3版

様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９　（共通）

科研費 KAKENHI

科学研究費助成事業　　研究成果報告書

令和　２ 年　 ６ 月 １０ 日現在

機関番号：１７７０１

研究種目：研究活動スタート支援

研究期間：2018～2019

課題番号：１８Ｈ０６３１２・１９Ｋ２１３９９

研究課題名（和文）流体解析を用いた口唇口蓋裂児の鼻腔通気障害改善方法の確立

研究課題名（英文）Establishment of the nasal airway obstruction improvement method of children with cleft lip and palate using the fluid analysis

研究代表者

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交付決定額（研究期間全体）：（直接経費）　　2,300,000円

研究成果の概要（和文）：本研究では上顎急速拡大(RME)がCLP児の鼻腔通気状態におよぼす影響を明らかにするために鼻中隔湾曲度、鼻腔断面積、鼻腔抵抗値、患側と健側の外鼻孔からの流出量の評価を行った。
UCLP児は患側に鼻中隔が湾曲しているため、鼻腔通気障害が生じていることが示された。さらにRMEにより、患側が健側より大きく拡大することで鼻腔通気障害が改善することが示された。これは患側がminor segmentであるため、顎整形力がより大きく作用した結果と考えた。以上、UCLP児に対するOSASを含めた呼吸管理の必要性とその対応法として、RMEの有効性が示された。

研究成果の学術的意義や社会的意義
口唇口蓋裂児(CLP児)には審美・哺乳・咀嚼・言語等の多職種医療従事者の成育的支援が実践されている。しかし、CLP児の約30%が閉塞性睡眠時無呼吸症候群(OSAS)に罹患していると報告されているにもかかわらず、呼吸の面からの支援は十分とはいえない。しかし、本研究で、SASは鼻腔から下咽頭までの上気道のあらゆる部位が原因となり発症する。その罹患率は定型発達児で２%とされている一方、CLP児は30%と著しく高いことから、OSASの主な原因部位として鼻腔が考えられ、その治療方法としてRMEの有効性が示され、歯科からの睡眠医療への貢献が期待される

研究成果の概要（英文）：This study evaluated RME induced changes in ventilation parameters in children with UCLP using computational fluid dynamics. Setting and Sample Population: Nineteen patients (10 boys, mean age 10.7years) who required RME had cone‐beam computed tomography images taken before and after RME. Methods: Nasal airway ventilation parameters were analysed via computational fluid dynamics, and nasal cross‐sectional area (CSA) was measured. Results: Maximum pressure, velocity and nasal resistance were significantly reduced by RME in the UCLP group. Air flow rate and CSA on the cleft side significantly were increased by RME in the UCLP group. Conclusions: In children with UCLP, increasing the quantity of airflow and CSA on the cleft side by RME substantially improved nasal ventilation

研究分野：小児歯科

キーワード：小児　OSA　流体解析　呼吸

様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９（共通）

１．研究開始当初の背景

The craniofacial morphology of children with unilateral cleft lip and palate (UCLP) differs from that of children without clefts. Maxillary arch constriction is frequently observed in operated patients with UCLP. Therefore, rapid maxillary expansion (RME) is often required in children with UCLP; in children without clefts, improvements in nasal airway ventilation and dentition expansion may be required. However, improvements in nasal airway ventilation associated with RME in children with UCLP are unclear, particularly in cases involving nasal airway ventilation obstruction. In studies investigating RME in patients with UCLP, the volume and cross sectional area of the nasal airway reportedly increase. However, nasal septum deviation and the other nasal airway forms are often associated with abnormalities in patients with UCLP. Therefore, it has been unclear whether expansion of nasal width diameter and dentition improves nasal airway ventilation.

Recently, computational fluid dynamics (CFD) has been used for evaluation of airway ventilation. Regardless of upper airway shape, CFD reproduces the flow of air and can evaluate air current in the nasal airway alone.

２．研究の目的

I speculated that CFD evaluation may be more precise in the evaluation of complicated nasal airways in children with UCLP. The current study investigated improvements in nasal airway ventilation associated with RME in patients with UCLP via CFD in which nasal airway ventilation could be evaluated without being influenced by the complexity of nasal airway shape.

３．研究の方法

The need for informed consent was waived by the relevant institutional review board (180073[657] Epi‐ver.1) because of the retrospective nature of the study. IRB permitted reuse of the tomography data for further examinations. The inclusion criteria were as follows: (1) age between 7 and 17 years and (2) the presence of diagnostic cone‐beam computed tomography (CBCT) scans for non ‐ routine orthodontic treatment. The patients with UCLP were included if they had (1) lip and palatal repair in early childhood, (2) maxillary constriction and a need for maxillary expansion before the secondary alveolar bone graft and (3) no previous bone graft surgery. The UCLP group comprised of 19 subjects (10 boys) with serial CBCT images taken at mean ages before (T1) and after (T2) RME, respectively. They required approximately 5 mm of maxillary expansion as part of their orthodontic treatment. Control patients exhibited Class I malocclusion; exclusion criteria for the control group were (1) craniofacial or growth abnormalities, (2) systemic disease and (3) temporomandibular joint disorder. The control group consisted of serial CBCT images of 20 subjects (11 boys). Control CBCT images were taken at T1 and T2, respectively. CBCT data were used to evaluate morphology and ventilation of nasal airway.

（１） Morphological evaluation

Volume‐rendering software (INTAGE Volume Editor; Cybernet, Tokyo, Japan) was used to manually create 3D images and evaluate intermaxillary molar width,nasal width10 and nasal septum deviation. Nasal septum deviation was measured by calculating the differences between the right and left nasal chamber width in coronal and axial sections at the level of maximal septum deviation. Nasal cross ‐ sectional areas (CSAs) were measured at the anterior and posterior regions of the nasal airway. Anterior CSA1 was defined as lying in the frontal plane through the ANS; posterior CSA2 was defined as lying in the frontal plane through 15 mm posterior to the ANS.

（２） Evaluation of nasal airway ventilation

The 3D nasal airway was manually generated using CBCT data and volume‐rendering software (INTAGE Volume Editor; Cybernet Systems, Tokyo, Japan). The 3D model was then converted to a smoothed model via mesh ‐ morphing software (DEP Mesh Works/Morpher; IDAJ, Kobe, Japan), without losing the patient‐specific pattern of the airway shape. The models were exported to CFD software (Phoenics; CHAM Japan, Tokyo, Japan) in stereo lithographic format. Analysis of the CFDs of the nasal airway turbulence models incorporated an airflow velocity of 200 mL/s in accordance with the growth stage of the subjects and a non ‐ slippery wall surface, and simulations were repeated 1000 times to calculate mean values. The nasal airway resistance was conformed to postnasal rhinomanometry and was calculated from air mass flow and the difference in pressure between the external nares and choanae, in accordance with Ohm's law. Airflow pressure and velocity were measured by using the maximum value of the nasal airway. The flow rates of cleft side and non‐cleft side external naris expiration were also calculated. We used the standardized threshold (from −550 to −1024 HU) of the nasal airway model, such that the nasal airway model resistance value obtained via CFD matched.

（3） Statistical analysis For each measurement,

Student's t test and the Mann‐Whitney U test were used to compare differences between the two groups. The significance of treatment changes (T1 and T2) was assessed via paired t test and Wilcoxon rank‐sum test. Pearson correlation coefficients were calculated to evaluate the relationship between treatment change in the nasal septum deviation and treatment change in the CSA of cleft and non‐cleft sides. For all tests, $P < 0.05$ was considered statistically significant. In accordance with our hypothesis that RME improves nasal airway ventilation conditions, we performed a sample size calculation based on the difference in treatment changes of nasal airway ventilation condition by RME. To calculate the β error, a power analysis using G*power 3.1.9.4 was performed (1−β error = 0.80, α = 0.05, two‐tailed test); the adequate sample size was 18 subjects. All measurements were repeated after 1 week by the same investigator (T.I.), and Dahlberg's formula was used to calculate measurement error. All repeated analyses suggested that the measurement errors were negligible.

４．研究成果

（1）Nasal and intermaxillary molar width

Nasal width and intermaxillary molar width at T2 were significantly greater than at T1. Nasal width after treatment was significantly greater in the UCLP group than in the control group. Intermaxillary molar width increased significantly in the UCLP group at T2, whereas the change was not significant in the control group.

（2）Nasal septum deviation

The deflected nasal septum in children in the UCLP group deviated towards the cleft side. At T1, nasal septum deviation was significantly greater in the UCLP than in the control group. Nasal septum deviation improved significantly in the UCLP group at T2.

（3）Cross‐sectional area

CSA1RL and CSA2RL were significantly smaller in the UCLP group than in the control group at T1; moreover, these areas were significantly increased in the UCLP group alone.

（4）Nasal airway ventilation

Maximum pressure was significantly greater in the UCLP than in the control group at T1; it was significantly reduced in the UCLP group at T2. Similarly, maximum velocity was significantly greater in the UCLP than in the control group at T1; it was significantly reduced in the UCLP group at T2. Nasal resistance was significantly less at T2 than before in the UCLP group. At T1, nasal resistance was significantly greater in the UCLP group than in the control group, and the treatment‐associated change was also significantly greater in the UCLP group.

（5）Cleft side and non‐cleft side

The CSA1 and CSA2 were significantly smaller on the cleft side than on the non‐cleft side at T1.The flow rate of expiration at T1 was significantly lower on the cleft side than on the non‐cleft side.

（6）DISCUSSION

In the current study, improvements in nasal airway ventilation, especially on the cleft side, were observed in children with UCLP after expansion. Before expansion, children with UCLP exhibited greater. Nasal septum deviation is regarded as a structural cause of nasal airway ventilation obstruction associated with UCLP. In the current study, nasal width was larger in the UCLP than in the control group at T1. However, children in the UCLP group had nasal obstruction. Therefore, in the UCLP group, nasal airway ventilation may not have been influenced by nasal width. Furthermore, nasal resistance in the UCLP group was greater than that indicated by conventional rhinomanometry data. However, the cross – section extends 30% – 50% degree in decongestion. The present study did not involve decongestion, and the subjects included children with high nasal airway resistance. This may explain why resistance in the present study was higher than the previously reported values.

The procedure used to measure nasal septum deviation in the present study differed from that in earlier studies, but the results were similar. The cross–section of the nasal airway on the cleft side was approximately 50%–60% of that of the non–cleft side, and the nasal airway volume was 75%. The nasal airway resistance on the cleft side was 2–3 times that on the non–cleft side. Before expansion, the nasal septum deviated towards the cleft side and the CSA on the cleft side narrowed in children with UCLP. Thus, we surmise that the flow quantity on the cleft side was half that on the non–cleft side because of increased nasal airway resistance.

Pressure, velocity and nasal resistance were reduced by RME.

Some previous morphological studies have reported nasal airway enlargement via RME in children with UCLP but few functional studies of the nasal airways in children with UCLP have been reported.

From these morphological studies and the morphological and CFD results of the current study, we conclude that RME improved ventilation of the nasal airway in children with UCLP by enlarging the nasal airway. Furthermore, nasal septum deviation in children with UCLP was reduced at T2.

Wang et al reported that when performing RME in children with UCLP, the non – cleft side required greater orthopaedic forces for lateral expansion than the cleft side, and that lateral expansion became wider on the cleft side than on the non–cleft side. In the present study, we suspected that because the cleft side exhibited greater lateral expansion, the difference in nasal chamber width between the cleft and non–cleft sides was reduced, and nasal septum deviation relieved this reduction. Trindade et al showed that the nasal airway cross – section of the cleft side was smaller than that of the non–cleft side at T1, but increased on both sides at T2, in children aged 8 years. Additionally, the difference between cleft and non–cleft side cross–sectional area was diminished by RME. In the current study, we concluded that the difference in flow quantity between cleft and non–cleft sides became small because the cross–sectional area of the cleft side increased more than that of the non–cleft side. Thus, we surmised that nasal septum deviation is reduced via greater expansion of the cleft side at T2 in children with UCLP.

Kobayashi et al reported that in children aged 11 years, normal nasal airway resistance was 0.34 Pa/cm3/s, and in children aged 12 years, it was 0.30 Pa/cm3/s. Nasal resistance values determined via CFD in the present study were similar to values obtained via conventiona rhinomanometry. Therefore, the reliability of CFD as an evaluation method was supported. However, standard deviation of CFD of the CLP group was large in our results.

First, it was not possible to examine nasal cycle effects. Second, CFD – derived values were not physically measured. Studies are needed incorporating physical measurements, to compare them with CFD–derived values, and to determine differences in the effects of RME on CLP and non–CLP subjects, using RME cases without CLP as controls in the future.

（7）CONCLUSION

In children with UCLP, before RME, the nasal septum deviated on the cleft side; thus, the nasal airway cross–section on the cleft side was narrow. Therefore, the airflow rate of the nasal airway of the cleft side was lower than that of the non–cleft side. However, the nasal airway cross–section extended only to the cleft side during RME. Therefore, the airflow rate of the nasal airway of the cleft side was significantly increased, to a similar extent as the non–cleft side. RME improved nasal airway obstruction in children with UCLP.

５．主な発表論文等

〔雑誌論文〕　計2件（うち査読付論文　2件／うち国際共著　0件／うちオープンアクセス　0件）

１．著者名 Iwasaki Tomonori、Yanagisawa‐Minami Ayaka、Suga Hokuto、Shirazawa Yoshito、Tsujii Toshiya、Yamamoto Yuushi、Ban Yuusuke、Sato‐Hashiguchi Makiko、Sato Hideo、Kanomi Ryuzo、Yamasaki Youichi	４．巻 22
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掲載論文のDOI（デジタルオブジェクト識別子） 10.1111/ocr.12311	査読の有無 有
オープンアクセス オープンアクセスではない、又はオープンアクセスが困難	国際共著 －

１．著者名 Shirazawa Yoshito、Iwasaki Tomonori、Ooi Kazuhiro、Kobayashi Yutaka、Yanagisawa‐Minami Ayaka、Oku Yoichiro、Yokura Anna、Ban Yuusuke、Suga Hokuto、Kawashiri Shuichi、Yamasaki Youichi	４．巻 －
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オープンアクセス オープンアクセスではない、又はオープンアクセスが困難	国際共著 －

〔学会発表〕　計0件

〔図書〕　計0件

〔産業財産権〕

〔その他〕

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