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Quantitative analysis of facial palsy using a three-dimensional facial motion measurement system

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ABSTRACT

Objective: The prognosis for facial nerve palsy (FNP) depends on its severity. Currently, many clinicians use the Yanagihara, House–Brackmann, and/or Sunnybrook grading systems to assess FNP. Although these assessments are performed by experts, inter- and intra-observer disagreements have been demonstrated. The quantitative and objective analyses of the degree of FNP would be preferred to monitor functional changes and to plan and evaluate therapeutic interventions in patients with FNP. Numerous two-dimensional (2-D) assessments have been proposed, however, the limitations of 2-D assessment have been reported. The purpose of this study was to introduce a three-dimensional (3-D) image generation system for the analysis of facial nerve palsy (FNP) and to show the correlation between the severity of FNP assessed by this method and two conventional systems.
Methods: Five independent facial motions, resting, eyebrow raise, gentle eye closure, full smile with lips open and whistling were recorded with our system and the images were then analyzed using our software. The regional and gross facial symmetries were analyzed. The predicted scores were calculated and compared to the Yanagihara and H–B grading scores. We analyzed 15 normal volunteers and 42 patients with FNP.
Results: The results showed that 3-D analysis could measure mouth movement in the anteroposterior direction, whereas two-dimensional analysis could not. The system results showed good correlation with the clinical results from the Yanagihara ($r^2 = 0.86$) and House–Brackmann ($r^2 = 0.81$) grading scales.
Conclusion: This objective method can produce consistent results that align with two conventional systems. Therefore, this method is ideally suited for use in a routine clinical setting.

1. Introduction

Facial nerve palsy (FNP) is a common clinical entity that is most commonly caused by Bell's palsy, Ramsay Hunt syndrome, trauma, tumors, or a middle ear infection. The prognosis of FNP depends on its severity; recovery from mild or moderate palsy tends to occur spontaneously, whereas patients often fail to recover from severe palsy [1]. Therefore, the quantitative analysis of FNP severity plays an important role in choosing therapy and determining a prognosis. Currently, many clinicians use the Yanagihara [2], House–Brackmann (H–B) [3], and/or Sunnybrook [4] facial nerve grading systems to assess the severity of FNP. In the Yanagihara system, which is accepted as the standard in Japan, regional facial function is analyzed based on the subjective measurement of 10 separate functions of the facial muscles [2]. The H–B system, which is the method adopted by the American Academy of Otolaryngology Head and Neck Surgery, requires the subject to perform a series of movements that are clinically assessed and then subjectively assigned an overall grade between I and VI [3]. The Sunnybrook system requires the subjective assessment of muscle tone in multiple regions of the face and of movement and synkinesis in five standard facial expressions [4]. The advantage of these grading systems is their ease of use in clinics without requiring specialized equipment. Although these assessments are performed by experts,

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inter- and intra-observer disagreements have been demonstrated [5]. The main problem in these subjective evaluations lies in absence of reliable and precise facial function measurements [6]. The objective diagnosis of facial function would aid in monitoring clinical changes and planning and evaluating therapeutic interventions in patients with FNP.

The objective analysis of facial function began with the development of two-dimensional (2-D) imaging systems that use various techniques to analyze complex facial movements [7]. However, none of the techniques have been generally accepted, because the measurement processes are complicated or require expensive instruments. Furthermore, there have been reports on the limitations of 2-D assessment of facial function [8–10]. We have developed a high-speed range finding system that measures both the three-dimensional (3-D) shape and the color texture of the human face; we have also developed original software that automatically registers facial landmarks [11,12]. In the current study, we introduce a 3-D image generation system for the analysis of facial symmetry. We analyzed 42 patients with unilateral FNP and compare the predicted scores with the Yanagihara and H–B grading scores.

2. Materials and methods

2.1. Principles of 3-D measurement

The 3-D measurements are obtained using a space-encoding method [11,12]. The slit ray from the laser light source intersects the surface of an object as a line, not as a spot. Simultaneously, the camera captures the reflected image on its image plane (Fig. 1a). The system then computes the distance from the line between the light source and the center of the camera lens to the object using trigonometric principle. The projected line is encoded using the space-encoding method. With this method, the light patterns are binary encoded by the appropriate switching of the semiconductor laser and the scanning of the slit ray by the polygonal mirror. Stripe patterns encoded in the binary system are projected in a regular sequence. As shown in Fig. 1b, 3-stripe patterns can create 8 space codes ($2^3 = 8$ combinations). Therefore, the 256 angle projections that would otherwise be necessary for scanning an object are decreased to 8 ($2^8 = 256$) stripe patterns. This decrease significantly shortens the measurement time.

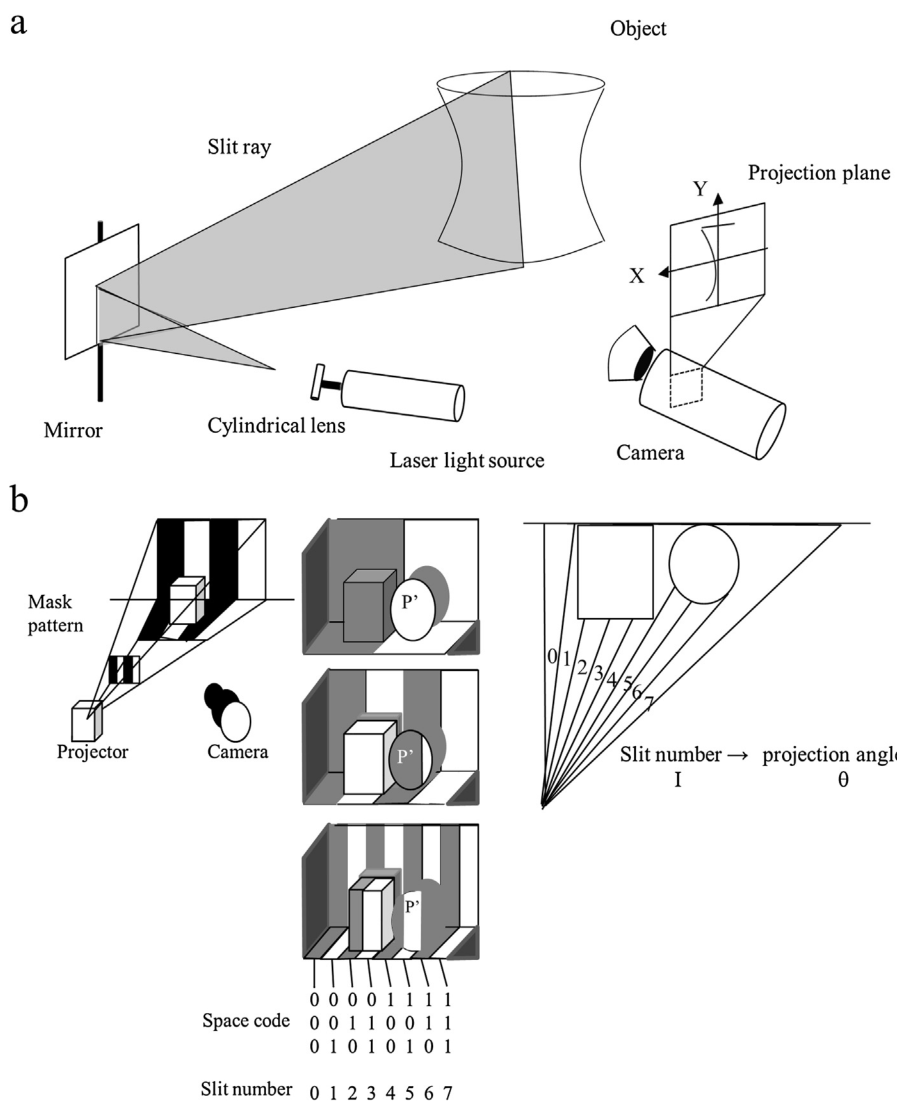

Fig. 1. 3-D measurement methods. (a) The slit ray projection method. A slit ray from a laser light source intersects the surface of an object. Simultaneously, the camera captures the reflected image onto its image plane. (b) The space-encoding method. Three-stripe patterns can produce eight space codes ($2^3 = 8$ codes; the slits are numbered 0–7).

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