Somatosensory evoked magnetic fields induced by electrical palate stimulation in patients with unilateral cleft lip and palate after palatoplasty

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ABSTRACT

Palatal sensation is important for articulation, feeding, and swallowing. However, palatal sensation in patients with cleft palate (CP) after palatoplasty has been investigated only inadequately because of the complexity and high costs of objective evaluation. This study compared the somatosensory evoked magnetic fields (SEFs) induced by electrical stimulation of the palates of patients with CP after palatoplasty and the palatal sensory thresholds (PSTs) of the stimulation with those of healthy (control) subjects. The CP group comprised 12 patients with cleft palate (CP) after palatoplasty. Evaluation of SEFs during palatal sensory stimulation in patients with CP after palatoplasty might lead to better corrective surgical methods that also preserve palatal sensation.

1. Introduction

Treatment of patients with cleft lip and palate (CLP) has emphasized improvement of the palatal morphology. Langenbeck was the first to close the hard palate of patients with CLP, but the technique he used was ineffective for language because of the short soft palate (Goldwyn, 1969). Therefore, Gnzer first proposed the pushback technique in 1920. Later, Wardill introduced improvements used worldwide (Wallace, 1987). Palatal morphology is known to affect oral function, especially language (Hellöväara, 2011; Zajac et al., 2012). Studies of correlation between palatal morphology and language in patients with CLP found that high anterior palatal asymmetry, narrowing of the posterior palatal width diameter, and shallow palatal height diameter tended to increase palatalized articulation (Nishikubo et al., 2009; Yamamoto et al., 2017). Prevention of inhibition of maxillary growth caused by scarring after palatoplasty is important for the acquisition of correct articulation.

However, patients with CLP might not fully recover palatal sensation after palatoplasty. Children with cleft palate (CP) had inferior three-dimensional cognitive function in the oral cavity compared to healthy children (Bakhtiyari et al., 2014). In addition, articulation problems are correlated with oral stereognostic ability (Jacobs et al., 1998). Children with CP who had poor articulation were found to have inferior oral

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three-dimensional cognitive function compared to children with CP who had better articulation (Andrews, 1973). A study of palatal taste sensation found that the palatal taste threshold was significantly higher in patients with palatal disorders of some types (oral cancer, CP, trauma to the palate, etc.) than in healthy subjects (Hammond et al., 1983). Furthermore, the tactile thresholds of the palate after palatoplasty are reportedly higher in patients with CLP than in healthy subjects (Uchiyama et al., 1998). Also, they vary depending on the surgical methods (Noguchi et al., 2004). Therefore, the degrees of palatal sensations of patients with CP are lower than that of healthy subjects. The oral functions of patients with CP are clearly poorer. However, the mechanisms of the palatal sensory disorder in patients with CP have not been examined using objective evaluation methods, especially in the central nervous system.

Magnetoencephalography (MEG) is especially useful for investigating functional brain activity. Actually, MEG records the magnetic fields generated by electrical activity in the brain. It has higher spatial resolution than electroencephalography (EEG) and higher temporal resolution than positron emission tomography, magnetic resonance (MR) imaging, and near-infrared spectroscopy. Somatosensory evoked magnetic fields (SEFs) measured using MEG were used for investigating somatotopic organization of the oral cavity, and change in sensation associated with aging and disease (Iwasaki et al., 2001; Hihara et al., 2017). In studies measuring SEFs during stimulation of the oral region, evaluations were made of primary somatosensory cortex of the contralateral hemisphere (Nakamura et al., 1998; Nakahara et al., 2004; Murayama et al., 2005). However, other reports have described components only of primary somatosensory cortex of the contralateral hemisphere around 20 ms and of both hemispheres after 30–40 ms (Hoshiyama et al., 1996; Nevalainen et al., 2006; Yoshida et al., 2006; Bessho et al., 2007; Maezawa et al., 2014a, 2014b; Hihara et al., 2017, 2020). The detection rate of components around 20 ms is lower than that of components around 60 ms in ipsilateral hemispheres (Bessho et al., 2007). The intensity is lower (Hoshiyama et al., 1996; Nakahara et al., 2004). Components with higher intensity within 100 ms and more reliable detection are approximately 40–60 ms (Hoshiyama et al., 1996; Nakahara et al., 2004; Bessho et al., 2007; Hihara et al., 2020). Both EEG and MEG have been used to examine palatal sensations in healthy subjects (McCarthy et al., 1993; Yoshida et al., 2006; Bessho et al., 2007; Maezawa et al., 2014a, 2014b), but only one report describes a study of the use of SEFs of the lip to examine sensory change for oral plate therapy in patients with CLP (Nevalainen et al., 2008). However, changes in lip and palatal sensation associated with palatoplasty have not been investigated using SEFs.

This study objectively evaluated palatal sensory disorder in patients with unilateral CLP (UCLP) after palatoplasty from the perspective of sensory processing in the brain.

It is considered that the scarring which occurs after palatoplasty inhibits nerve regeneration (Atkins et al., 2006), consequently resulting in palatal sensory disorder (Noguchi et al., 2004). Maezawa et al. (2011) performed SEFs measurements by application of electrical stimulation to the tongue of patients with lingual nerve injury. Although SEFs can be measured on the healthy side of the tongue, it was difficult or impossible to measure any component on the affected side. Consequently, it was hypothesized that the intensity of SEFs in patients with CP would be lower than that of control subjects. In addition, neither patients with tongue sensory disorder (Maezawa et al., 2011) nor a patient with lip sensory disorder (Maezawa et al., 2014a, 2014b) showed changes in the latency of SEFs compared to healthy subjects. Therefore, the hypothesis assessed for this study was also that there would be no difference in the latency of SEFs between those of patients with CP and healthy subjects.

2. Methods

2.1. Subjects

The UCLP group comprised 12 patients with UCLP (6 female and 6 male, mean age 18.4 years) who received push-back palatoplasty (Randoll and LaRossa, 1990) at mean age of 1.38 years. Eight patients were treated at the Department of Plastic and Reconstructive Surgery of Tohoku University Hospital. Three others were treated at other departments or hospitals. The control group comprised 31 healthy subjects (control; 12 female and 19 male, mean age 24.3 years) who had no craniofacial anomaly. All subjects were right-handed. The dominant hand was evaluated by the Edinburgh Handedness Inventory. None had a history of neurological disease. The study protocol was approved by the Ethics Committee of Tohoku University Graduate School of Dentistry (protocol number: 2018–3–015). Written informed consent was obtained from all participants or a legal guardian (parent) before the study.

2.2. Stimulation

The palatal electrical stimulator consisted of an individual mouth-piece made for each participant using BioStar IV (JM Ortho Co., Tokyo, Japan) with electrodes (Unique Medical Co., Ltd., Tokyo, Japan) attached to the equivalent part of the palate stimulator of the mouth-piece (Koeda et al., 2017) (Fig. 1A). Electrical stimulation transmitting devices of two types were used: an approved clinical device (Neuropack MEB-9400 S1; Nihon Kohden Corp., Tokyo, Japan) and a device commercially available for research (SEN-3401 Isolator SS-203; Nihon Kohden Corp.). The stimulation time was 0.2 ms. The stimulation frequency was 0.7 Hz. Stimulations were done 150 times. The stimulation intensity was set to five times the average sensory threshold, as obtained by increasing and decreasing the electric stimulation intensity at each stimulation site several times (Hihara et al., 2017). The stimulation was performed below the pain threshold. No subject reported feeling any pain. The hard palates were stimulated at four sites: the incisor papillae, the right and left lateral palate, and the central posterior palate (Fig. 1B). All subjects received electrical stimulation to the left wrist to measure the relative position and intensity of the SEFs during median nerve stimulation. The electrical stimulation intensity was set to the extent that the thumb of the left hand was slightly switched (motor threshold). The frequency of stimulation was 0.7 Hz. The number of stimulations was 150, as in the case of electrical stimulation to palate.

2.3. MEG recordings

In a magnetically shielded room, SEFs were recorded using a whole-head 200-channel MEG system (PQA160C; Ricoh Co., Ltd., Tokyo, Japan) (Fig. 1C). The head position of each subject was determined by coils at five points on the scalp. The head shape was digitized using a three-dimensional digitizer (Fast SCAN Corba; Polhemus, Colchester, VT) and was co-registered with the individual structural MR images using a 3 T MR system (Achieva; Philips Healthcare, Best, the Netherlands). The MEG signals were recorded from 50 ms before to 300 ms after the trigger points, digitized at 2000 Hz, and band-pass filtered between 1 Hz and 250 Hz.

2.4. Data analysis

The source locations and moments corresponding to the peak latency were estimated using the single equivalent current dipole (ECD) model, which was superimposed on individual MR images. The ECDs were calculated using the analytical software (MEG Laboratory, Ricoh Co., Ltd.) based on Sarvas’ law (Sarvas, 1987), which identifies the source of the magnetic signals assuming a spherical conductor. All ECDs were located on the central sulcus detected as described in a report by Youssry et al. (1997). Those with goodness-of-fit greater than 80 % were
Data obtained with about 150 stimulations were averaged after removing typical noise based on visual judgment. The baseline level was set at 4.0–9.0 ms after electrical stimulation. According to past reports, reactions were observed even around 20 ms during some parts of oral area stimulation. However, because it was of small amplitude, the waveform around 50 ms, which has higher intensity and higher detection rate, was used as a barometer (Hoshiyama et al., 1996; Nakahara et al., 2004). Therefore, for this study, the peak latencies at 41.5–66.5 ms in the primary somatosensory cortex were analyzed for comparison. The locations of the signal sources were evaluated separately for the left and right hemispheres. For the incisor papillae, central posterior palate, right and left lateral palate, the right and left hemispheres were assessed. For the left wrist, only the contralateral hemispheres from the stimulation site were assessed. The right and left hemispheres were regarded respectively as being of the non-cleft side (NS) and the cleft side (CS), based on the patients with left-sided CLP and the control subjects. In contrast, the right and left hemispheres were regarded respectively as being the CS and the NS for the patients with right-sided CLP. The root mean square error was used to estimate the peak latencies. The latencies, intensities, and response thresholds to electrical stimulation in each part of the palate were compared between the UCLP group and the control group using the Mann–Whitney U test. Significance was inferred for $P < 0.05$.

### 3. Results

SEFs were detected in the UCLP group in 5 cases in the incisor papillae (NS), 7 in the incisor papillae (CS), 4 in the posterior palate

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**Fig. 1.** A, Electrical stimulator for the palate consisting of an individual mouthpiece and four electrodes. The lower right panel portrays an enlarged view of the electrodes. The electrode diameter is 2.0 mm. The distance between the electrodes is 2.0 mm. The lead wires are of 0.65 mm diameter. B, Palate of a UCLP patient after palatoplasty. The circles represent areas of electrical stimulation. The dotted line represents the cleft area before palatoplasty. C, SEF measurement by MEG.

**Fig. 2.** Whole-head magnetic waveforms for the incisor papillae of a UCLP patient (15-year-old girl, left) and the control subject (21-year-old woman; control, right).
(NS), 6 in the posterior palate (CS), 4 in the NS of the palate (CS), 5 in the CS of the palate (NS), 6 in the CS of the palate (CS), and 12 in the left wrist. SEFs were detected in the control group in 17 cases in the incisor papillae (NS), 14 in the incisor papillae (CS), 12 in the posterior palate (NS), 10 in the posterior palate (CS), 11 in the NS of the palate (NS), 17 in the NS of the palate (CS), 18 in the CS of the palate (NS), 12 in the CS of the palate (CS), and 31 in the left wrist. Fig. 2 shows whole-head magnetic waveforms in the incisor papillae of a representative UCLP patient and a healthy subject (Control) in both hemispheres. Fig. 3 shows the isofield maps and ECD locations of the SEFs in the incisor papillae of a representative UCLP patient and a healthy subject in the CS. SEFs were detected in the primary somatosensory cortex in both cases. The dipole during palatal stimulation was found anteriorly inferior than the dipole during left wrist stimulation along the central sulcus in UCLP patients and in control subjects (Fig. 4).

The peak latency of the SEFs in the UCLP group was $48.5 \pm 3.5$ ms (mean ± standard deviation) in the incisor papillae (NS), $55.8 \pm 5.4$ ms in the incisor papillae (CS), $51.3 \pm 5.4$ ms in the posterior palate (NS), $53.8 \pm 8.2$ ms in the posterior palate (CS), $48.4 \pm 4.6$ ms in the NS of the palate (NS), $56.8 \pm 6.6$ ms in the NS of the palate (CS), $50.1 \pm 7.1$ ms in the CS of the palate (NS), $53.6 \pm 6.9$ ms in the CS of the palate (CS), and $18.8 \pm 1.1$ ms in the left wrist. The peak latency of the SEFs in the control group was $47.9 \pm 3.6$ ms in the incisor papillae (NS), $49.7 \pm 4.3$ ms in the incisor papillae (CS), $49.6 \pm 5.9$ ms in the posterior palate (NS), $54.8 \pm 5.2$ ms in the posterior palate (CS), $48.0 \pm 4.7$ ms in the left wrist.

Fig. 3. Isofield maps (upper) and ECD locations (lower) of the SEFs in the incisor papillae of a representative UCLP patient (15-year-old girl) and a control subject (21-year-old woman, control) in both hemispheres. Arrows indicate the directions and locations of the ECDs estimated by magnetic field patterns. NS, non cleft side hemisphere; CS, cleft side hemisphere.

Fig. 4. ECD locations of the SEFs in the left wrist and the incisor papillae of a representative UCLP patient (15-year-old girl) and a control subject (21-year-old woman, control) in both hemispheres. Responses were observed in the primary somatosensory cortex during both left wrist and palatal stimulation. Both UCLP patients and control subjects show the dipoles during palatal stimulation anteriorly and inferiorly along the central sulcus from the dipoles during left wrist stimulation.
the NS of the palate (NS), 48.2 ± 4.5 ms in the NS of the palate (CS), 50.8 ± 6.1 ms in the CS of the palate (NS), 49.6 ± 6.7 ms in the CS of the palate (CS), and 19.0 ± 1.0 ms in the left wrist. The latency was significantly longer in the UCLP group than in the control group in the incisor papillae (CS) (P < 0.01) and NS of the palate (CS) (P < 0.05). No significant difference in latency was found at other sites (Fig. 5 and Table 1).

The intensity of the SEFs in the UCLP group was 16.7 ± 2.6 nAm in the incisor papillae (NS), 15.7 ± 7.4 nAm in the incisor papillae (CS), 17.8 ± 7.4 nAm in the posterior palate (NS), 14.9 ± 4.7 nAm in the posterior palate (CS), 11.2 ± 3.2 nAm in the NS of the palate (NS), 11.6 ± 5.2 nAm in the NS of the palate (CS), 13.1 ± 7.4 nAm in the CS of the palate (NS), 12.3 ± 4.1 nAm in the CS of the palate (CS), and 18.4 ± 8.0 nAm in the left wrist. The intensity of the SEFs in the control group was 17.8 ± 8.6 nAm in the incisor papillae (NS), 17.0 ± 10.0 nAm in the incisor papillae (CS), 21.1 ± 12.4 nAm in the posterior palate (NS), 22.1 ± 11.7 nAm in the posterior palate (CS), 14.6 ± 5.0 nAm in the NS of the palate (NS), 14.7 ± 5.1 nAm in the NS of the palate (CS), 15.0 ± 7.0 nAm in the CS of the palate (NS), 16.9 ± 6.8 nAm in the CS of the palate (CS), and 21.3 ± 7.8 nAm in the left wrist. No significant difference in intensity was found (Table 2).

The sensory threshold of electrical stimulation in the UCLP group was 1.1 ± 0.8 mA in the incisor papillae, 1.9 ± 1.3 mA in the posterior palate, 1.5 ± 0.7 mA in the NS of the palate, and 1.6 ± 0.7 mA in the CS of the palate. The sensory threshold of electrical stimulation in the control group was 0.6 ± 0.2 mA in the incisor papillae, 0.9 ± 0.4 mA in the posterior palate, 1.0 ± 0.4 mA in the NS of the palate, and 0.9 ± 0.3 mA in the CS of the palate. Sensory thresholds of electrical stimulation in the UCLP group were found to be significantly higher than that in the control group in all sites: incisor papillae (P < 0.05), central posterior palate (P < 0.01), NS of the palate (P < 0.05), and CS of the palate (P < 0.01) (Table 3).

The correlation coefficients between the intensity of SEFs and sensory threshold of electrical stimulation in the UCLP group was 0.40 in the incisor papillae (CS), 0.22 in the incisor papillae (CS), – 0.05 in the posterior palate (NS), – 0.40 in the posterior palate (CS), 0.01 in the NS of the palate (NS), 0.43 in the NS of the palate (CS), 0.28 in the CS of the palate (NS), and – 0.13 in the CS of the palate (CS). No strong correlation was found between the intensity of SEFs and sensory threshold of electrical stimulation in the UCLP group (Table 4).

4. Discussion

This study is the first to detect and examine SEFs during palatal sensory stimulation in patients with CP after palatoplasty. Subjective assessment methods have indicated that patients with CP after palatoplasty have palatal sensory disorder (Hammond et al., 1983; Uchiyama et al., 1998; Noguchi et al., 2004). This disorder is mainly attributable to scar tissue caused by the invasion of palatoplasty performed in infancy, which impairs regeneration of the sensory nerves (Suda et al., 2000; Atkins et al., 2006). However, the degree of sensory disorder is difficult to assess quantitatively using only subjective assessment methods. For the present study, SEFs were measured in patients with UCLP during palatal sensory stimulation to measure responses within 100 ms in the cerebral cortex. Such measurements can quantify the transmission time of the stimulation and the signal intensity, and can thereby objectively evaluate the degree of palatal sensory disorder.

This study compared the SEFs during electrical stimulation of the
The latency was prolonged significantly in the CS hemisphere for the incisor papillae and in the contralateral hemisphere for the NS of the palate in the UCLP group compared to the control group, but no significant difference in intensity was found in any structure. Subjective evaluation during electrical stimulation found that sensory thresholds were significantly greater in the UCLP group than in the control group in all palatal structures.

4.1. Difference in Latencies between the UCLP and Control Groups

The latency was prolonged significantly in the CS hemisphere for the incisor papillae and in the contralateral hemisphere for the NS of the palate in the UCLP group compared to the control group (Fig. 5 and Table 1), which might be attributable to differences in innervation. Perception of the hard palate is received by the nasopalatine nerve from the incisive foramen and the greater palatine nerve extending from the greater palatine foramen. In healthy subjects, most perception of the hard palate is innervated by the greater palatine nerve (Langford, 1989). The nasopalatine nerve is not regarded as very important in clinical practice. The nasopalatine nerve has approximately 485 μm diameter, whereas the greater palatine nerve has diameter of approximately 1179 μm, which is about three times as thick as the nasopalatine nerve (Fujimoto, 1981). In general, thicker nerve fibers transmit the electrical signals faster. For that reason, the nasopalatine nerve, which has thinner nerve fibers than the greater palatine nerve, has a lower rate of nerve transmission than the greater palatine nerve. Therefore, prolonged latency in the UCLP group, as observed in this study, might be attributable to transmission of sensory perception by the nasopalatine nerve from the part of the palate that is no longer innervated by the greater palatine nerve because of the effects of palatoplasty.

The pushback method as performed at the Department of Plastic and Reconstructive Surgery in Tohoku University Hospital differs slightly from the conventional pushback method in that the periosteum is left in part of the palatal bone when the flap is raised to reduce postoperative scarring (Okada et al., 2006). The exposed bone surface without the periosteum forms scar tissue, which hinders nerve regeneration, but the nerves regenerate easily in areas where the periosteum remains (Suda et al., 2000). In the Tohoku University pushback method, the overlap between the flap on the CS and the bone surface where the periosteum remains is large. Consequently, the greater palatine nerve can extend easily to the incisal papilla. However, in the NS of the palate less overlap occurs between the flap and the bony surface where the periosteum is located. Therefore, the greater palatine nerve cannot extend easily to the incisal papilla. Instead, the nasopalatine nerve seems to extend along the remaining periosteum and to expand its dominant region to the NS of palate. This mechanism is plausible because the nasopalatine nerve has been reported to extend to the palate near the premolars in some healthy adults (Langford, 1989), and to expand its area of innervation with age (Liu et al., 2017). Consequently, latency was longer in the UCLP group than in the control group in the CS hemisphere during incisive papillae stimulation and the contralateral hemisphere during NS of palate stimulation, which are affected by the nasopalatine nerve. However, no latency was found to be significantly different between the UCLP group and the control group in the NS hemisphere during incisive papillae stimulation, the contralateral hemisphere during CS of palate stimulation, and both hemispheres during posterior palate stimulation, which are affected by the greater palatine nerve.

The present findings are insufficient to prove these propositions. Therefore, the process of nerve regeneration and nerve course after palatoplasty must be examined further using an animal CP model.

4.2. Differences in intensities and palatine sensory thresholds between the UCLP and control groups

No significant difference in intensity was found between the UCLP and control groups (Table 2), but significant differences at all stimulation sites between the UCLP and control groups were found from subjective evaluation of electrical stimulation (Table 3). Similar results

Table 1

|                | Incisor papillae | Posterior palate | Non-cleft side of palate | Cleft side of palate | Left wrist |
|----------------|------------------|------------------|--------------------------|----------------------|------------|
|                | NS (µs)          | CS (µs)          | NS (µs)                  | CS (µs)              |            |
| UCLP group     | 48.5 ± 3.5       | 55.8 ± 5.4*      | 51.3 ± 5.4               | 53.8 ± 8.2           |            |
| Control group  | 47.9 ± 3.6       | 49.7 ± 4.3       | 49.6 ± 5.9               | 54.8 ± 5.2           |            |

NS, non-cleft side; CS, cleft side. The latency was significantly longer in the UCLP group than in the control group in the incisor papillae (CS) (**P < 0.01) and non-cleft side of the palate (CS) (*P < 0.05).

Table 2

|                | Incisor papillae | Posterior palate | Non-cleft side of palate | Cleft side of palate | Left wrist |
|----------------|------------------|------------------|--------------------------|----------------------|------------|
|                | NS (nA)          | CS (nA)          | NS (nA)                  | CS (nA)              |            |
| UCLP group     | 16.7 ± 2.6       | 15.7 ± 7.4       | 17.8 ± 7.4               | 14.9 ± 4.7           |            |
| Control group  | 17.8 ± 8.6       | 17.0 ± 10.0      | 21.1 ± 12.4              | 22.1 ± 11.7          |            |

NS, non-cleft side; CS, cleft side. The intensities of the UCLP group and the control group were not significantly different.

Table 3

Palatine sensory thresholds of electrical stimulation for each area in the UCLP group and control group.

|                | Incisor papillae | Posterior palate | Non-cleft side of palate | Cleft side of palate |
|----------------|------------------|------------------|--------------------------|----------------------|
|                | NS µm            | CS µm            | NS µm                    | CS µm                |
| UCLP group     | 1.1 ± 0.8**      | 1.9 ± 1.3*       | 1.5 ± 0.7**              | 1.6 ± 0.7*           |
| Control group  | 0.6 ± 0.2        | 0.9 ± 0.4        | 1.0 ± 0.4                | 0.9 ± 0.3            |

The intensities of the UCLP group and the control group were not significantly different. The palatine sensory thresholds in all areas of the UCLP group were significantly higher than those of the control group (**P < 0.01, **P < 0.05).

Table 4

Correlation coefficients between the intensity of SEFs and sensory threshold of electrical stimulation for each area in the UCLP group.

|                | Incisor papillae | Posterior palate | Non-cleft side of palate | Cleft side of palate |
|----------------|------------------|------------------|--------------------------|----------------------|
|                | NS (nA)          | CS (nA)          | NS (nA)                  | CS (nA)              |
| UCLP group     | 0.40             | 0.22             | -0.05                    | -0.40                |
| Control group  | 0.01             | 0.43             | 0.28                     | -0.13                |

No strong correlation was found between the intensities of SEFs and sensory thresholds of electrical stimulation for each area in the UCLP group.
Surgery disrupted peripheral nerve regeneration. Therefore, the mucoperiosteum of the surgical wound. Scarring interferes with regeneration of nerve fiber regeneration might be impaired in areas where the bony surface was exposed and in scar areas created by suturing of tissues, thereby producing the higher sensory threshold.

The intensity of the SEFs detected in the primary somatosensory cortex in the UCLP group was not significantly different from that in the control group, even though the threshold of palatal sensation was significantly higher in the UCLP group. Therefore, a compensatory mechanism might amplify electrical signals sensed by the impaired palatal mucosa in the central nervous system. Consequently, palatal sensation can be restored by the application of certain stimuli.

4.3. Clinical application to patients with CLP

The potential decrease in palatal sensation because of palatoplasty should be minimized. The use of mucoperiosteal flaps in palatoplasty increases palatal sensory thresholds more than the use of supraperiosteal flaps (Noguchi et al., 2004). Many patients develop palatalized articulation (Ito et al., 2006). Maxillary growth and associated articulation disorders are better prevented by not creating or minimizing the raw surface after palatoplasty to preserve palatal sensation. The nasopalatine nerve extending from the incisor papilla is not regarded as important in healthy subjects, but it should be preserved to the greatest degree possible in patients with CLP to minimize postoperative damage to palatal sensation. The oral anatomy of patients with CLP differs from that of healthy people (Bohn, 1963; Trindade-Suedam et al., 2012). Some variations occur, but surgeons, orthodontists, and general dentists should have some knowledge of the oral anatomy of patients with CLP in clinical practice.

Results of this study indicate for the first time ever reported, that SEFs can be very useful as an objective method of measuring the degree of palatal sensory disorder in patients with CP. Our findings suggest that SEFs can be adopted as a new objective method for investigating palatal sensation in the future. The findings can be expected to engender the development of new surgical techniques that both correct the palatal morphology and preserve palatal sensation in patients with CP.

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Declaration of Conflicting Interest

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The potential decrease in palatal sensation because of palatoplasty should be minimized. The use of mucoperiosteal flaps in palatoplasty increases palatal sensory thresholds more than the use of supraperiosteal flaps (Noguchi et al., 2004). Many patients develop palatalized articulation (Ito et al., 2006). Maxillary growth and associated articulation disorders are better prevented by not creating or minimizing the raw surface after palatoplasty to preserve palatal sensation. The nasopalatine nerve extending from the incisor papilla is not regarded as important in healthy subjects, but it should be preserved to the greatest degree possible in patients with CLP to minimize postoperative damage to palatal sensation. The oral anatomy of patients with CLP differs from that of healthy people (Bohn, 1963; Trindade-Suedam et al., 2012). Some variations occur, but surgeons, orthodontists, and general dentists should have some knowledge of the oral anatomy of patients with CLP in clinical practice.

Results of this study indicate for the first time ever reported, that SEFs can be very useful as an objective method of measuring the degree of palatal sensory disorder in patients with CP. Our findings suggest that SEFs can be adopted as a new objective method for investigating palatal sensation in the future. The findings can be expected to engender the development of new surgical techniques that both correct the palatal morphology and preserve palatal sensation in patients with CP.
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