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学位論文要旨

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論文題名 Clinical Prediction Models for Upper Airway Volume Based on Soft Palate and Airway Lumen Dimensions in Adults With Varying Vertical Skeletal Patterns

垂直的骨格パターンの異なる成人における軟口蓋および気道内腔寸法に基づく上気道容積の臨床的予測モデル

論文内容の要旨（2000字程度）

Objective:
This study aimed to investigate the associations between soft palate morphology, pharyngeal airway lumen dimensions, and pharyngeal airway volume in adult women with different vertical skeletal growth patterns. Specifically, the objective was to examine how dimensions such as the soft palate length, vertical length, and cross-sectional airway area correlate with airway volume, and to develop clinical prediction models for upper airway volume based on these variables. The study also sought to assess intergroup differences in these anatomical features among hypodivergent, normodivergent, and hyperdivergent individuals, and explore their clinical implications in orthodontic treatment planning.

Materials and Methods:
This retrospective cross-sectional study analyzed pre-treatment records from 80 adult female subjects aged approximately 31.4 years (31.40 ± 11.17 years), all of whom had a normal body mass index (BMI) and no history of obstructive sleep apnea (OSA), craniofacial malformations, or prior orthodontic treatment. The subjects were divided into three groups according to their vertical skeletal pattern based on the Frankfort-Mandibular Plane Angle (FMA): hypodivergent (FMA < 26.9°), normodivergent (26.9° ≤ FMA ≤ 34.1°), and hyperdivergent (FMA > 34.1°).
Magnetic resonance imaging (MRI) was used to obtain detailed images of the soft palate and pharyngeal airway while subjects were in a supine position to mimic sleep-related posture. Key anatomical measurements included soft palate length (SPL), soft palate vertical length (SPVL), airway length (AIRL), and pharyngeal lumen areas at three anatomical levels (soft palate tip, second cervical vertebra, and epiglottis tip). Volumetric data such as retropalatal airway volume (RPV), retroglossal airway volume (RGV), and total pharyngeal airway volume (TPV) were extracted using Dolphin Imaging software.
Statistical analyses included intra-class correlation to assess measurement reliability, Kruskal-Wallis tests for intergroup comparisons, and Spearman's correlation to identify significant associations. Forward stepwise multiple linear regression was applied to develop prediction models for RPV and TPV using soft palate and airway dimensions as independent variables.

Results:
Eight regression models were developed—four for predicting RPV and four for TPV—one for each skeletal group and one for the total sample. Among these, six models showed high predictive accuracy, explaining between 50% and 77% of the variability in airway volume. The most consistent and significant predictor across all groups was the minimal cross-sectional area of the airway (MinAx). In the total sample, MinAx alone could explain a significant proportion of variance in both RPV and TPV (adjusted R^2 = 0.57 and 0.54, respectively).

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In the normodivergent group, the most robust models were achieved. For TPV, a combination of MinAx, soft palate length (SPL), soft palate vertical length relative to airway length (SPVL/AIRL), and lumen area at the soft palate tip (PALA-SPT) all contributed significantly (adjusted $R^2 = 0.77$). SPL also predicted RPV in the same group. These findings indicate that not only the size but also the proportion and shape of the soft palate affect airway volume.

Intergroup comparisons showed that hypodivergent subjects had significantly larger MinAx, RPV, and TPV than hyperdivergent individuals. Conversely, the hyperdivergent group exhibited significantly longer SPL and airway length. Hyperdivergent subjects also had narrower pharyngeal lumen areas at the soft palate tip and C2 level, reflecting anatomical limitations in their airway structure. RGV did not significantly differ among groups and was excluded from the final prediction models due to poor performance metrics.

Discussion:

This study is among the first to evaluate three-dimensional airway morphology and soft palate shape in relation to vertical skeletal patterns using MRI. The findings support the notion that vertical facial growth patterns significantly influence pharyngeal airway dimensions. MinAx emerged as a universal and reliable predictor of airway volume, aligning with previous literature highlighting its role in sleep-disordered breathing risk.

The results also suggest that a longer soft palate, particularly in hyperdivergent individuals, may contribute to reduced airway space, increasing the risk of velopharyngeal insufficiency and potentially obstructive sleep apnea. These anatomical insights could help orthodontists anticipate airway-related risks and make informed decisions regarding treatment strategies, such as mandibular advancement or maxillary expansion.

Although the study was limited to female participants due to data availability and was cross-sectional in design, it sets a foundation for future longitudinal research. Including male subjects and evaluating sagittal skeletal relationships could further enhance the understanding of craniofacial-airway interactions.

Conclusion:

1.Hypodivergent subjects had significantly greater airway volume and MinAx compared to hyperdivergent individuals, who exhibited longer soft palates and narrower airway structures.

2. Six out of eight prediction models were statistically robust, especially in the normodivergent group, where multiple soft palate and airway variables accurately predicted airway volume.

3.MinAx consistently predicted RPV and TPV across all groups, highlighting its clinical utility.

4.These results emphasize the importance of incorporating airway assessment into orthodontic treatment planning, particularly for patients with hyperdivergent skeletal patterns who may be at increased risk of airway compromise.