the other authors.

Table 1. Electronic search strategies in the selected databases.

Electronic database	Search string
MEDLINE	(cleft lip[MeSH Terms] OR cleft lip[Tiab] OR cleft palate[MeSH Terms] OR cleft palate[Tiab]) AND (morphometr*[Tiab] OR photogrammetry[Mesh] OR photogrammetr*[Tiab] OR stereophotogrammetr*[Tiab] OR anthropometr*[Tiab] OR Imaging, Three-Dimensional[Mesh] OR 3D[Tiab] OR three-dimensional[Tiab])
Web of Science	(TS = (“cleft lip”) OR TS = (“cleft palate”) OR TS = (“cleft lip and palate”)) AND (TS = (morphometr*) OR TS = (stereophotogrammetr*) OR TS = (photogrammetr*) OR TS = (“three dimensional imag*”) OR TS = (anthropometr*))
Embase	‘cleft lip’/exp OR ‘cleft lip’:ab OR ‘cleft palate’/exp OR ‘cleft palate’:ab OR ‘cleft lip palate’/exp OR ‘cleft lip palate’:ab AND (‘morphometry’/exp OR ‘morphometry’:ab OR ‘stereophotogrammetry’/exp OR ‘stereophotogrammetry’:ab OR ‘photogrammetry’/exp OR ‘photogrammetry’:ab OR ‘three dimensional imaging’/exp OR ‘three dimensional imaging’:ab OR ‘anthropometry’/exp OR ‘anthropometry’:ab) AND [embase]/lim
Cochrane Central Register of Controlled Trials (CENTRAL)	(“cleft lip” OR “cleft palate” OR “cleft lip and palate”) AND (morphometr* OR stereophotogrammetr* OR photogrammetr* OR three dimensional imag* OR anthropometr*)

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