Kinematic Analysis of Lips during Mastication by Two Infrared CCD Cameras

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ABSTRACT

The purpose of this study was to analyze the kinematic difference of lip before and after clinical treatment by the 3-D motion capture system. The approach employed in this analysis was as follows. The subjects were 5 volunteers who wanted to remake the dentures and three types of foods were selected by the texture. The 3-D motion capture system was composed of two infrared CCD cameras (Elite System, Bioengineering Technology & Systems Co., Italy) and was able to recognize multiple moving targets and calculate their 3-D coordinates. The features of this system were that no limits existed about number of markers that could be recognized in a single frame and that the special processing avoids problems related to white areas belonging to the background. The targets were hemispheres and covered with reflecting material. These were small enough not to hamper the mastication. The measuring points were mouth corners and chin. The data were collected before and after remaking dentures and were compared about velocity, rhythm and quantity of movement. It was found that lip movement was more active in the case of old dentures than new dentures. The result of this experiment showed that new dentures were fit well and lesser movements were required for the mastication.

1. INTRODUCTION

In dental region, mastication is one of the most important themes. There were plenty of studies about it. But it was few known how to make a bolus. When you eat something, first you put it on the tongue, the tongue put it on the teeth, and bite it. The cheek and the tongue work to keep food on the occlusal table of the teeth. Especially a few papers reported the movements of the soft tissue, which are lip, tongue and cheek, because it was very difficult to measure the soft tissue without harm. To analyze the movement of soft tissue is very useful for oral rehabilitation. If teeth were lost, there will have space. The space must be filled, but it must not be neither overfilled nor underfilled. The dentures should use space without interfering with the action of oral or facial structure. However there had been quantum jump of remote sensing in this decade. Thus no heavy device were needed on measurement. At first we used two CCD-video tracker and coordinate three-dimensional data in real time. We reported the movement of mouth corner of normal persons[1]. But that system could track only a few targets. This time we got a new motion capture system, which is able to catch many targets, and measured the movement of the lip.

The purpose of this study was to analyze the kinematic difference of lip before and after clinical treatment by the 3-D motion capture system.

2. METHOD

2.1 The Motion Capture System

A 3-D optical motion capture system consists of two infrared TV cameras (Elite System, Bioengineering Technology & Systems Co., Italy). The motion capture system can recognize multiple moving targets and calculate their 3-D coordinates in real time (Fig. 1). To reduce background

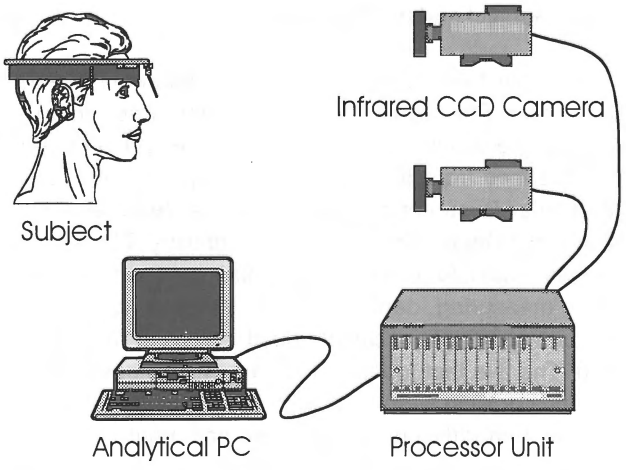

Fig.1 Motion Capture System

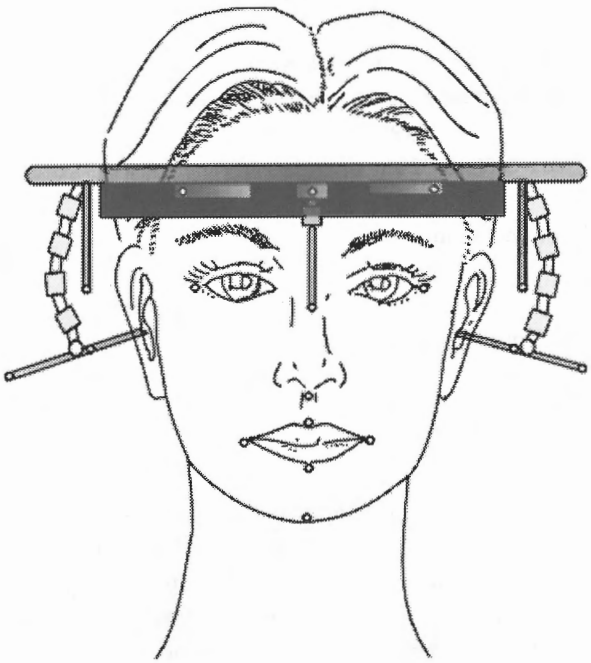

Fig.2 Headgear

noises, the lens of cameras were covered with an infrared ray filter and the cameras were able to work in only infrared band. The ring strobe, which is attached to lens, emits synchronized infrared rays and the camera detects the reflection of targets. These targets are covered with reflecting membrane, semispherical shape and 2 mm in diameter. A fast processor unit for shape recognition performs cross relation processing on the image signal sent from each camera, and recognizes the circular targets. Then the processor calculates the x and y coordinates of the marker centroid. This operation allows a remarkable increase of the resolution and precision because it can eliminate noises, which were background reflections. After it, the set of the markers is identified by manual, calibrated, and the 3-D coordinates of targets are worked out (Ferrigro & Pedotti, 1985).

2.2 The Subject and the Test Foods

The subject was a complete denture wearer (76 years old female). She wanted to have her dentures remade, because she couldn't eat smoothly with her old dentures. She was free from any signs and symptoms of Clanio Mandibular Dysfunction. New complete dentures were made in the Department of Geriatric Dentistry, T.M.D.Univ. She was given informed consent to participate in this study. Before measuring, dentures were examined about their size, bite condition, occlusal height, shape of fringe and fitting. The five test foods (gum, carrots, fish paste, peanuts and cookies) were selected. The reason for this was that they had different textures and commonly used for studies.

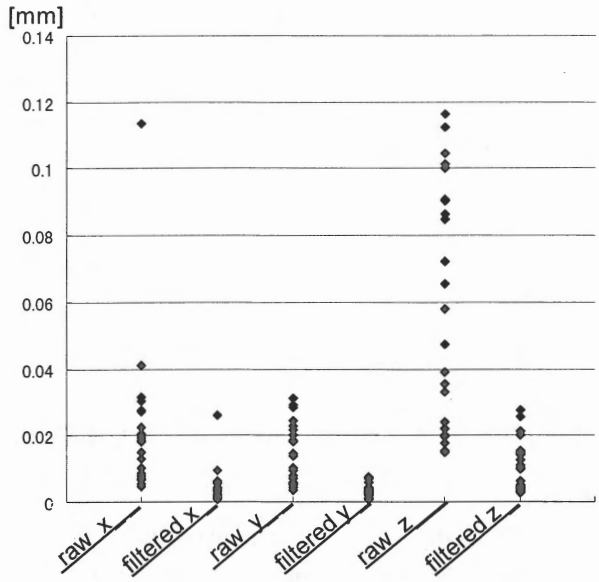

Fig.3 Difference of Standard Deviation of the Twnty-four Targets on the Grid Before and After Filtering

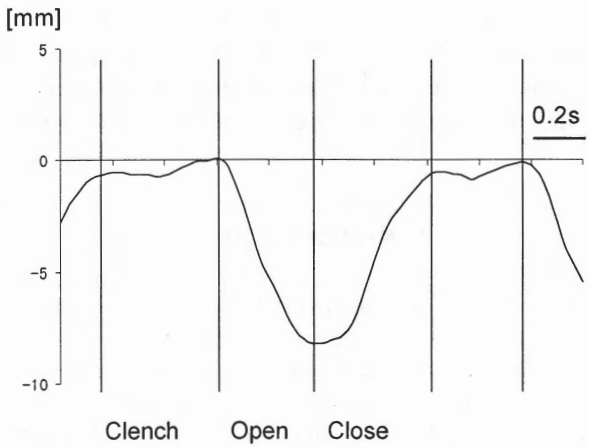

Fig. 4 Three Phases of Mastication
This is the horizontal movement of the chin.

2.3 Measuring

The measuring was done twice, before wearing the new complete dentures and after three weeks. She was instructed to place each test food on their tongue and to masticate them on the unilateral side until they swallowed it.

2.4The Targets

During mastication, usually the head of the subject moves. To cancel the movement, the original headgear was used (Fig. 2). On the headgear, six control targets were attached in different places to adjust the movement and two rods on which two targets were attached each to indicate the mandibular condyle points. The marks on

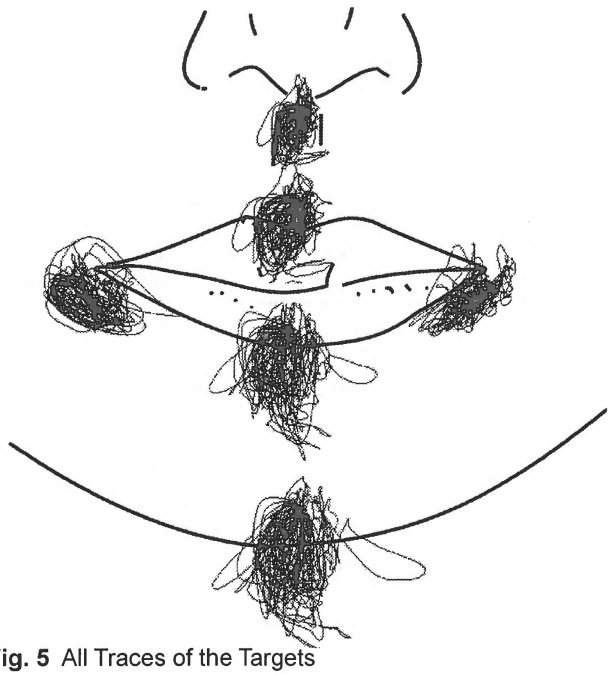

Fig. 5 All Traces of the Targets

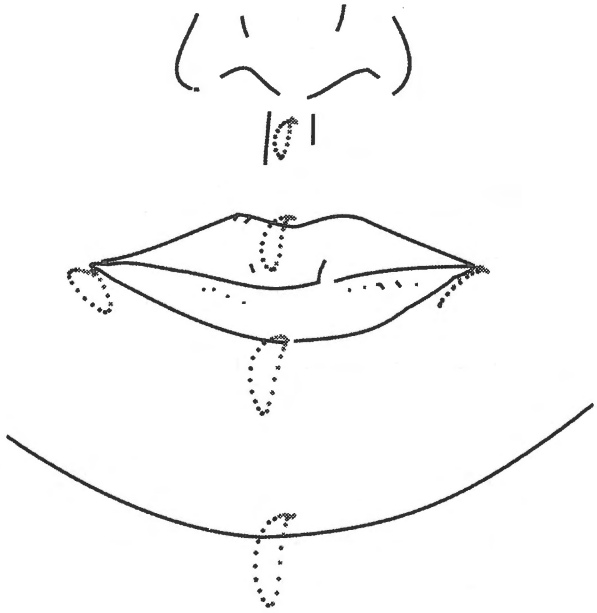

Fig. 6 Average Stroke

subject's face were each mouth corners, each canthus, the chin, the center of lower lip, and the center of upper lip and just below the nose.

2.5 Data Processing

Because of the noises due to the flickers, the filtering procedure was needed before standardizing the data. It is based on the so-known LAMBDA (Linear Auto-regressive Model Based Derivative Assessment) algorithm[2,3]. The optimal cut-off frequency is not fixed, but it is determined through the estimation of the bandwidth of the signal. This leads to fit the filtering procedure to the true frequency content of the acquired kinematic data, and allows the filter to cut the noise from the kinematic data. This gives the best performances especially when biomechanical data are concerned. Figure 3 shows that the standard diviations were different before and aftter the filtering, when the twenty-four stable targets on the grid were measured in the same condition of this study. It indicates that this filter is efficient. After the filtering procedure, the head movements were canceled using least squares. Six reference points were used for it. And the data of movement were standardized to compare each data. The standard axis on the subject's head was established by right-handed coordinate system. The axis x is from left to right, the axis y is vertical against the Camper's Plane (that is often used to determine the occlusal plane which consist of each traguses and the point just below the nosewing) and the axis z is antero-posterior. A stroke of mastication was composed with three phases which were an opening phase, a closing phase and a clenching phase (Fig. 4). The chin was selected for representing mandible movements and each phase was determined by it's position and speed. The surface of the skin, however, was softer than the bone, the accuracy was lower than that of measuring mandible directly.

3. RESULTS

Evaluations of the dentures were follows. The sizes of the old dentures were smaller than the new ones. The occlusal heights of the old dentures were lower than the new ones. Fitness of the old dentures was poor. Bite condition of the old dentures was unstable.

The Figure 5 shows the all traces of the targets. And Figure 6 indicates the average strokes. Each stroke was divided to twenty-four phases and the mean position of each period was calculated. During mastication, there were rhythmical and unrhythmical strokes. The ratios of rhythmical strokes were no statistical difference between new and old dentures (Table 1). The mean of a cycle was different only in fish past (Table 2). The difference of the lengths ,which were traces on lip,between the old and the new dentures (Table 3). All but peanuts were statistically decreased the length after clinical treatment.

4. DISCUSSION

It is concluded that Elite System is a very useful biomechanical measurement. The advantages of this system are follows. 1) It can measure many targets. 2) By this advantage, head movements can be canceled. 3) The targets can be measured without harm, because the targets are optically recognized.

By the evaluations of the dentures, it is concluded that the old dentures were clinically bad. The figure of traces below the nose was dynamically moved. This fact indicates that the shape of fringe is very important for the lip

Table 1 The Ratio of Rhythmical Strokes (%)

	carots	gum	fish paste	peanuts	cookies
New Dentures	78	81	97	94	83
Old Dentures	86	84	94	79	79

Table 2 The Average Time of One Cycle (s)

	carots	gum	fish paste *	peanuts	cookies
New Dentures	0.812	0.793	0.620	0.739	0.891
Old Dentures	0.897	0.785	0.769	0.840	0.872

* $p<0.05$

Table 3 The Difference of the Average Length (mm)

	carots	gum	fish paste	peanuts	cookies
below nose	-4.75 *	-4.36*	-3.83*	-1.12	-2.50*
upper lip	-6.87*	-5.81*	-6.63*	-1.75	-4.48*
lower lip	-6.88*	-8.13*	-7.96*	0.02	-2.52*
right coner	-6.92*	-5.94*	-6.49*	-1.93	-2.52*
left coner	-10.40*	-12.76*	-8.50*	-6.25 *	-8.46 *
chin	-6.35*	-7.11*	-7.48*	1.93	-0.91

* $p<0.05$

movement. It is known that the chewing rhythm is very useful to evaluate the mastication. The rhythmical chewing implies that the mastication does well and a bolus is made smoothly. In the same way, the larger the lengths of trace in lip are, the better the efficiency of the mastication is. Although in case of this study the traces of the lip were decreased after clinical treatment, there were no rhythmical differences between the old and the new dentures. This might be thought that the subject become used to the old dentures and she could eat food without matter. Consequently, it seemed reasonable to think that the lip movement is one of the important barometers to evaluate the mastication. In the future, numbers of subjects should be need for further investigation.

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