Computerized Checking of Overjet, Overbite and Occlusal Contact on 3D Dental Cast

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Abstract - Overjet, overbite and occlusal contact checking is necessary for diagnostic that the patient has got the correct bite after the treatment. Therefore this paper presents the computerized checking on overjet, overbite and occlusal contact on 3D dental cast. An algorithm on overjet, overbite checking can be done by cross-sectional plane cutting along the arch form curve. Then the projection of 3D data at the cross sectional area is calculated and displaying into 2D image that allow the user to measure the distance. For occlusal contact checking algorithm, the possible area is first determined at three millimeters above and below the occlusal plane. Then the overlap area is checked by determining the dot product between vector from lower to upper tooth and a unit vector on z axis. Next the tooth area that has the contact is painted with the color show the contact depth in millimeter that related to the occlusal contact force. The algorithm has been applied on cases, the distance of overjet and overbite that can be measure in 2D projection image has 97.25 percents correctly in comparison to 3D measurement that has been tested previously.

I. INTRODUCTION

Nowadays most dental treatment such as prostheses (crowns, fillings and dentures), orthodontics and orthognathic surgery needs an overjet, overbite and occlusal contact checking for diagnostic that the patient has got the correct bite after the treatment. For occlusal contact checking, this can be done by using articulating paper mark size to be descriptive of the occlusal load. For measurement of overjet and overbite, this can be analyses on lateral x-ray image.

However, there is a research by J.P. Carey and et.al [1] stated that there is no direct relationship between paper mark area and applied load could be found. The clinicians just assume the size of paper markings can accurately describe the markings' occlusal contact force content.

Overjet, overbite checking is more complicated for measuring the distances of overjet and overbite on the dental cast directly. Since overbite is indicated the distance that upper front teeth extend out over the lower front teeth as can be seen in fig 1(A). While overjet is indicated the distance that the upper teeth extend too far forward or the lower teeth not extend far enough forward.

In the present, there are commercial software available that can be used for overjet overbite and occlusal contact checking on digital dental cast in 3D such as: OrthoCAD [2], a product of Cadent Inc., developed for computer-aided treatment, 3Dxer [3], the product by Dimemnex Digital Lab has been used for orthodontics analysis, e-model [4], from Geodigm Corp is another 3D digital model service for orthodontics diagnostic. However, all diagnostics from the commercial are limited to provide only services and the commercial software sets are expensive.

Therefore, this paper presents the method on computerized overjet, overbite and occlusal contact checking on 3D digital dental cast. The program was written using C++ Builder and OpenGL library for 3D display. The data of dental cast was scanned using CT scanner and rendered into 3D or using optical 3D scanner and get the 3D data in STL format.

Figure 1: (A) Overbite: The upper front teeth extend out over the lower front teeth, sometimes causing the lower front teeth to bite into the roof of the mouth. (B) Overjet: The upper teeth extend too far forward or the lower teeth not extend far enough forward.

Figure 2: Cephalometric Analysis for measuring of Overjet & Overbite
II. METHOD

Upper and lower cast are separately scanned by optical 3D scanner or CT cone beam and registered position to the corresponding maxilla –mandible bite registration model. The dental cast both upper and lower has been extracted for the teeth surface by surface cutting from the registered dental cast as can be seen Fig. 3(A). Teeth surface is then aligned to a nice curve as shown in Fig.3 (B). Now the data in Fig 3 will be apply in this paper. The data is in STL file format which represents by coordinate of triangles and normal vectors. Also the data combine with mandible (lower cast) and maxilla (upper cast) models which need an analysis of overjet, overbite and occlusal contacts checking algorithms.

A. Overjet and Overbite Checking Algorithm

The horizontal plane is created from the standard arch form which is appropriate for patient teeth as shown in Fig.4.

Firstly, the arch form plane is divided by the median line into 2 parts: left and right. The median line is a direction guide for the vertical plane moving. The vertical plane is also the projection plane for showing the cross sectional of teeth model as well. The vertical plane can be moved differently into 3 ranges. First range the vertical plane is moving to the front. Next the vertical plane is rotating around the middle of median line. Then the last range, the vertical plane is moving to the back as shown in Fig. 5.

During the vertical plane moving, each triangle of teeth model will be determined whether it lies on which side of the vertical plane and show only left hand side while the other side is disappeared as can be seen in fig 5. This can be done by determining the dot product between the vector from each triangle to referent point on the plane and the plane’s normal vector. If the direction of vector from triangle to referent point is opposite to the normal vector of the plane, the dot product is negative. On the other hand, dot product is positive when two vectors have the same direction. So there are 4 different cases that might be happened. First, all of triangle’s corners are chosen in one side. Second, there are 2 triangle’s corners are in the condition for display. Third, only a triangle’s corner is in the condition. Forth, the triangle is not in the condition as can be seen in fig 6A. For smooth plane cutting, the triangle obtained by second case could be modifying by creating a cutting a line using equation (1). From this step, we obtain 2 new points. Then drawing a rectangular side from these new points and separates it into 2 triangles. In the same way, a triangle that is obtained from third case is modified by only drawing a line connects 2 new points.

The new point \( p \) comes from a line intersecting a plane. It is calculated by the following expression (1) [5].
\[ p = t + \lambda \vec{v} \]  
(1)

\( \vec{p} \) is a point on a plane.
\( \vec{t} \) is a point on a line.
\( \vec{n} \) is a normal vector of a vertical plane.
\( \vec{v} \) is a line direction.

Finally the plane cutting result in 3D has been projected into 2D for distance mmeasurement of overjet and overbite checking. Two dimension overjet/overbite image is provided as can be seen in fig 6(B) and 6(C) respectively.

### B. Occlusal Contact Checking

The critical area for interocclusal records is selected in order to reduce time analysis. The possible area can be calculated from teeth model at 3 mm above and below the occlusal plane as shown in fig 7.

![Occlusal Plane](image)

**Figure 7**: Possible area that will be calculated for occlusal contact checking (3 mm above and below the occlusal plane).

The overlap area is checked by determining the dot product between vector from lower to upper tooth and a unit vector on z axis. There is no contact area if the dot product is positive and there is an overlap area if it is negative value as demonstrated in fig 8(A) and fig 8(B) respectively.

![Figure 8](image)

**Figure 8**: (A) The upper tooth is not contact the lower tooth model. Dot product between a vector from lower to upper tooth and unit vector on z axis is positive. (B) The upper tooth overlaps the lower tooth. Dot product has negative value.

In fig 9, \( \vec{PA} \) is projected onto normal vector on lower tooth triangle \( \vec{n} \) then \( \vec{PB} \) is gotten as equation (2).

\[ \vec{PB} = \left| \vec{PA} \right| \cos \theta \vec{n} \]  
(2)

\[ \vec{PB} = \frac{\vec{PP} \cdot \vec{n}}{\left| \vec{PA} \right|} \]  
(3)

\[ \cos \theta = \frac{\vec{PA} \cdot \vec{n}}{\left| \vec{PA} \right|} \]  
(4)

\[ \cos \alpha = \frac{\vec{PP} \cdot \vec{k}}{\left| \vec{PP} \right|} \]  
(5)

![Figure 9](image)

**Figure 9**: Overlapping case, a depth of overlap \( |\vec{PP'}| \) is calculated in millimeter. Where \( P' \) is a projection of \( P \) on z axis.

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

From equation (2) – (5), our method can computes the depth of overlap according to the equation (6)-(8)

\[ |\vec{PP'}| = \frac{\vec{PA} \cdot \vec{n}}{\vec{n} \cdot \vec{k}} \]  
(6)

\[ \vec{PP'} = \frac{\vec{PA} \cdot \vec{n}}{\vec{n} \cdot \vec{k}} \]  
(7)

\[ \vec{PP'} = \vec{P'} - \vec{P} \]  
(8)

So point \( P' \) is calculate by the equation (9)

\[ P' = P + \frac{\vec{PA} \cdot \vec{n}}{\vec{n} \cdot \vec{k}} \]  
(9)

Finally point \( P' \) is determined by checking the point whether it lies in triangle plane [6]. If it is in the lower tooth triangle, then the upper tooth triangle is painted. The color of triangle depends on the depth of overlapping which relates to the maximum of depth in mm. The maximum of overlap depth \( (D_{\text{max}}) \) is then calculated. 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)
max \ D \ = - \ \frac{D}{D_{\text{max}}} \quad (12)

D is an overlapping depth at consider 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.

\[ \begin{align*}
0 & \leq D < 0.25D_{\text{max}} \quad (13) \\
0.25D_{\text{max}} & \leq D < 0.50D_{\text{max}} \quad (14) \\
0.50D_{\text{max}} & \leq D < 0.75D_{\text{max}} \quad (15) \\
0.75D_{\text{max}} & \leq D \leq D_{\text{max}} \quad (16)
\end{align*} \]

III. Result

The result of overjet, overbite checking can be seen in fig 10. The algorithm has been applied on 3 cases; each case has measured 5 difference positions by measure in 2D projection image in comparison to 3D measurement that has been tested with the real dental cast before.

The distance measure in 2D projection image has an error around 0.01-0.37 mm. The average of an error is 0.11 mm or 2.75%. Therefore The distance of overjet and overbite that can be measure in 2D projection image is 97.25 percents correctly.

The result of occlusal contact checking can be seen in fig 11, 12 for smooth and flat colouring respectively.

IV. Discussion and Conclusion

The algorithm of computerized checking on overjet, overbite and occlusal contact on 3D dental cast has been presented. An algorithm on overjet, overbite checking can be done by cross-sectional plane cutting. For occlusal contact checking, the overlap area is checked by determining the dot product and then showing the contact depth in millimeter. The distance of overjet and overbite that can be measure in 2D projection image has 97.25 percents correctly. While the result of occlusal contact checking is still in process for accuracy test in comparison between the contact depth in millimeter and the occlusal contact force. However, both algorithms still need to improve in terms of resolution that has been displayed on the screen.

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