THE “3-D OCCLUSOGRAM” SOFTWARE

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INTRODUCTION

The combination of an occlusogram and a profile radiograph has been used by Björk (1968)\(^1\) for the three dimensional illustration of growth related changes. Marcotte (1976)\(^2\) demonstrated the use of the occlusogram in the treatment planning and pointed out that the occlusograms allowed the clinician to determine the anchorage requirements, the arch length status, the final arch width, the teeth to be removed, and the final occlusal relationships. The possibility of the combination of the occlusogram with the headfilm was also suggested.

If the use of computer for the evaluation of cephalograms has gained almost universal distribution, on the other hand the computerised evaluation of the occlusograms -as suggested by Burstone\(^3\) already in 1979- has not gained much popularity. The same applies to the manual use of the occlusogram, which is only rarely encountered as part of treatment planning.

The tooth movements generated by an orthodontic treatment comprise mesio-distal, bucco-lingual or vertical displacements. Among them, the horizontal movements are by far the most important, especially because the vertical problems are often corrected by controlling the vertical development. It is therefore puzzling that the occlusogram has not played yet an important role as part of treatment planning. A likely explanation may be that the occlusogram has been considered time consuming and not very precise. In fact, due to the difference in magnification, the combination of the occlusogram with the headfilm has been considered difficult and unreliable. When performing the analysis on a scanned image, these differences in magnification can easily be accounted for by the computer, increasing speed, easiness and accuracy.

It was therefore determined to develop a user-friendly software which in addition to the advantages mentioned by Marcotte\(^2\) can also provide the bases for the computerised appliance design, as suggested by Fiorelli and Melsen\(^4\).

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The “3-D Occlusogram” (3-DO) procedure includes 4 stages, which are performed by different components of the software:

- Image Scanning and Setting
- Occlusal View Processing
- Lateral Cephalometric Processing
- Occlusogram Construction

Image Scanning and Setting

In this stage the occlusal images of both the dental casts and the lateral cephalometrics are acquired by using a flatbed scanner, which can be controlled by 3-DO as a TWAIN device. At this stage the actual scale of the images should be inserted and the unnecessary part of the graphic file cropped as well.
Occlusal view processing
At this stage the relevant software component allows to simulate the occlusal relationship between the upper and lower arch, by using three labelled points of occlusal contact as reference marks.
Afterwards, a symmetry line for both arches is selected and indicated by two points, which are chosen as symmetrical by the operator, on the image of the upper or lower study cast. It is important the symmetry line to intersect the facial midline in the anterior region.

Lateral Cephalometric Processing
In this stage the occlusal plane has to be indicated on the lateral cephalometric image.

Occlusogram Construction
The spatial combination of the lateral cephalometric image and the occlusal views of the upper and lower dental casts can now finish the three-dimensional set up of the patient.
As part of the treatment goal the operator indicates the desired final sagittal and vertical position of the front teeth in the lateral cephalometric view, and the transversal modification, needed in one of the two dental arches. Then the software will draw two transversally coordinated arches on the occlusal images. The anterior limit of the dental arches is defined by the desired final position of the front teeth, as indicated on the headfilm. The shape of the dental arches can subsequently be adjusted within certain limits, keeping the two arches coordinated.
Finally, the mesio-distal dimension of the teeth must be introduced into 3-DO. The teeth can be measured directly on screen within the software but, in some cases (such as mesially inclined molars and premolars in cases with a deep curve of Spee), it is recommendable to estimate the dental dimensions on the dental casts.
The software executes the alignment of the teeth, in the upper and lower arches, and displaces the molar contour in the lateral cephalometric view to its final position. As a result, all the needed movements of the teeth are clearly visible on the occlusal views, while the lateral cephalometric image shows the planned displacement for the molar and the incisors.
It is very important to remark that once the whole procedure has been executed, it is very easy and fast to modify some of the input parameters (such as the desired final incisor and jaw position, the transversal dimension of the arches and their shape, the symmetry axis and the teeth size) and recalculate a new treatment hypothesis.

A CLINICAL CASE
In the following it is shown the use of the software in the treatment planning of a patient, who – theoretically- could be treated in five different ways.
This patient is a 32-year-old female, who complains about her large overjet. She presents with a class II skeletal and dental relationship and a normal vertical pattern. The upper incisors are extremely proclined and spaced, while the lower incisor are proclined but in an acceptable range for a skeletal class II. Overjet is 11mm while overbite is 6mm.
In the lower dental arch 45 is missing, and there is a 1 mm shift of the midline towards the right side.
Based on the 3-DO, the following treatment possibilities were evaluated.
POSSIBILITY No. 1 (Fig. 1) Non extraction treatment with distal displacement of upper molars, followed by retraction of the upper front teeth.

For the establishment of a normal overjet and overbite, a major retraction and intrusion of the upper front teeth is needed, where the initial position of the lower incisors is kept unchanged. The occlusogram result shows the needed distal movements of the molars and of all the other teeth in the upper arch and the final class I molar relation (see Fig. 2). In the lower arch, where the right second premolar is missing, the occlusogram shows the necessary mesial movements of 46 and 43 (Fig. 3).

Fig. 1 Hypothesis 1 total occlusogram. Upper front teeth retraction with molar distal displacement. Note: the lower occlusal view is flipped

Fig. 2. The needed distal displacement of the upper right molar is shown on both the occlusal and lateral view.

On the occlusal view, the yellow cross represents the final position of the molar mesial contact point

Fig. 3 Necessary movements of the lower right cuspid and of the lower right first molar. Yellow crosses indicate the planned final position of the mesial point of contact of these teeth (mirror view)
POSSIBILITY No. 2. Extraction of upper first premolars followed by space closure through retraction of upper front teeth and mesial displacement of molars. (Fig. 4)

The treatment goal simulation, with respect to the incisors final position, is identical to that of treatment plan n.1. By setting the mesio-distal size of the first upper premolars equal to zero, the software simulates their extraction. The 3-DO result demonstrates the needed mesial movement of the two upper first molars, the needed distal displacement of the upper cuspids and incisors and the final class II molar relation. (See details in Fig. 5). The lower arch is treated as in the first suggestion.

Fig. 4. Treatment hypothesis 2. Upper first premolars extraction. Space closure by upper front teeth retraction and molar mesial displacement.

Fig. 5. Planned mesial movement of the upper right molar and distal lingual displacement of the upper right cuspid.
POSSIBILITY No 3. Minor retraction of the front teeth (diastema closure) and surgical advancement of the mandible, without any sagittal movement of the lower front teeth. (Fig. 7)

In this case the correction of the class II skeletal relationship and part of the excessive overjet will be obtained by means of a surgical advancement of the mandible (Fig. 6). Prior to surgery, a minor retraction of the upper front teeth, which closes the diastemata allows a reduction of the overjet.
The occlusogram shows how a class I molar and cuspid relation will be obtained, without any major sagittal movement in the posterior part of the upper arch. As a consequence of the mandibular advancement, a transversal expansion of the upper arch will be necessary. The final arch form is generated by the software and appears in Fig. 8. Since no displacement of the lower front teeth was planned, the orthodontic treatment in the lower jaw will be the same as in treatment plan 1 and 2.
POSSIBILITY No. 4. Minor retraction of the upper front teeth (diastemata closure), lower premolar extraction and lower front teeth retraction, followed by a larger surgical advancement of the mandible (Fig. 9).

A larger mandibular surgical advancement is planned, in order to reach a more straight profile. This mandibular movement can only be performed if one lower premolar is extracted (45 is already missing) and the lower incisors retracted, thus increasing the pre-surgical overjet. As in the previous case, a minor retraction of the upper front teeth allows for both a normalisation of the overjet and the space closure in the anterior district. The occlusogram shows clearly how a class III molar relation and a class I cuspid relation will be obtained.

In the lower occlusal view, the needed mesial displacement of lower molars and the distal displacement of the lower left cuspid are also shown (see details in Fig. 10). In the upper arch, a large amount of transversal expansion is needed, together with some mesial displacement in the posterior sectors.

Fig. 9
Treatment hyporthesis n. 4.
Major mandibular advancement with lower front teeth retraction.

Fig. 10 Planned mesial movement of lower first molars and distal movement of the lower left cuspid (mirror view).
POSSIBILITY No 5. Compromise treatment. Minor retraction of the upper front teeth (diastema closure).

In this case no movement is planned for the upper molars and no treatment in the lower arch. Thus the overjet reduction will not result in a normal incisor relation and a half cuspid class II molar relation will still be present at the end of treatment.

Such a result can also easily be simulated by means of 3-DO (Fig. 11)

Even if this last treatment results are far from being ideal, it can be useful to show the patient the limits of a minimal orthodontic treatment.

Fig. 11 Possibility No.5 Compromise treatment.

DISCUSSION

The above mentioned case demonstrates how the consequences related to a change in treatment plan can easily be transferred to the sagittal and the horizontal images of 3-DO. Alternative treatment approaches can thus easily be compared and their cost-benefit discussed with the patient.

The possibility of demonstrating the treatment goal to patients has been discussed repeatedly in relation to surgical planning. Sarver\(^5\) presented a software able to simulate the results of standard surgical procedures. Upton et al.\(^6\) recently evaluated a video software being able to simulate surgical results and concluded that the real outcome was different but mostly better than the simulated results.

The above-mentioned programs are all focussed only on the clinical image of the face i.e. the soft tissues. The software presented in this paper, on the other hand, elaborates the diagnostic materials, the headfilm and the study casts in such a way that a three dimensional image is obtained. The simulation of the necessary tooth movements expressed in three planes of space
allows for the design of the “custom made” appliance, which can lead to the most rational treatment. In fact, an exact three dimensionally defined treatment goal is not only the absolute precondition for the design of a correct appliance, but the only way quality control can be performed. If we don’t know where we are going, any place may be nice but, if orthodontics has to be goal oriented, a well-defined treatment goal is necessary. The treatment goal can be produced either manually, or by means of three-dimensional scanning equipment or by means of the software demonstrated above coupled with a common flatbed scanner. The latter has the advantage that after a rather short training period it is more rapid and more precise than the manual method without requiring any special and expensive equipment that the orthodontist does not generally already posses.

Orthodontists have being going along for almost a century without having to worry about the definition of an exact treatment goal why now? Most of the treatments have been carried out in growing individuals where the interaction between the ongoing development and the effect of the appliance is difficult to predict. Alternative treatment approaches will often lead to the same result due to the overwhelming influences of the genetic coding (Savoye, Loos, Carels, Derom, Vlietinck). In cases where treatments are dependent on exact tooth movements carried out there is, on the other hand, no doubt of the benefit of a well-defined treatment goal without which no exact force system and secondarily appliance can the produced.

REFERENCES


