A Study for Retrieving Teeth Gingival Margin from Three-Dimensional Digital Model

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ABSTRACT

Gingival margin (GM) identifies the necessary portion when people manufacture clear aligners. In automatic manufacturing system, it is considered as a three-dimensional (3D) line which needs to be cut and separated. This study proposes a model analysis method which is able to determine the 3D coordinate points of the patient's gingival margin based on curvature information.

1 Introduction

For a novel orthodontic device, clear aligners not only complete the orthodontic mission, but reduce people's psychological burden on orthodontic treatment. They are also for the reasons of comfortable wearing and elegant appearance [1]. With the development of digitization of computer simulation, such as in 3D scanning and printing fields, the adoption of clear aligners for modern treatments is getting wider and more popular.

1.1 Background

Because clear aligners fit the teeth without oppressing the gums, people do not suffer from aligners irritation. Trimming along the gum line is a quite significant step in post-processing during the production process of clear aligners. Currently, in most cases, the gum line is manually generated, trimmed and polished [2], which is sometime inaccurate and affects the comfort of orthodontic treatment.

1.2 Purpose

To suit the need, we proposed a practical solution, a GM retrieval algorithm for digital 3D dental models. By calculating the curvature from each vertex of the 3D model, we got important clues for identifying GM's boundaries. We aim to find the vertex set of the GM and connect them into a 3D line, which is manufacturable, as shown in Fig. 1.

1.3 Target

Retrieval of a 3D GM's identification line is a critical process step in the automatic manufacturing process for clear aligners. During the processing of cutting the finished clear aligner product, the 3D GM's lines can provide the most suitable cutting route according to the contour of the patient's gum. In the future, it is very likely to replace the manual trimming by using laser cutting to process automatically during aligner manufacturing.

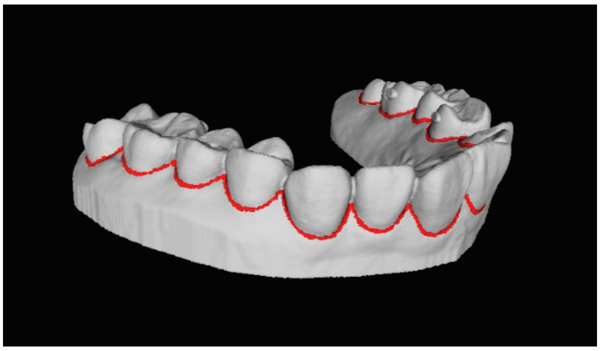

Fig. 1 The retrieved 3D vertices of the gingival margin

2 Experiment

Curvature is one important feature to evaluate for the ratio of dip angle change with respect to the arc length at a given point on a surface. In a 3D case, we detected the surface curvature for every vertex on a digital model to find out important clues regarding the gum line.

2.1 Materials

Based on the information of the triangular mesh in the digital model, we regarded the vertices within two layers as nearest vertices, which is more reasonable than choosing a set of nearest vertices within a cut-off distance.

In computational geometry, four main surface curvatures, says mean, Gaussian, maximum, and minimum curvatures, are commonly used to present how severe the surface is. Since GM presents a "valley" shape, both mean and minimum curvature effectively detect GM [3], as shown in Fig. 2. We consider the minimum curvature that is most likely to fit our purpose.

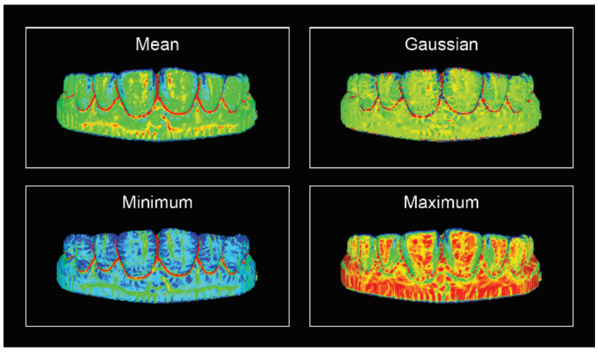

Fig. 2 Four main surface curvatures measures of the digital model

2.2 Methods

In our pipeline, it is very straightforward as shown in Fig. 3. We (a) pre-processed the 3D dental model based on smooth filter to achieve a stable result, (b) normalized the posture of the digital model and made it flat on the XY-plane, (c) based on the z-component in the vertex position information and extracted the vertices around the teeth, (d) defined a region of interest (ROI) in the minimum curvature that can completely filter out the GM, and (e) used DBSCAN [4][5], a density-based clustering algorithm, to separate the GM from other irrelevant parts.

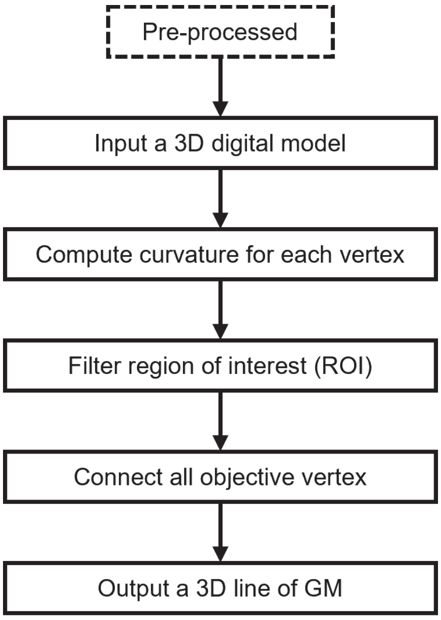

Fig. 3 The proposed pipeline of searching gingival margin

3 Results and Discussion

A satisfying result as far was achieved in the task of searching for GM. We successfully retrieved the GM and related vertex set by computing and filtering their curvature. However, the interdental space and the certain parts of the arch and crown also have valley shape surface features similar to GM.

To solve this problem, we chose DBSCAN as the practical method for quickly removing certain parts of the arch and crown and reserving the GM, but it doesn't work for removing interdental space. Because the interdental space and GM are continuous in point cloud data, how to separate them becomes another important issue.

In dental models, the malaligned degree of the teeth was positively correlated with the difficulty of retrieving the GM. Therefore, the first work is to classify the dental models according to the malaligned degree, then set different parameters for different types to achieve the best results, as shown in Fig. 4 and Fig. 5.

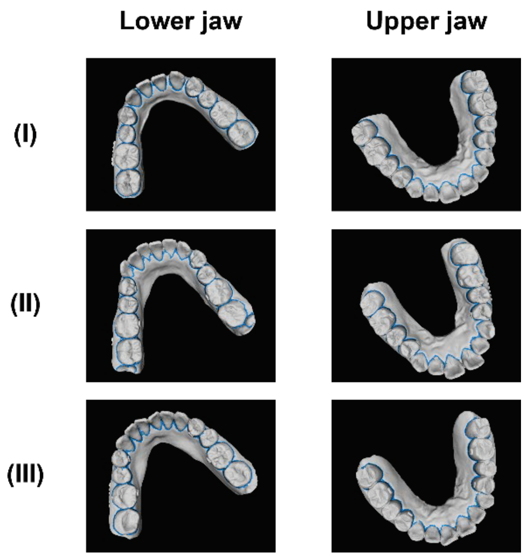

Fig. 4 The related vertex set in mildly malaligned dental models

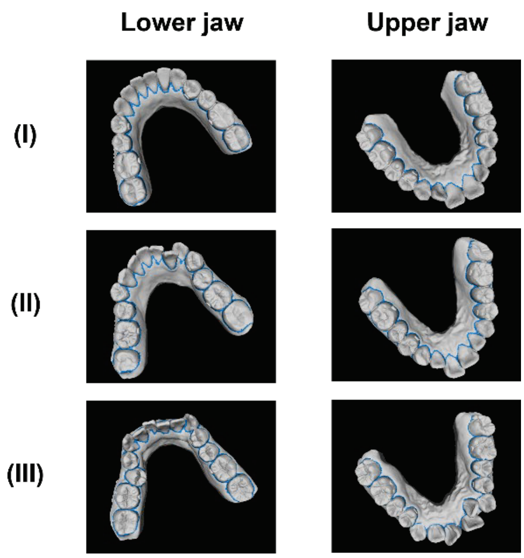

Fig. 5 The related vertex set in moderately malaligned dental models

4 Conclusions

This paper discusses a practical method for retrieving gingival margins in a 3D digital dental model. This method plays a critical step in the process of automatically manufactoring clear aligners. In future work, to implement generating 3D GM's lines, we are going to do more analysis on the feature processing of the digital dental model and separate the interdental space and GM.

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