Advances in Speech–Language Pathology, March 2007; 9(1): 65–72

informa
healthcare

Electropalatography home training using a portable training unit for Japanese children with cleft palate

YURI FUJIWARA

Hiroshima University Hospital, Hiroshima, Japan

Abstract
The primary objective of this study was to determine the effectiveness of electropalatography (EPG) home training using a portable training unit (PTU) for clients with residual articulation disorders. The participants were five Japanese children with cleft lip and palate ranging in age from 8 to 13 years when they began EPG home training. These children had residual articulation disorders caused by abnormal tongue-palate contact, although four of them had received conventional speech therapy for 3 to 8 years before starting EPG training. The WinEPG system (Articulate Instruments, Edinburgh) was used to make recordings during the initial assessment and the monthly follow-up. The participants received EPG training sessions when they attended for their monthly recordings. A training programme was developed for each participant, and they were instructed to carry out their homework assignments using the PTU. After 7 to 9 months of home training, marked changes in the EPG patterns and "centre of gravity" values were observed in four of the five participants. The remaining one participant, who had not experienced speech therapy before, needed a longer period of EPG training to achieve good results. Our preliminary data suggested that EPG home training was effective in school-aged participants who had residual articulation disorders.

Keywords: *Cleft palate, electropalatography, portable training unit, home training, treatment efficacy.*

Introduction

Palatalized articulation is reported to be the predominant abnormal articulatory pattern among the post surgical cleft palate patients with sufficient velopharyngeal function (Ainoda & Okazaki, 1996; Ainoda, Yamashita, & Tsukada, 1985). Based on radiographic and electropalatographic studies, Okazaki, Onizuka, Abe, and Swashima (1980) described palatalized articulation as the error pattern in which dental and alveolar consonants are produced with articulatory contact involving the back of the tongue against the posterior border of the hard palate. Using electropalatography and sound spectrography, Yamashita and Michi (1991) described palatalized misarticulation (PM), along with other two types of tongue-palate misarticulation: lateral misarticulation (LM) and nasopharyngeal misarticulation (NM). PM was defined as constriction or closure occurring at the posterior border of the hard palate and the anterior of the soft palate with air passes along the midline. LM occurs when the tongue maintains complete lingual-palatal contact continuously and air flows laterally out of an occluded dental arch through spaces posterior to the molars. And NM describes the condition where the tongue maintains complete lingual-palatal contact continuously and the air stream flows out through the nose. The retracted place of articulation has been well documented in speakers with cleft palate regardless of their native language and has a reputation for requiring long-term speech therapy for remediation (Trost, 1981; Whitehill, Stokes, & Yonnie, 1996).

Several studies have reported the effectiveness of visual feedback therapy using EPG for residual articulation errors associated with cleft palate. A treatment procedure using EPG was successful in acquiring correct tongue placement even for older children or adults with late repair of cleft palate (Gibbon & Hardcastle, 1989; Whitehill et al., 1996). It is also reported that EPG therapy was more efficient than conventional therapy in changing articulatory patterns in participants with cleft palate (Gibbon et al., 2001; Michi & Yamashita, 1993). However, although EPG is a valuable therapy tool, the clinical use of EPG has been limited to a few research facilities in Japan, with the result that not many people have yet received the benefit of EPG therapy. In order to increase accessibility of EPG therapy, EPG4, a portable training unit (PTU), was

Correspondence: Yuri Fujiwara, Speech Clinic, Division of Specific Dentistry, Hiroshima University Hospital, 1-2-3 Kasumi, Minami-ku, Hiroshima 734-8553, Japan. Tel: +81 82 257 5729. Fax: +81 82 257 5692. E-mail: fujiwara@hiroshima-u.ac.jp

ISSN 1441-7049 print/ISSN 1742-9528 online
Published by Informa UK Ltd.
DOI: 10.1080/14417040601120904

developed (Jones & Hardcastle, 1995). In Scotland, four clinic centres of cleft palate possess EPG systems and a number of PTUs. The PTUs are loaned from the clinic centres so that visual feedback treatment with a local speech therapist can take place close to a client's home (Gibbon, Stewart, Hardcastle, & Crampin, 1999).

This paper describes the effect of EPG home training using a portable training unit (PTU) for cleft palate patients with residual articulation disorders. To our knowledge, the only other report of the use of PTU for home training is Gibbon et al. (1999).

Method

Participants

Five participants, four males and one female, aged 8–13 years (mean 10.75 years) participated in the study. Three of them had a unilateral cleft lip and palate and two had a bilateral cleft lip and palate. The primary cheiloplasty was performed when they were around 3-months-old. For the participants with bilateral cleft lip, each side of the clefts was operated separately with 2 to 3 months intervals. The primary palatoplasty was performed between 1 and 2-years-old. Four of them had received conventional speech therapy at the local speech clinic for 3 to 8 years before starting the EPG home training. The fifth child had never undergone speech therapy because he lived so far away from our clinic, with each trip taking more than 3 hours by Shinkansen (a high speed train). The other four participants also came from distant places, which made frequent visit of the clinic difficult. Considering their difficulty in travelling to the clinic, EPG home training using a PTU was proposed. In an agreement with the children and their caregivers, the programme of EPG home training was started. The project team consisted of one dentist and five speech therapists.

Prior to EPG therapy, each child's velopharyngeal function was examined, using a simple cold mirror test, the Nasometer, and nasoendoscopy, by a dentist and a speech therapist. Velopharyngeal function was adequate in all children except one, who required a speech appliance and underwent a pharyngeal flap operation during the course of EPG therapy (Table I).

All participants showed residual articulation disorders, including palatalised and lateral misarticulation. Table II shows the pre-intervention speech/error profile during single syllable production. The judgement was based on auditory impression, inspection of articulatory movement with EPG, and airflow examination using a cold stainless steel mirror. The terminology used to describe the error patterns was derived from Japanese categorical system of articulation problems in individuals with cleft palate which was developed by the Committee on Cleft Palate Speech, Japan Society of Logopedics and Phoniatrics (Ainoda et al., 1993) (Appendix 1).

In our cases, palatalized articulation was the predominant error pattern and lateral articulation was noticed in two participants. The term "interdental" is used for /s/ or /ts/ in the profile of KY and IK. Both of them used to present palatalized articulation for dental sounds, but they tried to use interdental sounds on purpose, because they were instructed to protrude the tongue tip between the teeth for practice during conventional speech therapy. "Acceptable (production)" in Table II means slightly deviated from "Normal", but intelligible speech.

As a normal example, a cumulative frame was generated from the EPG recording of five adults without present or past speech, language, or hearing problems, following the method described by McLeod, Roberts, and Sita (2006). Figure 1 shows an example of EPG patterns of Japanese alveolar stop /t/ in /ata/ and a cumulative frame of maximum contact frames of five normal adults. This horseshoe pattern is similar to that of the English alveolar stop (McLeod & Roberts, 2005).

Therapy procedures

After the initial assessment, a training programme was developed for each child. Lingua-alveolar voiceless stop /t/ was selected as the first target sound for every participant, because it was realized as palatalized articulation in all of the participants, and it seemed easier for them to change tongue contact pattern for stops than for fricatives and affricatives. During the first visit to the clinic, a speech therapist demonstrated a model EPG pattern of the target sound and explained the difference between the

Table I. Characteristics of participants.

Participant	Gender	Cleft type	Starting age (year;month)	Period of CST	VPI
KY	Female	BCLP	8;4	3Y4M	No
AK	Male	UCLP	9;4	4Y4M	Yes → No
IK	Male	BCLP	8;9	5Y8M	No
HN	Male	UCLP	13;11	8Y	No
FK	Male	UCLP	12;11	never	No

Note: CST: conventional speech therapy. VPI: velopharyngeal insufficiency. BCLP: bilateral cleft lip and palate. UCLP: unilateral cleft lip and palate.

Table II. Speech/Error Profile (perceptual assessment of single syllables).

	KY	AK	IK	HN	FK
/p/ /b/	○	○	○	○	○
/s/	interdental	palatalized	interdental	palatalized	lateral
/ts/ /dz/	palatalized	palatalized	interdental	palatalized	palatalized
/t/ /d/	palatalized	palatalized	palatalized	palatalized	palatalized
/ʃ/	lateral	Δ	Δ	palatalized	palatalized
/tʃ/ /dʒ/	lateral	Δ	Δ	palatalized	palatalized
/k/ /g/	○	○	○	○	○

Note: ○ normal; Δ acceptable.

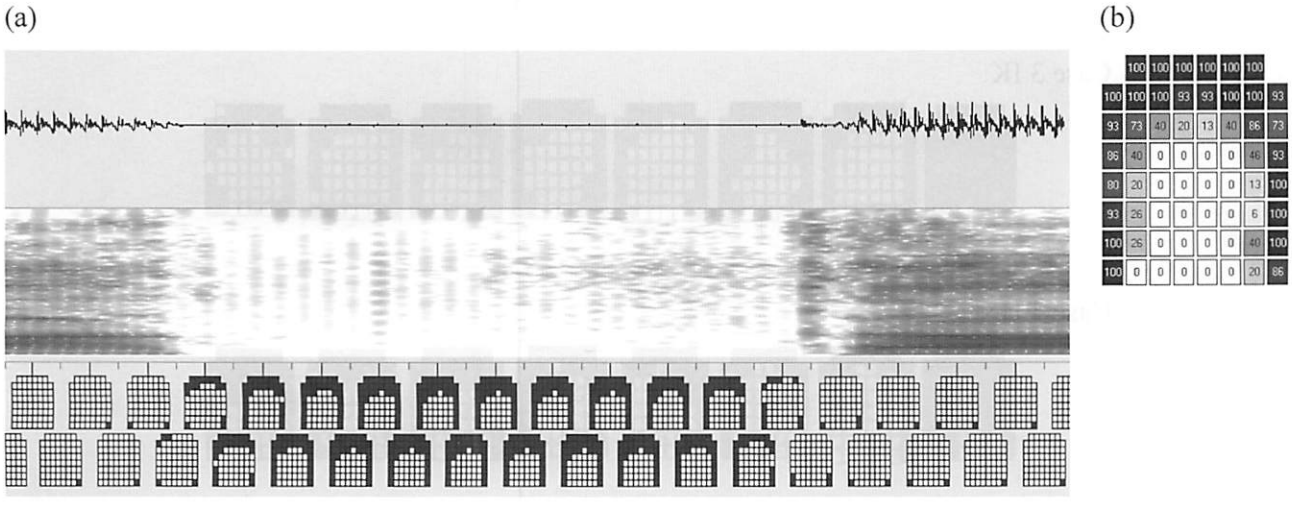

Figure 1. An example of (a) normal EPG pattern for /t/ in /ata/ and (b) a cumulative frame, generated from the maximum contact frames of five normal adults.

client's pattern and the model. The caregivers also saw the difference and understood what the correct EPG pattern looked like. During monthly check-ups at the clinic with the speech therapist, the participants received EPG training sessions after the EPG recordings. The practice progressed from single syllable production to word initial and final position (i.e., the syllable-initial-word-initial position and the syllable-initial-word-final position), and then to short sentences. At each level, appropriate homework was assigned with written instruction and a printed model pattern. Participants brought the PTU home and were asked to practise for 30 minutes each day with EPG visual feedback.

Data recording

The WinEPG system (Articulate Instruments Ltd.) was used to make simultaneous recordings of EPG and acoustic data. The participants were instructed to read aloud speech samples that were displayed on the EPG monitor. The speech samples were syllables (Appendix 2), words, and sentences that included dental, alveolar, and palatal sounds. The syllable samples were repeated four times at each recording. A recording was made during the initial assessment and in every follow-up session, i.e., approximately once a month.

EPG data analysis

For this study, the EPG frames of maximum contact during the stop closure for /t/ in /ata/ were selected during each data recording, because it was the first target sound for five participants as mentioned before. The "centre of gravity" (COG) value was calculated from this frame as a quantitative measure. As the COG value represents the relative concentration of electrodes in the anterior-posterior dimension (Hardcastle & Gibbon, 1997), it is useful for measuring progress from an incorrect posterior placement to a correct anterior placement.

Results

Changes in EPG patterns

Figure 2 shows the consecutive changes in the EPG pattern for the target sound /t/ in /ata/, obtained at the initial assessment and during the seven monthly follow-up sessions. Although there was some variability in performance for each participant, especially for FK, the most typical pattern was selected. Each frame represents the maximum contact pattern for /t/. The reliability check of the EPG annotations was conducted on one participant, and there was a high

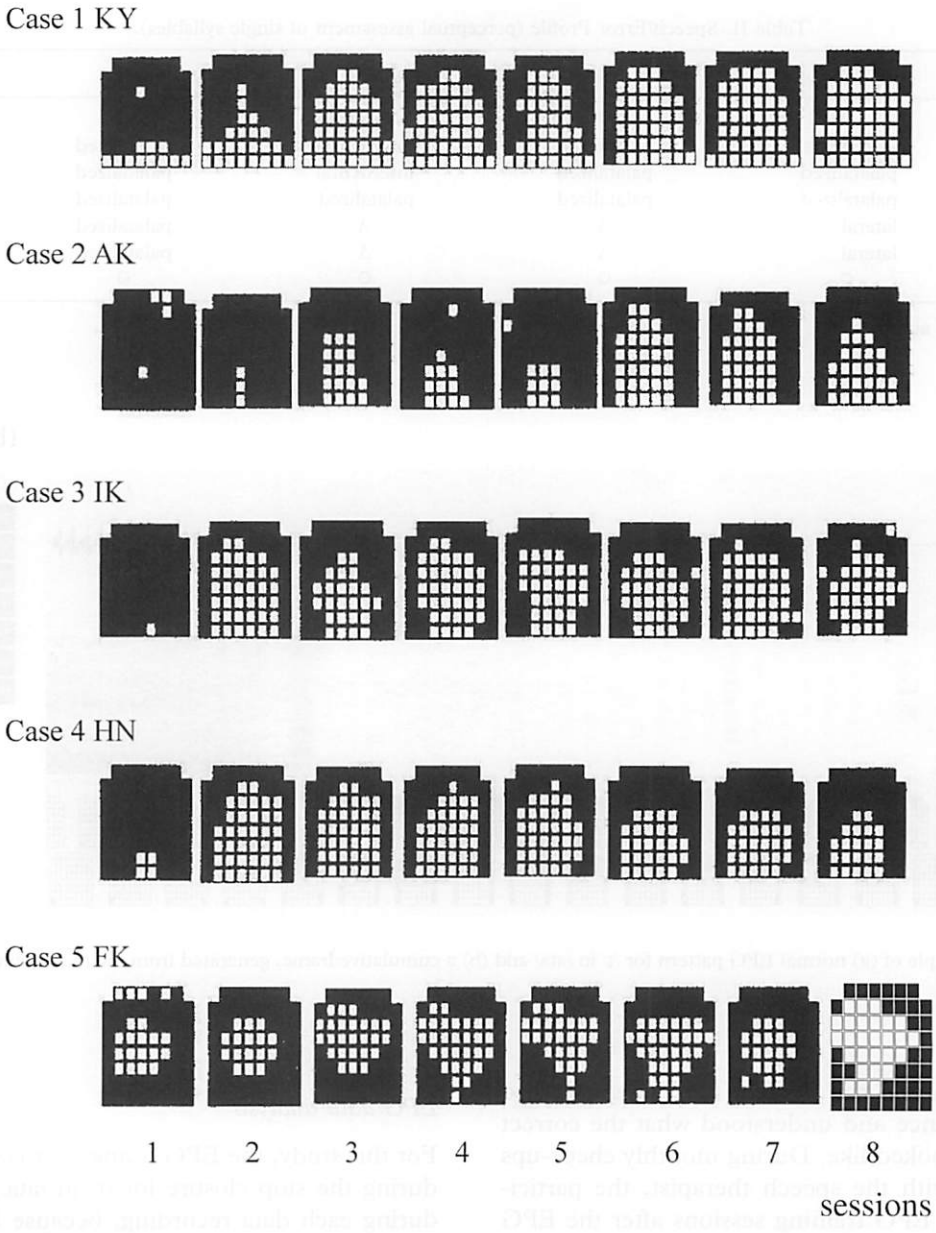

Figure 2. Consecutive changes in the EPG patterns for the target sound /t/ in /ata/ from the initial assessment until the eighth session (left to right).

level of accuracy (95%) between the researcher and the collaborator for the identification of the maximum point of contact.

Participant 1 (KY)

KY began EPG home training at the age of 8 years 4 months, after 3 years and 4 months of conventional speech therapy. At the initial recording, her EPG pattern for /t/ showed "increased contact", which was described by Gibbon (2004) as one of the most frequently observed EPG characteristics of speech produced by individuals with cleft palate. At the second and third recordings, she paid too much attention to placing her tongue tip forward, so that the lateral margins of her tongue blade did not make contact with the lateral electrodes at the last two rows of the EPG plate. At the fourth recording, she achieved the normal horseshoe pattern. After working on palatalized /t/, /ts/, and /s/ for 7 months, she practiced /tʃ/ and /ʃ/, which were realized as lateral misarticulation, for another 5 months. As previously described, practice of each sound progressed from single syllable production to the syllable-initial-word-initial and the syllable-initial-word-final position, and short sentences. At each level of practice, PTU was used for visual feedback. At each level, her performance was checked to ensure that correct articulation was maintained without visual feedback and finally without the EPG plate in the mouth. KY underwent a total of 12 1-hour sessions at the clinic approximately once a month over a 13-month period, and she was dismissed from the EPG therapy having acquired perceptually acceptable realizations for all of the target sounds.

Participant 2 (AK)

AK started EPG home training at the age of 9 years 4 months, after 4 years and 4 months of conventional speech therapy at a local elementary school. As his velopharyngeal function was initially insufficient, a speech appliance was attached to his EPG plate. At 9 years 8 months (between the fourth and fifth recordings), he underwent a pharyngeal flap operation and gained good velopharyngeal function, which was determined by nasoendoscopy performed by the dentist. Like KY, his EPG patterns for /t/ showed "increased contact" at the initial recording, and only a gradual reduction in contact was observed in subsequent months. A significant reduction in the amount of tongue palate contact occurred between sessions 4 and 5, which was following the pharyngeal flap operation. Following /t/, he practiced /s/, /ʃ/, /d/, /ts/, /dz/ in this order. The procedure of his training was the same as the first case. AK underwent a total of 12 one hour sessions at the clinic over a 15-month period, and he was dismissed from the EPG therapy with acquiring perceptually acceptable realization for all of the target sounds.

Participant 3 (IK)

IK had received conventional therapy for 5 years and 8 months before starting EPG therapy at the age of 8 years 9 months. The "increased contact" pattern observed in the initial recording quickly changed to a normal pattern at the second session. He worked on /t/, /ts/, and /s/ in this order. IK received a total of 10 1-hour sessions at the clinic over a 10-month period after which these targets were correctly produced and he was dismissed from EPG training. He still required additional practice for /k/ which was realized as a glottal stop during conversation, however. Because EPG feedback is not suitable for velar sounds, conventional therapy took place.

Participant 4 (HN)

HN started EPG home training at the age of 13 years 11 months, after attending conventional therapy at a local elementary school for 8 years. His EPG patterns also showed "increased contact" pattern at first, but changed into a normal horseshoe pattern at the second session. He then worked on other phonemes in the following order: /t/, /s/, /ts/, /dz/, /ʃ/, /tʃ/, and /dʒ/. Home training using PTU was especially effective for him, because he was the oldest among the participants and fed up with conventional therapy. In contrast, he played an active role in EPG therapy and achieved perceptually acceptable speech at the time of entering a senior high school. HN underwent a total of 13 1-hour sessions at the clinic over a 14-month period.

Participant 5 (FK)

FK had not previously undergone speech therapy. He joined our programme when he was 12 years 11 months, and his EPG pattern differed markedly from those of the other cases. He could make the horseshoe pattern when he just touched his tongue to the palate; however, when he attempted to produce plosive sounds, the back of the tongue elevated to touch the velar part. He had a difficult time eliminating his abnormal tongue behaviour for almost 1 year, but finally attained acceptable lingual-palatal contact pattern and perceptually acceptable realization for /t/. He worked on /t/, /d/, /ʃ/, /ts/, /dz/, /s/, and /tʃ/ in this order. FK underwent a total of 12 1-hour sessions at the clinic over a 15-month period. Besides the 12 sessions at the clinic, additional 30 online sessions via Yahoo! Messenger™ were adopted once a week. Yahoo! Messenger™ is free software which allows video conferencing. This makes it possible for the speech therapist at the remote clinic to check the articulatory movement of the child while he was using the PTU at home.

Changes in the COG value

Figure 3 shows the consecutive changes in COG values for each participant. The normal COG value for /t/ was 5.04 which was based on the data collected from the five adults served as a normal control group. At the initial recording, the COG values of all participants were below 5; however, they increased from the first to the last recording in every case except in FK.

Discussion

We investigated the effect of EPG home training using PTU for children with residual articulation disorders associated with cleft palate. In the course of EPG home training, marked changes in the EPG patterns and COG values were observed for /t/ in

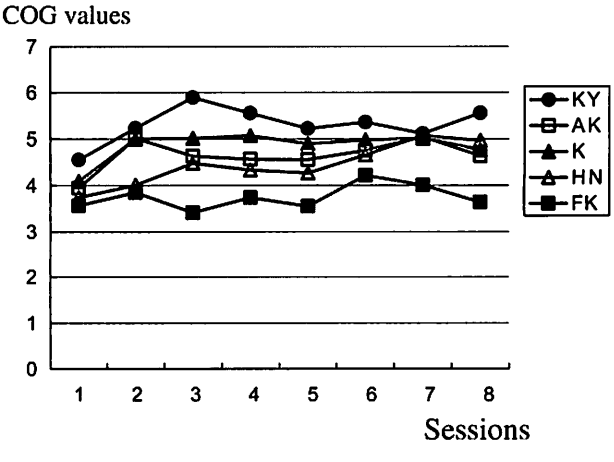

Figure 3. Consecutive changes in centre of gravity values.

four of the five participants. Following the first target sound /t/, each participant practiced three to seven sounds including dental, alveolar and palatal sounds which were perceptually judged as palatalized or lateral misarticulation. Four of the participants acquired perceptually acceptable realizations for all of the target sounds and were dismissed from the EPG therapy after a total of 10 to 13 once a month sessions at the clinic. The duration of home training using PTU was approximately 10 to 15 months. These four participants had received conventional therapy for 3 to 8 years before they started EPG home training. Compared to this long duration of conventional therapy that showed insufficient results, the EPG training produced remarkable changes within a short period of time.

Two studies have compared the efficacy of therapy with and without EPG visual feedback. Yamashita, Michi, Imai, and Suzuki (1988) reported therapeutic procedures for the /s/ phoneme in five participants with cleft palates aged 4 to 15 years. Three of them received visual feedback therapy using dynamic palatography (DP), and two of them received conventional therapy. The results indicated a much quicker effect of visual feedback therapy than of conventional therapy. Gibbon et al. (2001) also reported the effect of visual feedback therapy for articulation disorders associated with cleft palate. Twelve participants, aged 5 to 18 years, participated in their study. To examine the difference between the visual feedback therapy (EPG therapy) and conventional therapy (non-EPG therapy), five participants had four sessions of EPG therapy followed by four sessions of non-EPG therapy. The remaining seven participants had four sessions of non-EPG therapy first and then four sessions of EPG therapy. They concluded that EPG therapy was more efficient than non-EPG therapy in changing articulatory patterns for most of the participants.

The merit of EPG training is that it provides immediate information on tongue placement to the users. They can easily understand the target pattern and recognise what they are doing. On the other hand, during conventional therapy, it is difficult for the patients to understand slight differences in tongue placement from auditory feedback alone. They are not sure if they are doing the right thing, and a vague grasp of the target may lead to decreased motivation and ends in limited progress. Four of our participants had attended conventional therapy for 3 to 8 years before beginning EPG therapy, and their parents were frustrated by the long-standing speech therapy, which did not produce satisfactory results. That is the reason why they agreed to start the new therapeutic method using EPG.

In this study, a PTU was used for home training. To our knowledge, no previous study has used a PTU for visual feedback training at home. One of the merits of PTU home training was to reduce the number of treatment sessions. Michi, Suzuki, Yamashita, and Imai (1986) reported therapeutic process in which dynamic palatography was used for a 6-year-old girl with repaired cleft lip and palate. She presented the same type of speech errors as our participants and underwent a total of 49 1-hour sessions of visual training conducted approximately once a week over a 12-month period to attain acceptable speech. It was impossible for our participants to visit the clinic every week, instead, they brought the PTU home and practiced everyday by themselves. They visited the clinic once a month and a total number of sessions were 10 to 13, approximately a quarter of Michi's case. PTU was especially beneficial for clients who live in remote locations and have limited access to speech therapy. Both the participants and their families took advantage of the visual feedback training with PTU. They could see the improvement while working on their assignments daily, which increased motivation and hope.

Although PTU is very convenient for EPG home training, a monthly check-up session is essential for improvement of articulatory precision. In addition to visually checking the EPG patterns, it is necessary to check if they can use an appropriate air flow control while producing the target sounds. For example, some child showed a good horseshoe pattern for alveolar stops, but oral pressure for alveolar stops was not accumulated, because of the habitual glottal stops. Attention should be paid when practicing short sentences with PTU. Some child just read aloud the printed sheet of sentences without looking at the monitor of the PTU. It is necessary to make sure if a child and his/her caregiver have fully understood the home work with PTU.

The fifth participant, FK, lives in a remote place and did not have a chance to receive speech therapy before. Then, EPG home training was introduced at the age of 12 years 11 months. Compared to the other four participants, his improvement was exceptionally slow. His EPG pattern for /t/ was different from the other participants' pattern. It is similar to the alveolar-velar double articulation (AVDA) described by Gibbon, Ellis, and Crampin (2004). They discussed four possible explanations for developing AVDA: (1) impaired speech motor control, (2) a past history of velopharyngeal dysfunction, (3) abnormal hard palate size and shape, and (4) the presence of fistulae. In the case of FK, his velopharyngeal function was sufficient and no fistula was found, but his hard palate was narrow and high arched. His abnormal shape of the hard palate might be the cause of developing an irregular tongue palate contact. It is also speculated that his inexperience of conventional speech therapy caused him to delay in improvement, because he had never worked on motor control of his tongue. However, he has finally overcome the difficulty through the aid of PTU and Yahoo! Messenger described above. Another

possibility of using PTU with a videophone was implied by this case.

Although our preliminary data suggested that EPG home training, using PTU, was effective in school-aged participants with residual articulation disorders, several problems remain to be solved before widening the clinical use of WinEPG and PTU in Japan. One is the economical fabrication of an artificial plate, which is time-consuming and costly. The other is organising a support network for EPG therapy. In Scotland, a network called "CleftNet Scotland" has been established, which links cleft palate centres around Scotland with EPG specialists based at Queen Margaret University College (Edinburgh) in order to improve access to EPG therapy (Gibbon, et al., 1998). In Japan, few institutions and hospitals have purchased the RION EPG system. However, few of them could run the system because of the lack of information for clinical use. With declining demand for EPG, RION company ceased manufacturing in 1996. Introducing new EPG system and PTU to Japan, technical and clinical support is of the essence.

Acknowledgements

The EPG project members express our gratitude to Dr. Alan Wrench (Articulate Instruments Ltd.) for his technical support via frequent email exchanges and a 1-day workshop at Queen Margaret University College in Edinburgh. Part of this paper was presented at the 4th International EPG Symposium held at the Edinburgh Conference Centre on 29–30 September 2005.

References

Ainoda, N., & Okazaki, K. (1996). Results of systematic speech sound monitoring in children with cleft palate. *Folia Phoniatrica et Logopedica, 48*, 86–91.

Ainoda, N., Okazaki, K., Ohira, A., Katoh, M., Tanokuchi, F., Fukuda, T., Miura, M., & Sawashima, M. (1993). International survey on cleft palate speech evaluation and categorization. *The Japan Journal of Logopedics and Phoniatrics, 34*, 292–297.

Ainoda, N., Yamashita, K., & Tsukada, S. (1985). Articulation at age 4 in children with early repair of cleft palate. *Annals of Plastic Surgery, 15*, 415–421.

Gibbon, F. E. (2004). Abnormal patterns of tongue-palate contact in the speech of individuals with cleft palate. *Clinical Linguistics and Phonetics, 18*, 285–311.

Gibbon, F., Crampin, L., Hardcastle, W. J., Nairn, M., Razzell, R., Harvey, L., & Reynolds, B. (1998). CleftNet (Scotland): A network for the treatment of cleft palate speech using EPG. *International Journal of Language and Communication Disorders, 33*, 44–49.

Gibbon, F. E., Ellis, L., & Crampin, L. (2004). Articulatory placement for /t/, /d/, /k/ and /g/ targets in school age children with speech disorders associated with cleft palate. *Clinical Linguistics and Phonetics, 18*, 391–404.

Gibbon, F., & Hardcastle, W. (1989). Deviant articulation in a cleft palate children following a late repair of the hard palate: a description and remediation procedure using electropalatography (EPG). *Clinical Linguistics and Phonetics, 3*, 93–110.

Gibbon, F., Hardcastle, W. J., Crampin, L., Reynolds, B., Razzell, R., & Wilson, J. (2001). Visual feedback therapy using electropalatography (EPG) for articulation disorders associated with cleft palate. *Asia Pacific Journal of Speech, Language and Hearing, 6*, 53–58.

Gibbon, F., Stewart, F., Hardcastle, W. J., & Crampin, L. (1999). Widening access to electropalatography for children with persistent sound system disorders. *American Journal of Speech-Language Pathology, 8*, 319–334.

Hardcastle, W. J., & Gibbon, F. (1997). Electropalatography and its clinical application. In M. J. Ball, & C. Code (Eds.), *Instrumental clinical phonetics* (pp. 149–193). London: Whurr Publishers.

Jones, W., & Hardcastle, W. J. (1995). New developments in EPG3 software. *European Journal of Disorders of Communication, 30*, 183–192.

McLeod, S., & Roberts, A. (2005). Templates of tongue/palate contact for speech sound intervention. In C. Heine, & L. Brown (Eds.), *Proceedings of the 2005 Speech Pathology Australia National Conference* (pp. 104–112). Melbourne: Speech Pathology Australia.

McLeod, S., Roberts, A., & Sita, J. (2006). Tongue/palate contact for the production of /s/ and /z/. *Clinical Linguistics and Phonetics, 20*, 51–66.

Michi, K., Suzuki, N., Yamashita, Y., & Imai, S. (1986). Visual training and correction of articulation disorders by use of dynamic palatography: Serial observation in a case of cleft palate. *Journal of Speech and Hearing Disorders, 51*, 226–238.

Michi, K., & Yamashita, Y. (1993). Role of visual feedback treatment for defective /s/ sounds in patients with cleft palate. *Journal of Speech and Hearing, 36*, 277–286.

Okazaki, K., Onizuka, T., Abe, M., & Sawashima, M. (1980). Palatalized articulation as a type of cleft palate speech: observation by dynamic palatograph and cineradiography. *The Japan Journal of Logopedics and Phoniatrics, 21*, 109–120.

Trost, J. E. (1981). Articulatory additions to the classical description of the speech of persons with cleft palate. *Cleft Palate Journal, 18*, 193–203.

Whitehill, T. L., Stokes, S. F., & Yonnie, M. Y. H. (1996). Electropalatography treatment in an adult with late repair of cleft palate. *Cleft Palate-Craniofacial Journal, 33*, 160–168.

Yamashita, Y., & Michi, K. (1991). Misarticulation caused by abnormal lingual-palatal contact in patients with cleft palate with adequate velopharyngeal function. *Cleft Palate-Craniofacial Journal, 28*, 360–366.

Yamashita, Y., Michi, K., Imai, S., & Suzuki, N. (1988). The efficacy of Dynamic Palatography in articulation training for post operative cleft palate patients with articulation disorders – Assessing the training procedure of the /s/ phoneme. *Journal of the Japanese Cleft Palate Association, 13*, 242–252.

Appendix 1

Japanese categorical system of articulation problems in the cleft palate

I. Those related to velopharyngeal (VP) dysfunction
   1. Reflecting present VP dysfunction
      About resonance: Hypernasality
      About oral pressure sounds: Distorted Consonants with or without audible nasal emission
   2. Reflecting past (or present) VP dysfunction
      About articulation: Glottal stops
      Pharyngeal stops
      Pharyngolaryngeal fricative

II. Rarely related to VP dysfunction
About articulation: Palatalized articulation
Nasopharyngeal articulation
Lateral articulation
Others

Appendix 2

Speech sample for syllables

/s/: /asa/ /asɯ/ /ase/ /aso/
/ts/: /atsɯ/
/dz/: /adza/ /adzɯ/ /adze/ /adzo/
/t/: /ata/ /ate/ /ato/
/d/: /ada/ /ade/ /ado/
/tʃ/: /atʃi/
/dʒ/: /adʒi/
/ʃ/: /aʃi/