Manifold Learning-based Analysis of Surgical Difficulty Factors in Impacted Mandibular Third Molar Extraction

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***Abstract*— Surgical difficulty factors in impacted mandibular third molar extraction have been successfully characterized using manifold learning-based analysis. By employing the unsupervised feature extraction method based on principal component analysis (PCA) to anatomical features in panoramic dental images, it was found that the first two principal components explained 51.9% of the total variance. Furthermore, in conjunction with PCA, linear discriminant analysis (LDA) was adopted to classify the surgical difficulty by operation time. Accordingly, the area under the curve (AUC) derived from the receiver operating characteristic (ROC) curve, showed that the classification performance was high with an AUC index of 0.8. Finally, we can tell which feature has positive effects on surgical difficulty.**

I. Introduction

Studies have analyzed preoperative factors of the surgical difficulty factors in impacted mandibular third molar extraction. [1] However, it is hard to evaluate them because of the large variation among patients. Therefore, this study introduces manifold learning to evaluate these factors based on PCA and proposes an index with high performance for the preoperative prediction of the difficulty of mandibular third molar extraction.

II. Materials and methods

Features measured from X-ray images are shown in Figure 1. (1)Spatial Relationship: The intersection angle θ. (2)Depth: The distance between the orange-yellow line intersection and the red-yellow line intersection. (3)Ramus Relationship: The ratio of $\overline{AB}$ to $\overline{CD}$.(4)Root width: The ratio of the maximum mesiodistal width of the mandibular third molar to the width at the midpoint of the roots, indicated by the two blue arrows.[2] (5)The number of roots. (6) Abnormal root curvature. PCA was applied to reduce dimensionality and simplify the dataset after obtaining the operation time and the six features above.

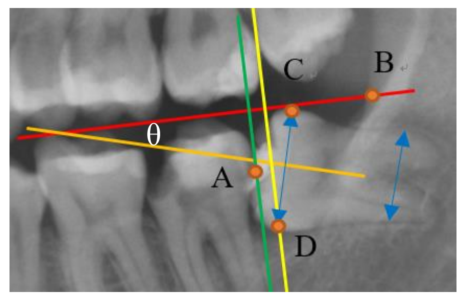

Figure 1 X-ray images with anatomical features.

III. Results and discussion

A. Principal Component Analysis (PCA)

Figure 2 shows that 51% of the information can be conserved after downscaling to a 2D space.

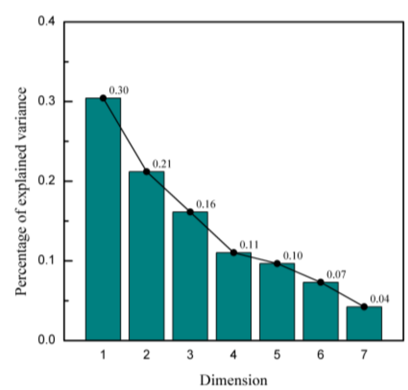

Figure 2 Dataset scree plot.

Figure 3 shows the relationship among the seven features. We can distinguish whether positive or negative correlation between any two of them.

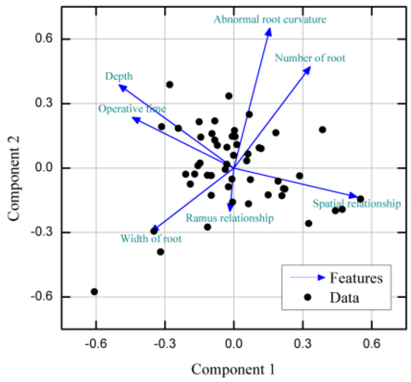

Figure 3 Principal component analysis biplot of the dataset.

B. *Linear Discriminant Analysis (LDA)*

The data are divided into short-time and long-time operations, expressed by black and red dots respectively. We can categorize them by projecting the data onto the eigenvector calculated by PC1 and PC2. The hollow dots and the blue line in Figure 4 show the result of the projection.

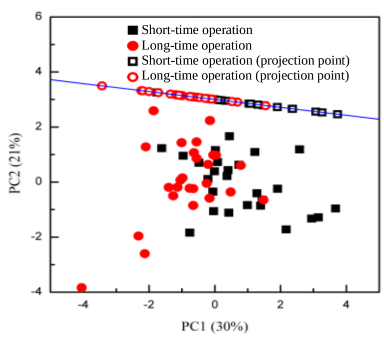

Figure 4 Two-dimensional spatial comparison of the dataset distinguished by operation time.

C. *Receiver Operating Characteristic (ROC) Curve*

Four combinations of features were analyzed. Figure 5 shows that the AUC of the index generated by PCA is the highest among all.[1] [3-6]

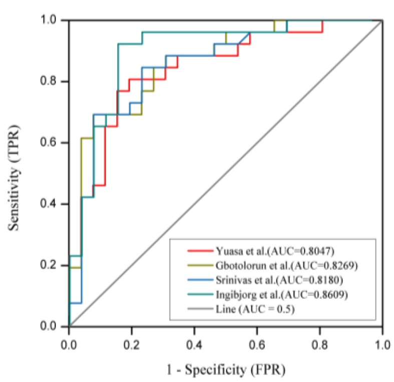

Figure 5 ROC curve chart of different feature combinations.

IV. Conclusion

Based on the examination of the dental X-ray images, we carried out a manifold learning-based analysis of surgical difficulty factors. The features obtained from the panoramic radiographs were analyzed not only using the unsupervised learning model of PCA but also utilizing the supervised learning models of LDA. PCA succeeded in reducing the dimensionality to two principal components while LDA performed well in classifying surgical operation time with the feature vector calculated by the PCs. After demonstrating that the selected features can effectively correspond to the surgical difficulty, the ROC curve was used to evaluate the classification results of different feature combinations. It was observed that the AUC values of all four feature groups were above 0.8, indicating that the unsupervised learning model designed in this study is effective in distinguishing surgical difficulty. Nevertheless, the AUC value can tell which feature has positive effects on the surgical difficulty.

Last but not least, the innovative cross-disciplinary technique proposed in this study suggests that a machine-learning-based approach has the potential to provide some new metrics for preoperative difficulty prediction for the extraction of impacted mandibular third molars, which provides clinicians with more efficient treatment plans.

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