Evolution of the 3-Dimensional Video System for Facial Motion Analysis

Ten Years' Experiences and Recent Developments

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Abstract: Since the implementation of the computer-aided system for assessing facial palsy in 1999 by Frey et al (*Plast Reconstr Surg.* 1999;104:2032–2039), no similar system that can make an objective, three-dimensional, quantitative analysis of facial movements has been marketed.

This system has been in routine use since its launch, and it has proven to be reliable, clinically applicable, and therapeutically accurate. With the cooperation of international partners, more than 200 patients were analyzed. Recent developments in computer vision—mostly in the area of generative face models, applying active-appearance models (and extensions), optical flow, and video-tracking—have been successfully incorporated to automate the prototype system.

Further market-ready development and a business partner will be needed to enable the production of this system to enhance clinical methodology in diagnostic and prognostic accuracy as a personalized therapy concept, leading to better results and higher quality of life for patients with impaired facial function.

Key Words: three-dimensional video-analysis, 3-dimensional, objective measurements tool, facial grading system, facial palsy, documentation, face

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The incidence of facial palsies is estimated to be about 20 to 25 per 100,000 people per year.[1] Causes of facial palsy include infections, tumors, vascular lesions, traumatic events, and idiopathic and congenital disorders. Facial palsy is a distressing condition, aesthetically and functionally. Patients may suffer from facial asymmetry, impaired emotional expression, and difficulties performing basic daily functions, such as eating, drinking, speaking, and communicating their feelings and intentions. Functional reconstruction through dynamic and static surgical methods can be offered to patients with irreversible facial palsy.

In plastic and reconstructive surgery, the quantitative analysis of facial motion is important for quantifying the degree of facial palsy, estimating the postoperative course of recovery, and evaluating surgical methods. Until now, measurements of the vectors of maximum displacement in facial movements (eg, the superior movement of the midportion of the superior eyebrow and the lateral movement of the oral commissure) have been assessed according to different grading schemes.[2–7] Most authors use the House–Brackman grading system,[4] which enables an approximate grading of the degree of facial palsy. Although facial-grading research has been pursued over the last 50 years, no existing method of objective facial measurement has universally been accepted. Therefore, when comparing surgical results, serious problems occur: surgeons use different methods to evaluate the outcome, making comparisons between surgical techniques difficult.[8,9]

Since 1998, we have concentrated our efforts on assessing facial movements by 3-dimensional measurements[10] as part of the International Registry for Muscle Transplantation, founded in 1986.[11,12] The maintenance and improvement of our standardized objective 3-dimensional video-analysis system was supported by a research assignment of the Austrian Federal Ministry for Education, Science and Culture. In the past decade at our department, this system[9,10,13–19] has proven to be a reliable and sensitive tool for quantifying and evaluating complex mimic movements, easily applicable and used in the daily clinical routine. According to Neely et al[20] in a recent article on measuring facial motion: "The big issue is that facial motion analysis has not kept pace with the advancements in other areas, audiology for example. In that comparison, we are back with the tuning fork and whispered voice."

Hence, the purposes of this article are to describe the progress of the 3-dimensional video-analysis system and its feasibility of automation, and to encourage serious investigations and improvements of 3-dimensional video facial-motion analysis in the medical fields.

To the best of our knowledge, this is the first research of its kind to be reported.

MATERIALS AND METHODS

The 3-dimensional video-analysis system as described in this article[10] consisted of a mirror system, a calibration grid, and a commercial digital video camera (Fig. 1). Eighteen standardized reproducible anatomic landmarks in the face were placed in the face (Table 1, Fig. 2). Subjects were videotaped under standardized conditions and were instructed to perform 9 standardized facial movements (Table 2) after a verbal signal, in a set order. Facial animations were digitally collected preoperatively and postoperatively (6, 12, and 18 months). Data were transferred to a personal computer (PC) for editing. Subsequently, Facialis software and FaciShow (Laboratory for Biomechanics of the Swiss Federal Institute of Technology, Zurich, Switzerland) were used to calculate the 3-dimensional coordinates of the landmarks, as to visualize data. Two- and three-dimensional trajectories of each landmark in movement can be presented (Figs. 3, 4).

Ethical approval was obtained from Medical University of Vienna Ethics Committee prior to the commencement of the study in 2001, which was extended in 2009 (EK No. 186/2009).

RESULTS

With the cooperation of international partners in Norway, Italy, and Germany, 241 patients with facial palsy were filmed with this

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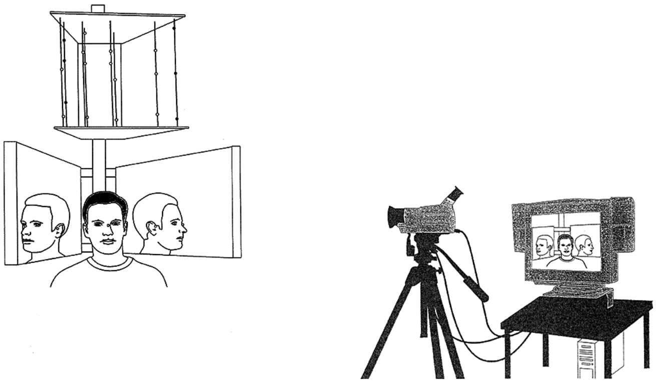

FIGURE 1. Schematic diagram of the 3-dimensional video-analysis system (Frey et al, 1999; reproduced with the permission of Lippincott Williams & Wilkins).

TABLE 1. Abbreviations of Standardized Facial Landmarks

CN (Static)	Central Nose
LAN	Left ala of the nose
LB	Left brow
LLE	Left lower eyelid
LMC	Left mouth corner
LML	Left midlateral point of the lower lip
LMU	Left midlateral point of the upper lip
LT (static)	Left tragus
LUE	Left upper eyelid
PH	Philtrum
RAN	Right ala of the nose
RB	Right brow
RLE	Right lower eyelid
RMC	Right mouth corner
RML	Right midlateral point of the lower lip
RMU	Right midlateral point of the upper lip
RT (static)	Right tragus
RUE	Right upper eyelid

system. These were 27 children (age up to 14 years), 19 teenagers (age between 15 and 18 years), and 195 adults (age from 19 years up). The patient population consisted of patients with bilateral facial palsy (5%), and right- and left-sided patients with facial palsy, evenly distributed, with 47% right and 48% left (Table 3); their etiologies (Table 4) and operation techniques are listed in Tables 5 and 6. Moreover, we have collected nearly 1000 films of patients in the last decade, with a postoperative average follow-up of 32 ± 32.7 SD months for each patient (maximum 180 months).

Technical advancements in PC hardware and improvements based on users' and patients' feedback have enhanced the system. Analysis has been accelerated and has been made more precise with advances in computer software technology. In 1998, the complete analysis procedure for a 3-minute session video took on average 5 hours, allowing 20 minutes to mark and videotape patients, 10 minutes to transfer the video from the camera to the PC, 40 minutes to process the video for analysis, and 230 minutes to analyze the data with Facialis software. Most of the time was taken up by manually tracking the landmarks in each frame. After a technical boost of the software in 2005, semiautomatization of the system shortened the whole analysis procedure by approximately 25%.

Calibration of the 3-dimensional space between the mirror system had to be performed before each analysis (Fig. 5; calibration grid of the of the 3-dimensional video-analysis system). The semiautomatic calibration (Fig. 6) guides the user to calibrate the 3-dimensional area between the mirrors with each click of the mouse. The size-expanded marker and high-contrast feature enable the software to find the midpoints of the markers automatically. Thus, at the calibration procedure, the user needs merely to verify the process.

Each frame of the facial movement was processed with an overview image (Fig. 7), where every landmark was tagged manually by the user. With the semiautomatic program, the Facialis software automatically guides the user to the designated landmarks in successive frames, once all landmarks of the first frame have manually been marked. This improvement diminished mistakes and time-consuming landmark adjustments. Accuracy of the analysis is enhanced with the zoom software (Fig. 8, left lower corner), which enables users to have a second window with software zoom (1×, 2×, 4×, 6×, 8×) function while tracking the landmarks. This zoom can let an analyzer magnify an area of interest. With this magnification, accuracy in marking the midpoints was higher: 2× magnification became twice as accurate as without zoom; 4× magnification became 4 times as accurate. Analytical improvement generated by the software zoom was in direct proportion to an increase in the amount of the zoom.

Because of the steadfast reliability of the 3-dimensional video-analysis system in the last decade, the main objective was to advance to a fully automatic, standardized, 3-dimensional facial video-analysis system, applying tomorrow's technology. In the following paragraphs, we share our progress and experiences on the path to such automation.

TABLE 2. Abbreviations of Standardized Animations, Performed by All Subjects in Sequential Order as Shown Earlier

English Version	Abbreviations	German Version
Maximal lifting of the eyebrows	mha	Maximales Heben der Augenbrauen
Closure of the eyelids as in sleep	sas	Schliessen der Augen wie im Schlaf
Maximal closure of the eyelids	ml	Maximaler Lidschluss
Maximal showing of the teeth	mzz	Maximales Zähnezeigen
Maximal showing of the teeth and maximal closure of the eyelids together	mlmz	Gleichzeitig Maximaler Lidschluss und Maximales Zähnezeigen
Smiling with showing teeth	lzz	Lächeln mit Zeigen der Zähne
Smiling with lips closed	lgl	Lächeln mit geschlossenen Lippen
Pursing of the lips	mzp	Mund zuspitzen und pfeifen
Pulling down the mouth corners	mwu	Mundwinkel nach unten ziehen

Frey et al, 1999; Reproduced with the permission of Lippincott Williams & Wilkins.

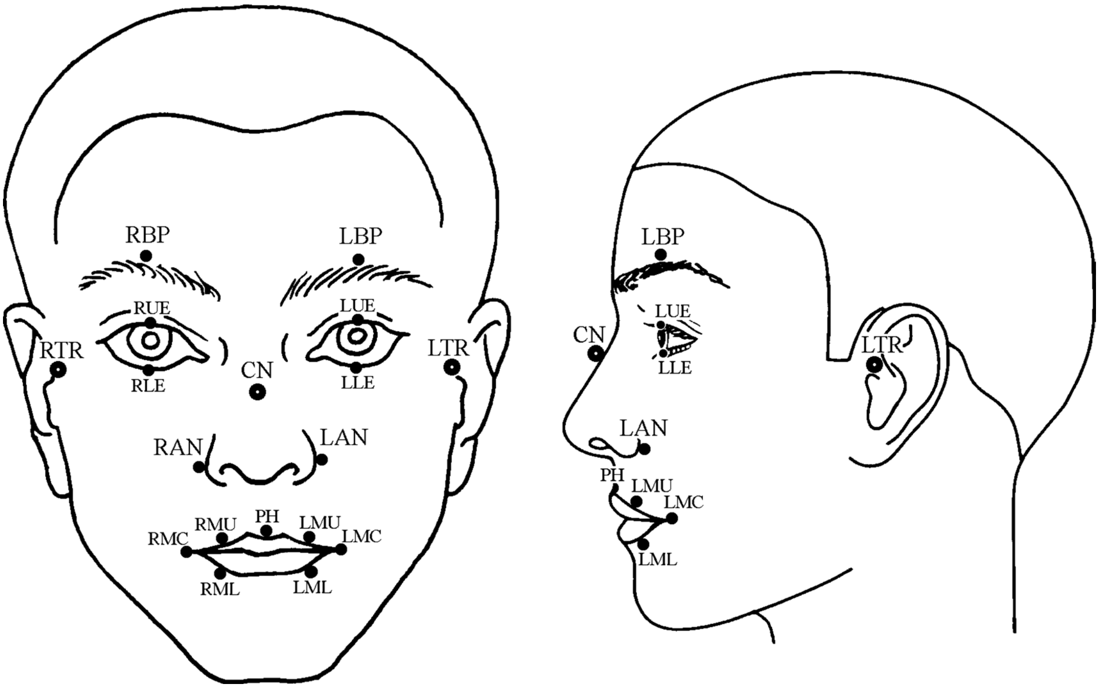

FIGURE 2. Placements of dynamic and static landmarks on the face in frontal and lateral aspects (Giovanoli et al, 2003; reproduced with the permission of Elsevier).

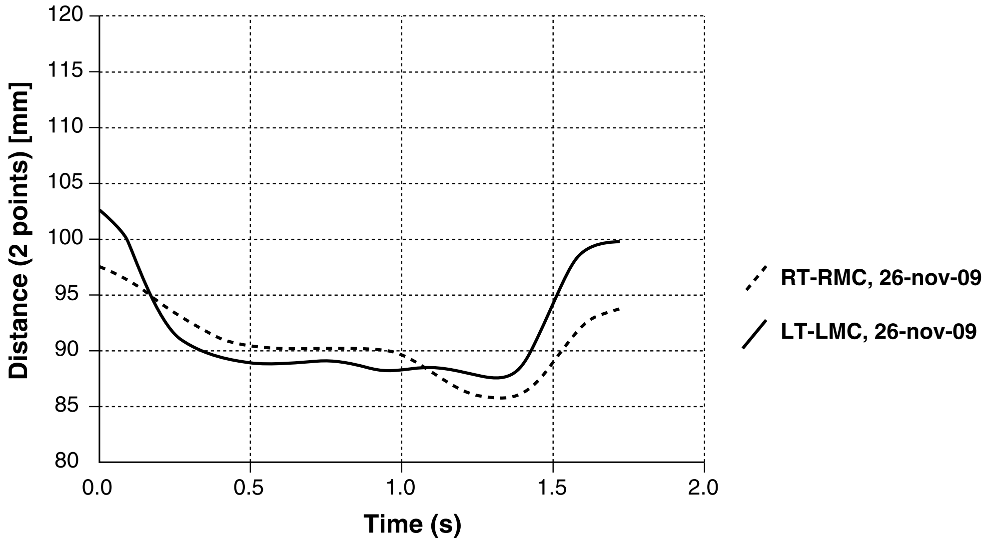

FIGURE 3. FaciShow, visualization of smile movement, showing distance/time graph between landmarks (dotted line: right tragus [RT] – right mouth corner [RMC] and continuous line: left tragus point [LT] – left mouth corner [LMC] points), whereby the x-axis shows the time in seconds [s] and the y-axis is the distance between the landmarks of interest, in millimeters [mm].

The first obstacle for automating the system was found to be the low contrast of some facial landmarks, which kept the system from tracking the landmarks automatically. Shadows of facial creases interfered and sometimes blocked the visibility of the landmarks. To improve the software's recognition of the landmarks, passive markers were purchased and attached to the skin. These markers were adhesive and reflective, showing a good contrast to the facial surface. The first tests were run with Technical University of Vienna, applying techniques of computer vision, particularly generative face models that apply active appearance models[21,22] (AAMs and extensions), optical flow,[23–25] and video tracking.[26] These techniques offer new means for measuring facial features and dynamics. Statistical models such as AAMs and related generative models[27,28] have been neglected in this field.

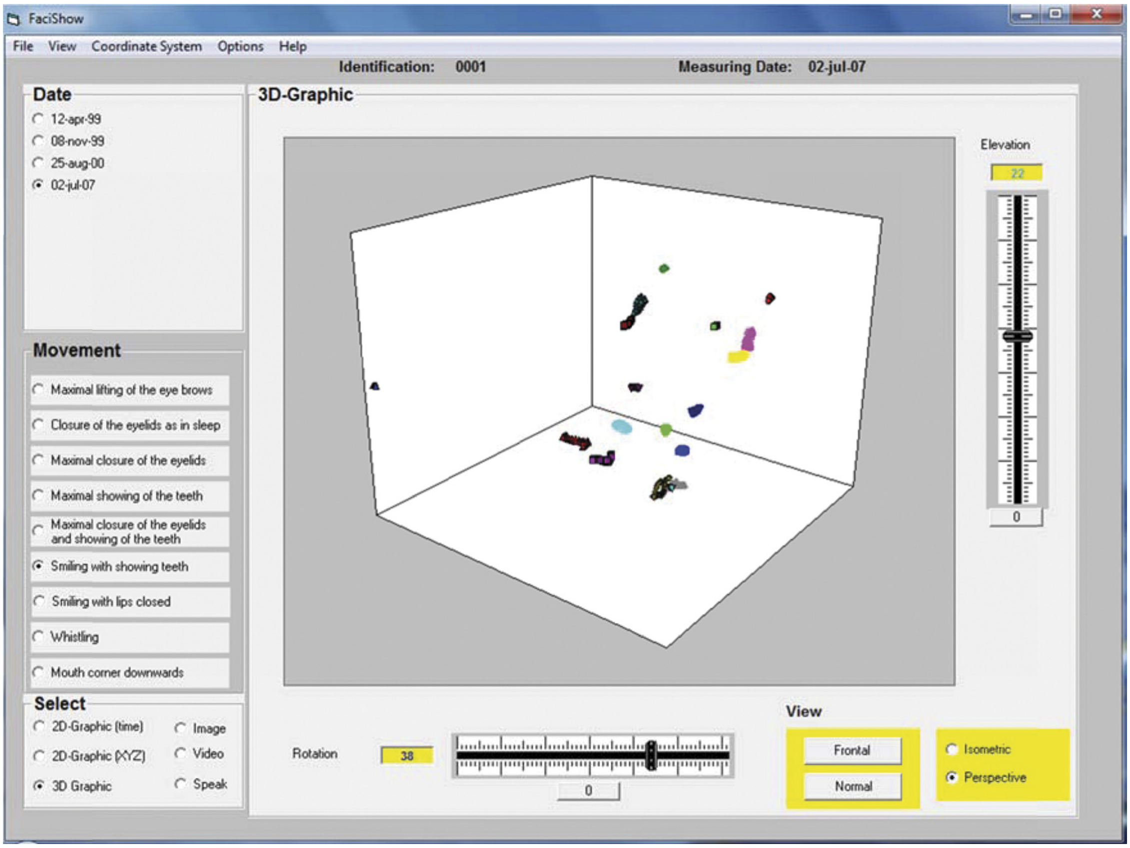

FIGURE 4. FaciShow, 3-dimensional visualization of all landmarks, smiling with teeth showing.

TABLE 3. Patient Population: Distribution of Gender, Age, and Side of Palsy of the Patients

Gender, Age, and Side of Palsy	n	%
Female	139	58
Male	102	42
0–14 y	27	11
15–19 y	19	8
>19 y	195	81
Right facial palsy	114	47
Left facial palsy	115	48
Bilateral facial palsy	12	5

TABLE 4. Etiology of Facial Palsy Patient Population

Etiology of Facial Palsy (n = 241)	n	%
Congenital	28	11
Idiopathic	23	10
Postoperative	105	44
Traumatic	21	9
Infection	12	5
Mobius syndrome	10	4
Ischemic stroke	1	0.4
Cerebral hemorrhage	2	0.8
Unknown	39	16

TABLE 5. Operation Techniques of the Facial Palsy Patient Population

Operation (n = 490)	n	%
Cross-face nerve graft	151	31
Temporalis transposition	66	13
Masseter transposition	19	4
Territorially differentiated gracilis muscle transplantation	30	6
Gracilis muscle transplantation	67	13
Corrective operations, static procedures	117	24
Other operations	40	8

TABLE 6. Details of the Cross-Face Nerve Operation Techniques

Cross-Face Nerve Operation (n = 151)	n	%
Single	77	51
Double	46	30
Distal end-to-side neurorrhaphy	28	19

Tracking was successful, but the passive markers were insufficient. The best landmarks from our tests were 3 mm in diameter and had a black ring around a white midpoint (1.5 mm) (Fig. 9). Because of the high contrast between these markers and the skin, the landmarks were tracked with 100% accuracy (Fig. 10). But because the markers

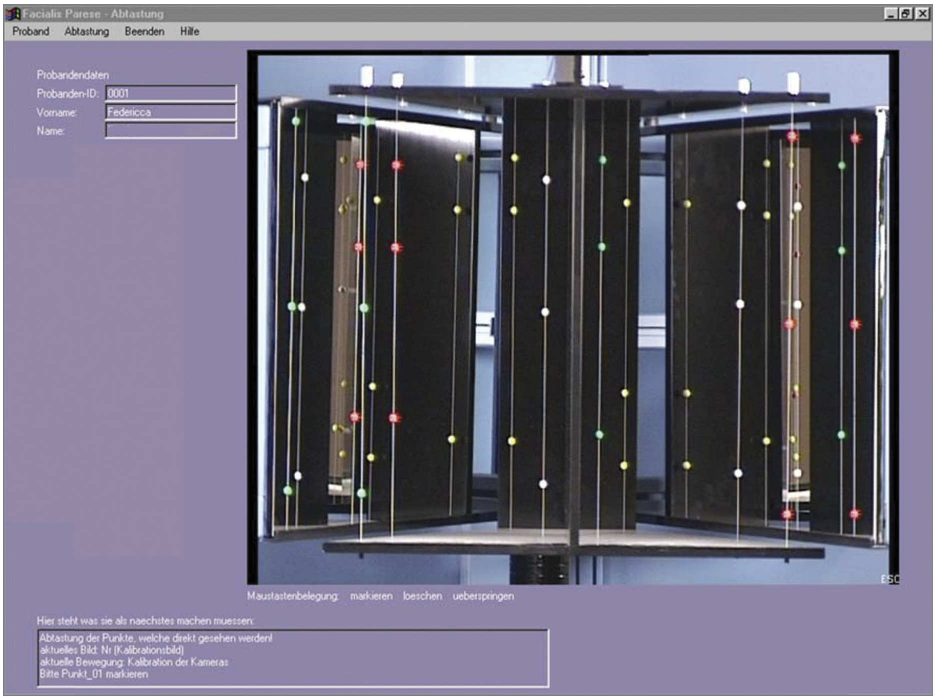

FIGURE 5. Calibration grid of the of the 3-dimensional video-analysis system.

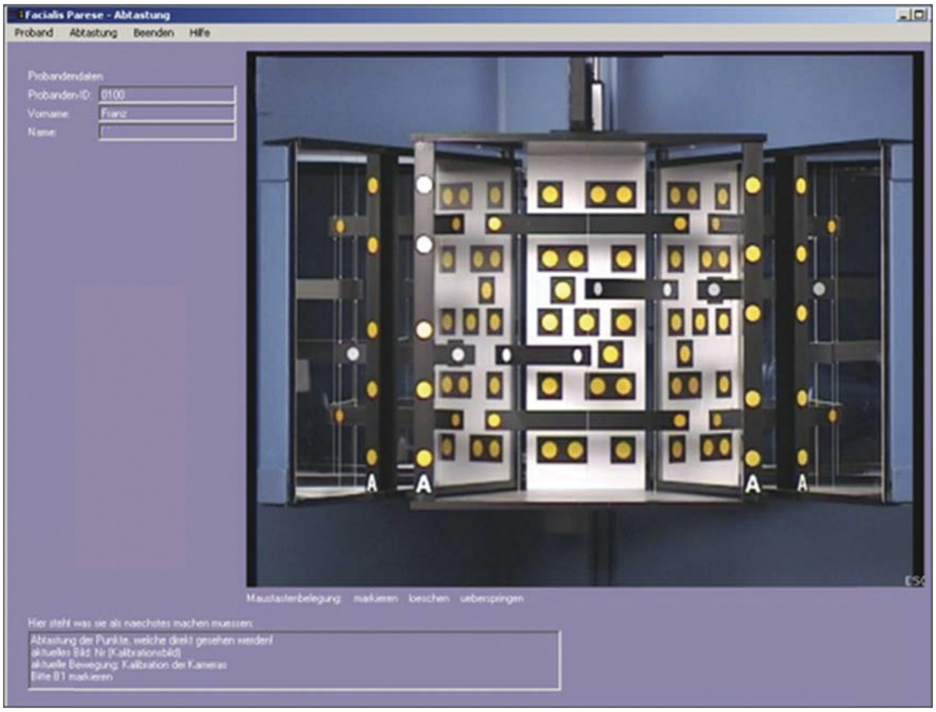

FIGURE 6. Semiautomatic calibration grid of the of the 3-dimensional video-analysis system.

were inflexible, they fell off when they were placed in creases (eg, the nasolabial fold and where the skin is thin and soft, as in the upper eyelid rim); each eyelid movement disturbed the marker and sometimes pinched it into the eyelid creases—which restrained the patients' natural movements. The attachment of markers to the skin was unreliable and unsuitable. Tests showed that attaching markers smaller than 3 mm required additional effort and these markers had insufficient contact to the skin to adhere properly.

Since the larger passive markers compromised the accuracy and of the analysis and the smaller markers could not be attached adequately, we changed our focus to active markers, which emit light when switched on. With the cooperation of Lucotronic (Lutz Mechatronic Technology e.U., Innsbruck, Austria), we designed several markers (Fig. 11). The larger ones were unsuitable, as these were as disturbing as the passive ones. We therefore chose the smallest ones possible (Fig. 11 [5]), 2 mm in diameter. The cable used to supply them

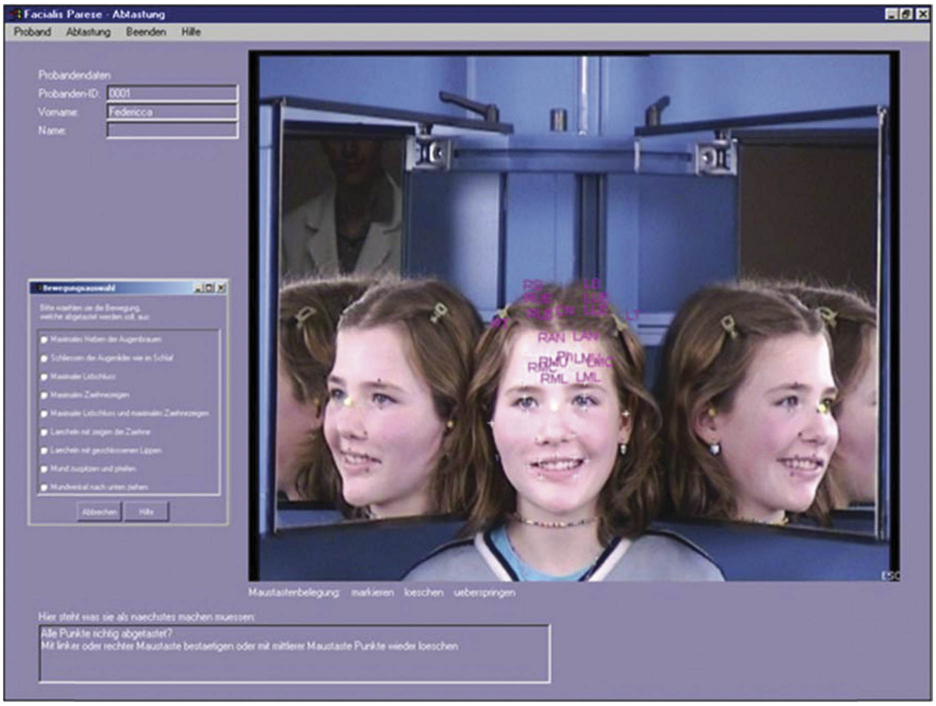

FIGURE 7. Screenshot of Facialis software analysis.

FIGURE 8. Screenshot of Facialis Zoom software: zoom software enables the user to magnify the area of interest with the zoom windows in the left lower corner.

with electricity needed to be as light as possible, so as to be flexible in the face and not block the whole view of the face. The question of the fixation on the face was raised after these marks were seen. Though the cables were as thin as possible, they were rigid enough that any slight movement would detach them.

We then tried mastic, a resin obtained from the mastic tree (*Pistacia lentiscus*) and used as a skin glue by makeup artists in the film industry. Its adhesive strength was excellent, and it kept the markers well attached to the skin, except for the eye region (Fig. 12). Here, the mastic irritated the eye. This procedure took more than 40 minutes—which is impracticably time-consuming. Because of the irritation, we concluded that mastic was unsuitable.

Recent 3-dimensional images are capable only of catching images in still photographs, and no video sources are provided. The only more sophisticated 3-dimensional image system is the 3dMd,[29] which can take images at 48 frames per second. Therefore, 3-dimensional

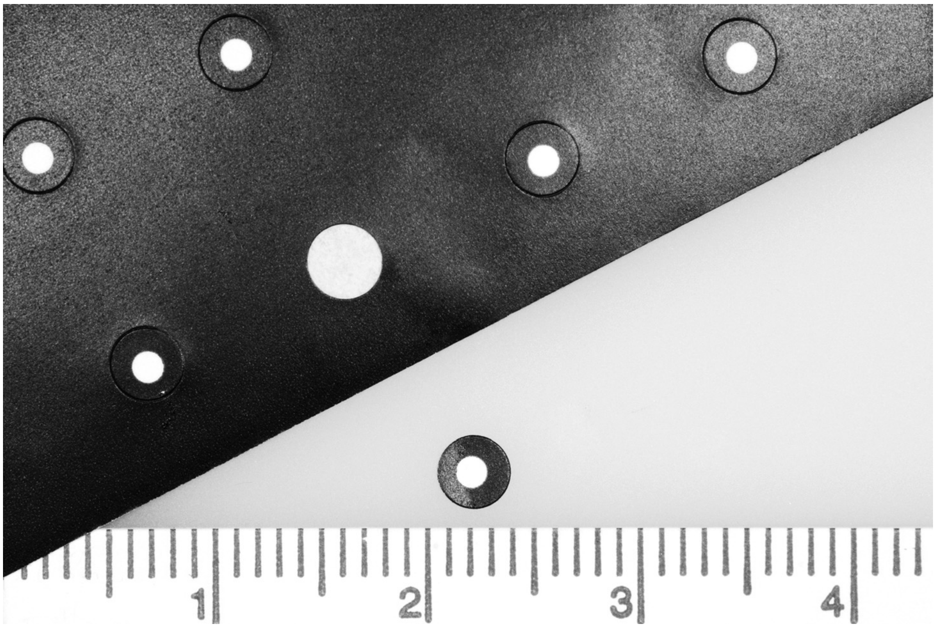

FIGURE 9. Passive self adhesive landmark produced by Bene (Waidhofen/Ybbs, Austria).

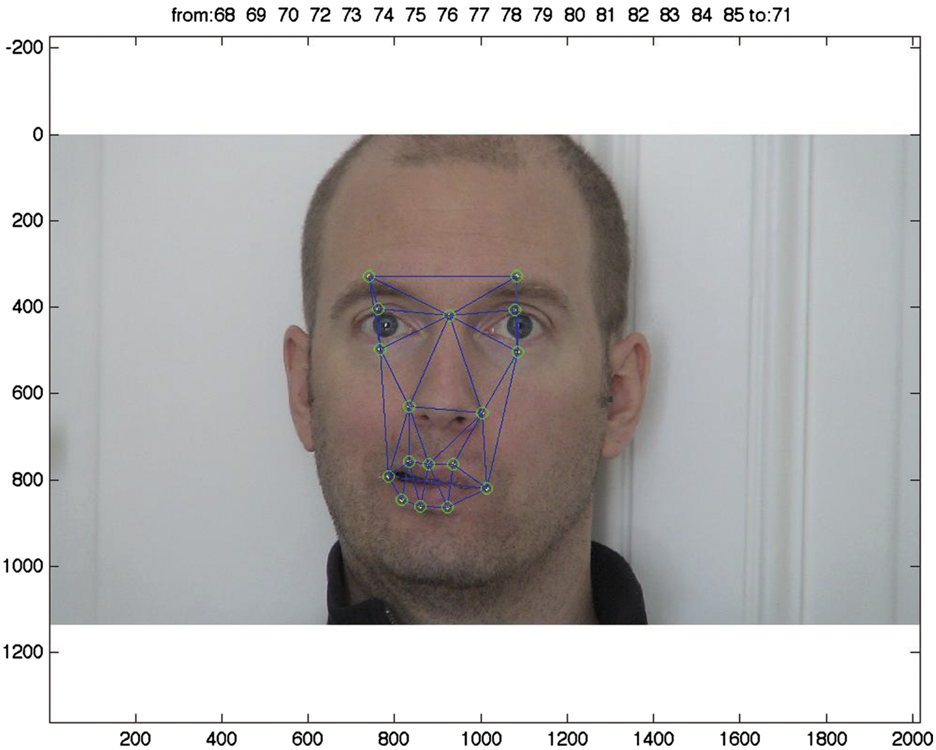

FIGURE 10. Landmark tracking with self-adhesive landmarks, applying AAM and extensions (2008 and reproduced with the permission of the Institute of Computer Graphics and Algorithms, Pattern Recognition and Image Processing Group, Technical University in Vienna, Austria).

imaging can only be an additional documentation system of the videoanalysis.

With the cooperation of Technical University in Vienna, Austria, and University of South Florida, United States, we used the strain pattern extracted from nonrigid facial motion as a simplified and adequate way to characterize the underlying material properties of facial soft tissues (Fig. 13). This pattern serves as a classification feature, since strain is related to the biomechanical properties of facial tissues that are unique for each individual. It is less sensitive to illumination differences (between enrolled and query sequences) and face camouflage because it remains stable as long as reliable facial deformations are captured. Images or videos of facial deformations can be acquired with a regular video camera, and no special imaging equipment is needed; the facial-strain pattern of an expressive face reveals a person's facial dynamics.[30] This system tracked nearly 99% of all pixels; however, a 3-dimensional calculation of the pixel excursions in millimeters was not possible.

The solution for automating the 3-dimensional video-analysis system was achieved with the commercial software Adobe After Effects CS 5 (Adobe Systems Incorporated, San Jose), where a mean

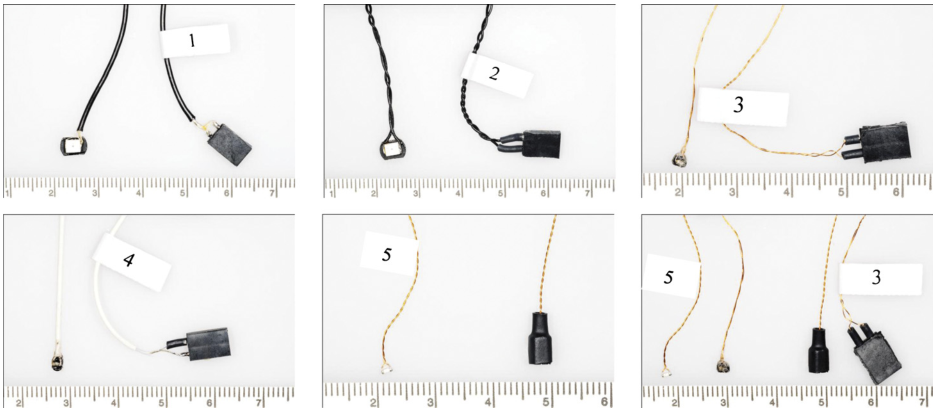

FIGURE 11. Protoypes of active makers, produced by Lucotronic. (1) 5-mm marker, cable outlet on one side. (2) 5-mm marker, cable outlet on 2 sides, (3) 2-mm marker, cupper-wove cable. (4) 2-mm marker, rubber cable coating. (5) final 2-mm marker adapted from number 3; (5-3) final 2-mm active marker in comparison with the original number 3.

FIGURE 12. Active Lucotronic markers in the face for trial video.

shift-tracking algorithm[31] was implemented by the Center for Virtual Reality and Visualization Research, Ltd, Vienna, Austria (Fig. 14). Tracking results were nearly 99%. Landmarks covered by skin creases were recalculated with software programs designed by the Institute of Computer Graphics and Algorithms, Pattern Recognition and Image Processing Group, Technical University in Vienna, Austria.

DISCUSSION

Traditional assessments of facial movement and degree of facial dysfunction rely on subjective judgment of a trained observer. Attempts have been made to standardize these methods, but observer error and the lack of a subtle, precise, and complete vocabulary of language concerning facial motion limit subjective methods of description. Numerous subjective and objective diagnostic tools to quantify facial palsy have been proposed. Many centers worldwide have developed their own diagnostic procedures, yet an international standard remains to be established.[32]

Subjective diagnostic tools to analyze facial movements, such as the Sydney,[33] Sunnybrook,[34] and House–Brackmann[4] facial grading systems, or patient questionnaires, such as FaCE Scale Instrument,[35] are subject to investigator rating.[36] The House–Brackmann[4] facial grading system was established in 1985 and is currently the North American standard for rating and reporting facial palsy. To improve the grading system, subsections have been developed. Well-known subsection-grading systems dealing with facial synkinesia are the Facial Grading System,[34] the regional House–Brackmann facial nerve-grading system,[37] the Sydney facial grading system[36] and patient questionnaires, as the Synkinesis Assessment Questionnaire[38] and the FaCE Scale Instrument.[35] These are easily applicable, inexpensive tools, but often too broad in scope to be useful for evaluating a specific area of interest. They provide only rough estimates of facial function. Pronounced intersubject and interobserver variability has been reported,[32] limiting the clinical use of subjective tools, especially for therapy concept planning and evaluation of therapeutic interventions.[9,13]

Objective diagnosis of facial function is necessary for planning and evaluating therapeutic interventions in patients with facial palsy.[9,18] Systems proposed to analyze facial movements objectively[3,7,9,10,32,39–53] (Table 7) use various techniques to visualize complex facial movements by measuring and analyzing landmarks

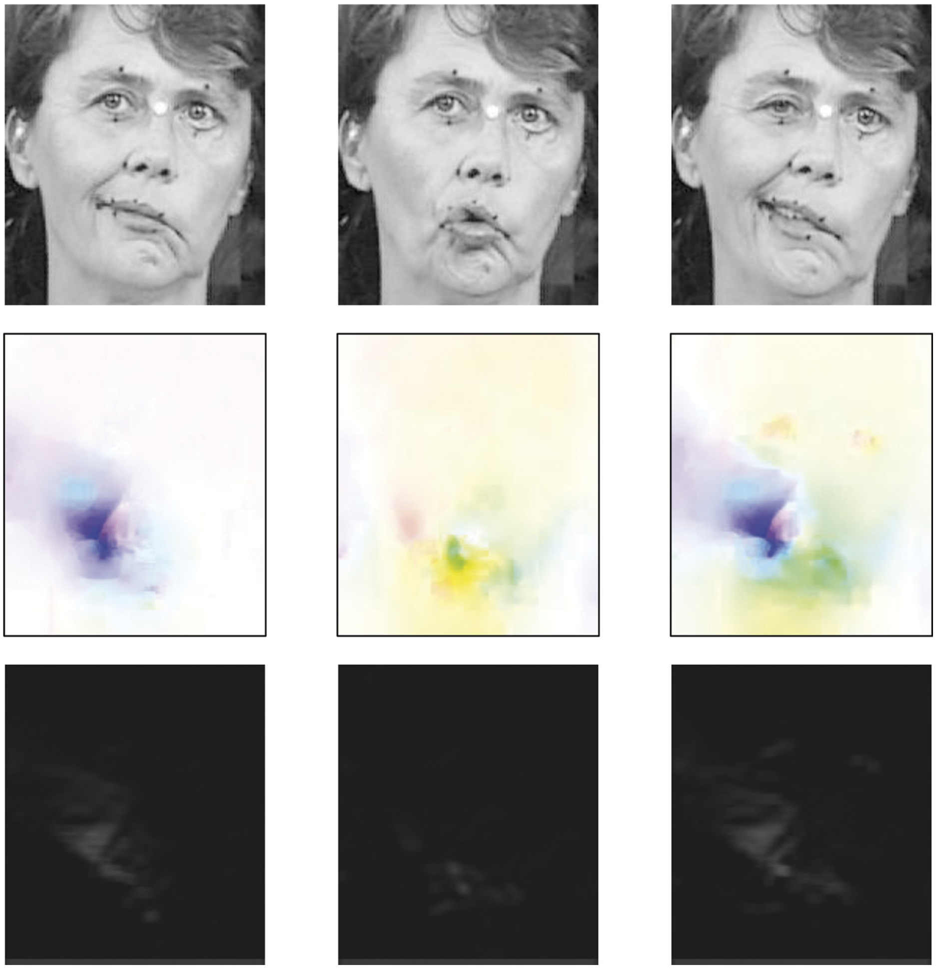

FIGURE 13. Results of optical flow (row 2) and optical strain (row 3) on selected frames which contained peak expressions in the example sequence. The intensity of the color in the optical-flow images represents higher magnitude, whereas colors represent different directions of the vectors. In the optical-strain images, whiter regions represent higher strain magnitude, while black regions contain no strain (2010 and reproduced with the permission of the Department of Computer Science and Engineering, University of South Florida, Tampa, FL).

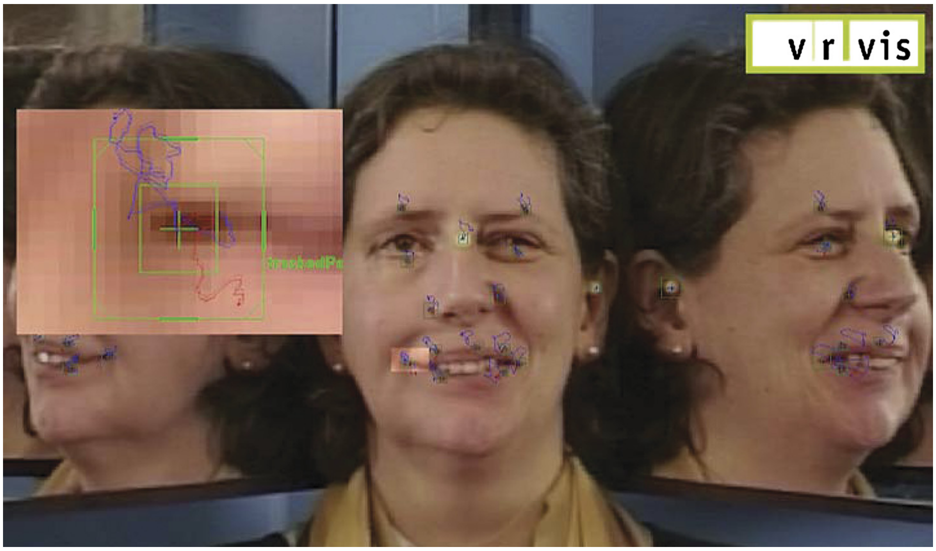

FIGURE 14. Visualization of the automatic tracking feature. The zoom window shows the track of the right mouth corner, whereas the red track is the excursion that has been tracked, and the blue track is the excursion that is going to be tracked (2010 and reproduced with the permission of Center for Virtual Reality and Visualization Research, Ltd, Vienna, Austria).

in the face,[7,9,32,43,46,49] pixels,[9,40,45] variation in light reflections,[44] and contour lines of the surface[42] through photographs[3,41,45] or video recordings of facial movements.[32,43,46,49] Objective diagnostic tools have been developed to focus on movement in specific areas of the face, such as the forehead,[48] the eyes,[47,50] and the lips.[51,53]

Objective diagnostic tools to analyze facial function are more precise than subjective tools. Wu et al showed that synkinetic movements of the face occurring with eyelid closure were diagnosed significantly more frequently with objective than with subjective diagnostic tools.[54] Three-dimensional analysis allows the most exact assessment of complex facial function. Gross et al found that 2-D analysis underestimates 3-dimensional amplitudes by as much as 43%.[55] Therefore, 3-dimensional analysis of facial function is crucial in preoperative and postoperative evaluation of facial movements, as for planning of surgical therapy concepts, treatment evaluation, and research.[9] Diagnostic systems using 3-dimensional video-analysis, like the system developed by Frey et al,[13,18,56,57] provide both quantitative and qualitative data on facial function.[58–60]

Our department has been using an objective 3-dimensional video-analysis system since 1998. Although the analysis process of this system has been very time consuming, it has been validated and proven reliable in assessing the therapy for facial palsy.[13–17,61]

The further goal of 3-dimensional video-analysis is to distribute this system for evaluating complex facial movements, through which we aim to create an international standardized facial grading system that is easily applicable, efficient, and affordable in the daily clinical routine.

A standardized, objective, automatic facial motion analysis system would benefit not only plastic and reconstructive surgery but also otolaryngology, ophthalmology, neurosurgery, and oral and maxillofacial surgery. Patients with facial palsy, but also patients with congenital facial malformations (eg, cleft lip and palate), posttraumatic facial deformities, degenerative and autoimmune conditions, or deformities after tumor surgery will profit from improved analysis of facial form and function. Objective evaluation of the face before operations that have a high risk of injuring the facial nerve—eg, acoustic neuroma (median incidence of postoperative facial palsy 59.2%,[62] depending on tumor size[63]), cholesteatoma (mechanism of facial-nerve paralysis due to cholesteatoma: direct pressure on the nerve,[64] impaired circulation in the facial nerve[65]; early decompression

TABLE 7. List of Objective Diagnostic Analysis Systems in the Last Decades

Author	Method	Acquired Data
Burres 1985	Surface electromyographic recording and measurement of specified facial landmarks at rest and during defined facial expressions with handheld calipers	Displacement of markers during motion; no multiregional analysis
Neely et al, 1992	Facial light reflectance	Facial-contour changes; no measurement of direction of magnitude of motion
Frey et al, 1994	Measurement of specified facial landmarks at rest and maximal facial expressions with Faciometer	Displacement of markers during motion; no multiregional analysis
Johnson et al, 1994	Tracking of facial markers on photographs	Measurement of direction of displacement of the markers
Yuen et al, 1994	Light-interference theory, in which illumination through a grid created contour lines upon an object	Quantitative assessment of facial movements and the severity of facial palsy
Isono et al, 1996	Tracking of facial markers on photographs	Measurement of direction of displacement of the markers
Meier-Gallati et al, 1998	Facial light reflectance	Facial contour changes; no measurement of direction of magnitude of motion
Sargent et al, 1998	Digital photographs, tracking of facial markers, pixel-subtraction	2-D analysis of facial motion
Frey et al, 1999	3-D videoanalysis, tracking of static and dynamic facial markers	3-D quantification of displacement, direction and time pattern of facial movements, analysis of overall symmetry of the face
Coulson et al, 1999	3-D videoanalysis, tracking of facial markers	3-D measurements of displacements of facial markers
Somia et al, 2000	Tracking of facial markers around the eyes, special helmet for the camera	Measurement of displacement, velocity, and acceleration of eyelid motion
Heckman and Schön-Hupka 2001	Serial digital photographs, digital overlay technique	Measurement of brow-mobility: distances, areas and angles
Wachtman et al, 2001	2-D videoanalysis, feature points marked on digital image	Speed, acceleration, direction of motion, and displacement
Linstrom 2002	Infrared light source, infrared-light sensitive, camera light-reflective facial markers	Quantification of displacement of markers, time pattern of motion
Nakamura et al, 2003	Video recording of facial movements, measurements on still images	Measurement of eye opening width during different mouth movements
Tomat and Manktelow 2005	Video recording, tracking of facial markers around the mouth on still frames	2-D analysis of smile movements, displacement, and angles of motion
Mishima et al, 2006	3-D video-based motion-capture system, no facial markers, infrared cameras	3-D analysis of mouth motions
Manktelow et al, 2008	Measurement of specified facial landmarks at rest and maximal facial expressions with handheld ruler	Displacement of markers during motion; no multiregional analysis and measurement of direction
Sawyer et al, 2008	3-D stereophotogrammetry, facial-surface landmarks	3-D analysis of resting position and smile; measurement of vectors, distances, and angles

improves outcome,[66] and 46.2% of cases involved facial paralysis[67]), and parotid-gland operations (the commonest postoperative complication: temporary facial palsy 23.6%[68])—could provide essential information for postoperative management and legal documentation. The objective evaluation of different surgical concepts will promote evidence-based medicine and quality control in the field of facial-nerve surgery, helping the surgeon to create an individual reconstructive procedure to reanimate the paralyzed face. Furthermore, it will enhance biofeedback rehabilitation of patients with facial palsy by providing feedback of the recovery progress,[50,69–71] consequently achieving early occupational rehabilitation.[72] The exact quantification and determination of the degree of facial palsy will offer important support in evaluating pensions and compensations, reducing socioeconomic costs caused by long-term unemployment. Applications in dermatology could be the objective documentation of patients with scleroderma or patients before and after botulinum toxin treatments.[48,73] In neurology, the quantification and documentation of facial disorders such as dyskinesia and localized dystonia (eg, blepharospasm, Meige syndrome, spastic torticollis, hemifacial spasm)[74,75] could optimize biofeedback rehabilitation, physical therapy, and speech therapy. A further area of application could be the access of age-specific facial function (eg, alternating emotional expression in patients with Alzheimer disease, compared with healthy elderly controls[76]). Benefits in psychologic and in psychiatric patient management could be made more exact by the objective quantification and classification of patients' mental state (eg, depression, for which methods to quantify the seriousness of diagnosis are lacking). Developments in this field focusing on functional magnetic resonance imaging are still in their early stages. The face, the mirror of the mental state, shows various patterns of active and static characteristics, which could be captured and classified to establish a reliable, fast, and cost-efficient breakthrough: the "visible" classification of depression. The objective automatic 3-dimensional video-analysis system could improve the long-term assessment of facial function in children with congenital facial palsy or other congenital malformations, such as impairment of craniofacial growth.[77] The continuous analysis of the child's face could enhance longitudinal studies in tracking facial landmarks on a wrinkle-free face with changing facial proportions.

The social and scientific impacts of this system (Table 8), as mentioned previously, are just a narrow part of what the system will be able to contribute to the scientific medical community. Interdisciplinary communication among medical fields will be able to use one common standardized objective language to talk about facial palsy. This language will provide optimal objective diagnostics and personalized therapy concepts, leading to better results and a higher quality of life of patients with impaired facial function.

TABLE 8. Fields of Application for the 3-D videoanalysis System

Medical Fields	Field of Application
Plastic and reconstructive surgery	Facial-nerve surgery, facial reconstruction, tumor operations, trauma surgery, congenital facial malformations
Ophthalmology	Eyelid surgery (eg, tumor, trauma)
Oral and maxillofacial surgery	Congenital facial malformations (eg, cleft lip and palate), tumor operations, trauma surgery
Otolaryngology	Ear surgery (eg, tumor, cholesteatoma, trauma), parotid-gland operations
Neurosurgery	Acoustic neuroma surgery
Dermatology	Facial structure, botulinum toxin treatments
Neurology	Facial palsy, facial dyskinesia, facial dystonia
Physical medicine and rehabilitation	Biofeedback rehabilitation, physical therapy, speech therapy
Psychiatry and psychology	Emotional expression (eg, depression, Alzheimer disease)

CONCLUSION

A 3-dimensional video-analysis system has been an accurate and reliable tool in our clinical routine since 1998. It has documented precisely, analyzed, and visualized the main complaints of 241 patients with facial palsy, with more than 1000 videos made to track the rehabilitation progress after each operational therapy.

This system provides essential data to personalize the surgical-therapy concept of each patient with facial palsy, so as to quantify the operational outcome and assist the surgeon in making decisions about any subsequently necessary therapeutic procedures. There are no comparable tools at this moment to acquire video, photograph, and 3-dimensional motion-analysis documentation.

Technical improvements in this 3-dimensional video-analysis system have increased the speed of data analysis, leading to the development of an automatic standardized, objective, sensitive, and quantitative system for evaluating complex facial movements. With this achievement in view, we are searching for a business partner for precommercial development, so as to have the product prepared for production and distribution, with the aim of marketing an international standardized facial grading system that is easily applicable, efficient, and affordable in the daily clinical routine.

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