COMPUTERIZED ALGORITHM OF OCCLUSAL CONTACTS CHECKING FOR DENTAL CAST SETUP

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ABSTRACT

This paper introduces a method for occlusal contacts checking of three-dimensional dental cast setup. An occlusal contact is important for patient appropriate grinding. This method is developed for AlignBracket3D® software, which is 3D computer graphic aided planning software for orthodontic diagnosis and treatment. By projection technique and point in triangle testing, the occlusal contacts area is obtained. If there is occlusal contacts area, the area was painted. There are 2 options for coloring. Both of them paint with relative depth of overlap. The results are reasonable that the overlap teeth surface was painted actually. The occlusal contacts information may guide user to desire the accurate planning and treatment.

1. INTRODUCTION

Recently modern technology, we can use 3D computer graphic aided planning software for orthodontic diagnosis and treatment instead of the original manual. It can reduce dentist training time, improve efficiency through the reduction of human errors and simulate the treatment planning. There are worldwide commercial software such as OrthoCAD®[1], emodel®[2] and Virtual Dental Patient Software©[3]. They are commercial software for only service. They are high cost for us, so we developed the software, AlignBracket3D®, by ourselves for reducing the cost and matching to the Thai dentist requirements. AlignBracket3D® was developed by using Borland C++ Builder™ and OpenGL which provide an advanced and affordable solution for computer aided digital model setup and planning. We simulate patient teeth by fitting the teeth template into the dental cast. We move 3D model through 2D monitor visualization. This limitation may cause missing position such as over deep biting. This paper, we propose the technique to consider the occlusal contacts. The Occlusal Contacts is one of the functions in AlignBracket3D® software that help users to check a depth of biting and make occlusal analysis for occlusal correction. Occlusal contacts tool is one of the most important modules that users can check occlusal contacts for helping better treatment planning. An appropriate grinding for the patient is provided by occlusal contacts information.

The purpose of the study is to demonstrate an area of occlusal contacts. We can show occlusal contacts area by two coloring alternative methods, smooth (gradient color) and flat (step color). Each color is relatively with depth of bite.

2. METHODS

Upper and lower cast are separately scanned by CT cone beam and registered to the corresponding maxilla – mandible bite registration model. Original upper and lower teeth surface is simulated from the registered cast as can be seen figure 1(a). The original upper – lower teeth surface is aligned to nice curve as shown in figure 1(b). These two set of 3D digital upper and lower teeth surface models are checked by occlusal contacts algorithm. They are STL file format which perform the coordinate of triangles and its normal vector of models. Our models are constructed from the net of triangles. The occlusal contacts area is obtained by following steps.

2.1. Data preparation

We need to select a critical area for interocclusal records. By this step, it causes an analysis time reducing. The lowest point of each upper tooth and the highest point of each lower tooth are calculated. The selected triangles are limited by lowest point + 2.5 mm and highest point – 2.5 mm in z – axis as shown in figure 2. By this step, the time to analyze an occlusal contact is reduced.
2.2. Automatic finding of tooth landmark

The centre extremity is a point which acts for tooth position. Distance between upper tooth and lower tooth is calculated by following expression

\[ D = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2} \]  

(1)

where \( D \) is a depth of overlap, \((x_1, y_1, z_1)\) is a upper tooth position and \((x_2, y_2, z_2)\) is a lower tooth position.

Three nearest lower teeth match with upper tooth. From figure 3, dot product between \( \overrightarrow{AP} \) and major unit vector on Z axis (\( \hat{k} \)) is checked. The \( \theta \) is an angle between \( \overrightarrow{AP} \) and \( \hat{k} \). If dot product is negative number, upper tooth does not contact lower tooth as can be seen in figure 3(a). If dot product is not negative number, upper tooth closed or overlap with lower tooth as shown in figure 3(b).

\[ \cos \theta = \frac{\overrightarrow{AP} \cdot \hat{n}}{\overrightarrow{PA}} \]  

(4)

\[ \cos \alpha = \frac{\overrightarrow{PP'} \cdot \hat{k}}{\overrightarrow{PP'}} \]  

(5)

where \( \theta \) is an angle between \( \overrightarrow{PA} \) and \( \overrightarrow{PB} \) and \( \alpha \) is an angle between \( \overrightarrow{PP'} \) and \( \overrightarrow{PB} \).

From equation (2) – (5), the method computes the depth of overlap according to the formula

\[ |\overrightarrow{PP'}| = \frac{\overrightarrow{PA} \cdot \hat{n}}{n \cdot \hat{k}} \]  

(6)

2.3. Contact checking using point projection technique

In figure 4, \( \overrightarrow{PA} \) is projected onto normal vector on lower tooth triangle (\( \hat{n} \)). \( \overrightarrow{PB} \) is gotten.

\[ \overrightarrow{PP'} = \frac{\overrightarrow{PA} \cdot \hat{n}}{n \cdot \hat{k}} \]  

(7)

\( P' \) is depth of overlap between upper and lower teeth. It has the same direction of major unit vector on Z axis.

Since,

\[ \overrightarrow{PP'} = \frac{\overrightarrow{PA} \cdot \hat{n}}{n \cdot \hat{k}} \]

Figure 2. (a) Upper teeth surface with selected crown (pink) (b) Lower teeth surface with selected crown (magenta).

Figure 3. (a) The upper tooth does not contact lower tooth (\( \cos \theta > 0 \)). (b) The upper tooth contacts with lower tooth (\( \cos \theta \leq 0 \)).
so point $P'$ is calculated by the formula

$$P' = P + \frac{PA \cdot \hat{n}}{\hat{n} \cdot \hat{k}}$$

(9)

Last, point $P'$ is checked. If it is in the lower tooth triangle, the upper tooth triangle is painted. The color of triangle depends on depth of overlap relative with maximum of depth in mm.

2.4. Checking of point whether it lies in triangle plane [4]

From figure 5(a), point $P'$ in $V_1V_2V_3$ triangle. The cross product of $\overrightarrow{V_1V_3}$ and $\overrightarrow{V_1P'}$ as shown in figure 5(b) do point the same direction with the cross product of $\overrightarrow{V_1V_2}$ and $\overrightarrow{V_1P'}$ as shown in figure 5(c). On the other hand, $P'$ point out $V_1V_2V_3$ triangle as can be seen figure 6(a). The cross product of $\overrightarrow{V_1V_2}$ and $\overrightarrow{V_1P'}$ as shown in figure 6(b) do point the opposite direction with the cross product of $\overrightarrow{V_1V_2}$ and $\overrightarrow{V_1P'}$ as shown in figure 6(c).

Figure 5. (a) point $P'$ in the $V_1V_2V_3$ triangle  (b) The cross product of $\overrightarrow{V_1V_2}$ and $\overrightarrow{V_1P'}$  (c) The cross product of $\overrightarrow{V_1V_2}$ and $\overrightarrow{V_1P'}$

Figure 6. (a) point $P'$ out the $V_1V_2V_3$ triangle  (b) The cross product of $\overrightarrow{V_1V_2}$ and $\overrightarrow{V_1P'}$  (c) The cross product of $\overrightarrow{V_1V_2}$ and $\overrightarrow{V_1P'}$

2.5. Determine gradient of occlusal contacts

The maximum of overlap depth ($D_{\text{max}}$) is analyzed. For smooth coloring, we shade the color by the following expression.

$$R = \frac{D}{D_{\text{max}}}$$

(10)

$$G = 1 - \frac{D}{D_{\text{max}}}$$

(11)

$$B = 1 - \frac{D}{D_{\text{max}}}$$

(12)

Where $D$ is an overlap depth at any point. The triangle which contains maximum overlap depth point is painted by red.

For flat coloring, we divide the color into 4 steps by the following expression.

- Pink: $0 \leq D < 0.25D_{\text{max}}$
- Purple: $0.25D_{\text{max}} \leq D < 0.50D_{\text{max}}$
- Orange: $0.50D_{\text{max}} \leq D < 0.75D_{\text{max}}$
- Red: $0.75D_{\text{max}} \leq D \leq D_{\text{max}}$

In the same way, this method is also applied for lower teeth coloring.

3. RESULTS

A study population comprising 4 cases was tested by the Occlusal Contacts algorithm. Each case has 2 set of teeth models. They are original teeth surface and alignment teeth surface. The teeth surface before alignment or original teeth surface is evaluated occlusal contacts by smooth coloring as shown in figure 7 and flat coring as shown in figure 8.
After align original teeth to nice curve, we’re obtained alignment teeth surface. It’s also evaluated occlusal contacts by smooth coloring as shown in figure 9 and flat coloring as shown in figure 10, too.

The results are reasonable that the overlap teeth surface was painted according to real situations.

4. DISCUSSION AND CONCLUSION

The occlusal contacts algorithm is already applied for AlignBracket3D® software. We are going to prepare new cases for more testing the algorithm. The occlusal contacts information may guide user to desire an accurate planning and treatment. The algorithm will be improved about time processing and smooth coloring.

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REFERENCES


