Available online at www.sciencedirect.com

SciVerse ScienceDirect

British Journal of Oral and Maxillofacial Surgery 52 (2014) 688–692

BRITISH Journal of Oral and Maxillofacial Surgery

www.bjoms.com

Anatomy-based image processing analysis of the running pattern of the perioral artery for minimally invasive surgery

Sang-Hee Lee [a], Minho Lee [b], Hee-Jin Kim [a,*]

[a] Division in Anatomy and Developmental Biology, Department of Oral Biology, Human Identification Research Center, Yonsei University College of Dentistry, 50 Yonsei-ro, Seodaemun-gu, Seoul, 120-749, Republic of Korea

[b] Department of Biological Science, Sangji University, 83 Sangjidae-gil, Wonju-si, Gangwon-do, 220-702, Republic of Korea

Received 17 December 2013; accepted 13 July 2014
Available online 28 July 2014

Abstract

We aimed to elucidate the tortuous course of the perioral artery with the aid of image processing, and to suggest accurate reference points for minimally invasive surgery. We used 59 hemifaces from 19 Korean and 20 Thai cadavers. A perioral line was defined to connect the point at which the facial artery emerged on the mandibular margin, and the ramification point of the lateral nasal artery and the inferior alar branch. The course of the perioral artery was reproduced as a graph based on the perioral line and analysed by adding the image of the artery using MATLAB. The course of the artery could be classified into 2 according to the course of the alar branch - oblique and vertical. Two distinct inflection points appeared in the course of the artery along the perioral line at the ramification points of the alar branch and the inferior labial artery, respectively, and the course of the artery across the face can be predicted based on the following references: the perioral line, the ramification point of the alar branch (5∼10 mm medial to the perioral line at the level of the lower third of the upper lip) and the inferior labial artery (5∼10 mm medial to the perioral line at the level of the middle of the lower lip).

Keywords: Perioral artery; Minimally invasive surgery; Dermal filler; Image processing

Introduction

The facial artery arises from the external carotid artery, and passes in to the face as it crosses the mandible.[1] Its area of distribution depends on where it terminates. Mitz et al. said that its terminal branch of varied from the angular artery to the perioral weak branch.[2] Koh et al. classified its distribution patterns into 6 categories as: forehead (4%), angular (36%), nasal (44%), alar (3%), superior labial (7%), and inferior labial (6%) in 47 Korean cadavers.[3] Pinar et al. also classified the facial artery as: angular (22%), nasal (60%), alar (12%), superior labial (4%), and hypoplastic (2%) in 25 Turkish cadavers. Although there were slight differences in the classification, the facial artery was commonly found to terminate after it had passed the ala of the nose (88% of Koreans and 94% of Turks),[4] and Yang et al. reported a branch of the facial artery that travelled through the inferior palpebral region instead of the angular artery.[5] This means that the facial artery supplies mainly the perioral region, which is bounded by the nasolabial fold, the labiomental crease, and the nasal base. The trunk of the facial artery and the branches it distributes to the perioral region (the inferior alar branch,[6] the alar branch,[7] the superior labial artery, and the inferior labial artery) are collectively known as the perioral artery.

The perioral artery is often manipulated during flap surgery or when a dermal filler is being injected. For facial

* Corresponding author at: Division in Anatomy and Developmental Biology, Department of Oral Biology, Human Identification Research Center, Yonsei University College of Dentistry, 50 Yonsei-ro, Seodaemun-gu, Seoul, 120-749, Republic of Korea. Tel.: +82 2 2228 3067; fax: +82 2 393 8076.
E-mail address: hjk776@yuhs.ac (H.-J. Kim).

http://dx.doi.org/10.1016/j.bjoms.2014.07.098
0266-4356/

reconstruction, various perioral flaps (such as the nasolabial flap, facial artery musculomucosal (FAMM) flap, and Abbe flap)[8–10] have been designed with an adequate blood supply from the perioral artery in mind, and the survival of these flaps is dependent mainly on the vascularisation from the perioral artery. Injection of a dermal filler has been used to increase volume for facial rejuvenation. However, careless manipulation leading to damage to the perioral artery during such injections could result in vascular complications such as necrosis of the alar rim,[11–14] which is one of the most serious complications of this technique.[15]

Our study of the perioral artery is based on descriptions of the surrounding anatomical structures such as the buccinator, modiolus, and oral commissure.[4,6–11,16] However, these descriptions could not adequately explain the tortuous course and branching point of the artery, and precise metric data was needed to make them applicable clinically. We therefore tried to reproduce the whole course of the artery as a polynomial curve and analysed it by image processing.

The aims of this study were to elucidate the course of the perioral artery with the aid of image processing, in which images are treated as 2-dimensional signals with amplitude,[17] and to suggest accurate references for minimally-invasive procedures.

Material and Methods

Nineteen Korean and 20 Thai cadavers (26 male and 13 female, mean (range) age 73 (46–95) years donated to the dental and medical school were used for the study. From the 39 cadavers we acquired 59 hemifaces (21 bilateral, and 17 unilateral, specimens) because there were some hemifaces that had been disfigured during dissection of the cadavers by students. Latex solution (Neoprene, Lot No. 307L146, DuPont, France) coloured red (Colorant Universel, Castorama, France) was injected through the common carotid artery in all cases before dissection to enable clear visualisation of the facial artery.

Except a few cases in which the inferior labial artery was the terminal branch of the facial artery, the facial artery emerged at the margin of the mandible (FE point) and ascended towards the ala of nose as the ramification point of the lateral nasal artery and the inferior alar branch. The location of the ramification point was measured as polar coordinates: the R point [distance (ℓ) and angle (θ)]. A plane was established by 2 axes parallel to the lip line and the facial sagittal midline. The origin of this plane was the lateral corner of the nasal base (NB point). Based on this plane, ℓ and θ were measured with the aid of digital callipers (CD-15CP, Mitutoyo).

The image processing of the whole course of the perioral artery was as shown in Fig. 1. A straight line connecting the margin of the mandible, and the ramification points was defined as the perioral line. The facial artery runs tortuously along this line, making many intersections. For further analysis, we rotated the curve, so that the perioral line played a part as the horizontal axis. The point at the margin of the mandible was set as the origin of the perioral line, and the coordinates of the various intersection points between the facial artery and the perioral line and turning points of the facial artery were measured using digital callipers. The X-coordinates of points of each curve were normalised to standardise the length of the perioral line, as its length and the proportions of the upper and lower lips differed among subjects. The perioral line was divided into 2 portions based on the lip line (cheilion to cheilion), and the length of the 2 portions was changed to 50 mm for both. Based on the normalised coordinates of the points, each curve indicating each perioral artery was reproduced by shape-preserving piecewise cubic interpolation[18] using MATLAB (MathWorks, Natick, MA, USA). To distinguish safe from dangerous zones we first converted each continuous curve into spatially discrete 2-dimensional rectangular grids (100 mm x 50 mm) in which each pixel value is either 1 or 0. In the grid system, each curve is described as a matrix. Finally we analysed the

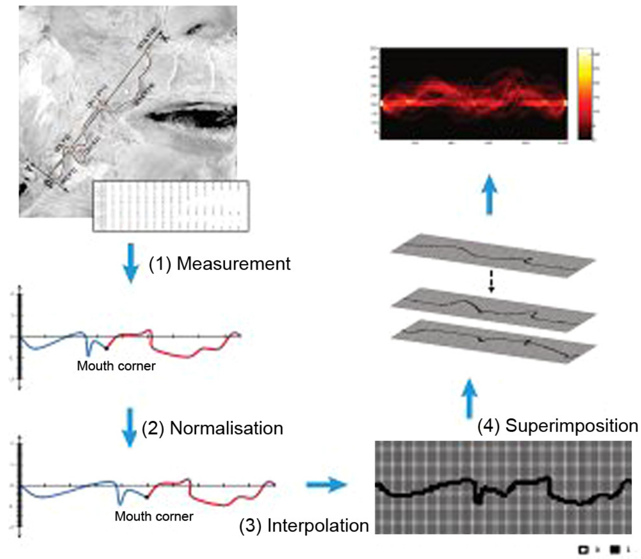

Figure 1. Image-processing analysis of the course of the perioral artery. (1) Measurement: A straight line connecting the FE and R points was defined as the perioral line (PO line). The FE point was set as the origin of the PO line, and the coordinates of the various intersection points between the facial artery and PO line and turning points of facial artery were manually measured using digital callipers. (2) Normalisation: The X-coordinates of points of each curve were normalised to standardise the length of the PO line, as the length of the PO line and the proportions of the upper and lower lips differ among subjects. The PO line was divided into 2 portions based on the lip line (cheilion to cheilion), and the length of the 2 portions was changed to 50 mm for both. (3) Interpolation: based on the normalised coordinates of points, each curve that indicated each PA was reproduced by shape-preserving piecewise cubic interpolation using MATLAB (MathWorks, Natick, MA, USA). To distinguish safe and dangerous zones, we first converted each continuous curve into a spatially discrete 2-dimensional rectangular grid (100 mm x 50 mm) where each pixel value was either 1 or 0. In the grid system, each curve could be described as a matrix. (4) Superimposition: we could analyse the relative density of each pixel of by summing up all matrices and counting the number of times that each position overlapped.