DENTURE MOBILITY MEASURING SYSTEM OF COMPLETE DENTURES USING FOUR INFRARED VIDEO CAMERAS

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ABSTRACT

The purpose of this study was 1) to assemble and verify the system to measure simultaneously the mobility of the upper and lower complete denture and the movement of the mandible, and 2) to analyze the relation between denture movements and the path of closure of the lower jaw during functions. A three-dimensional motion capture system with four infrared TV cameras was used. Twelve targets with infrared rays reflecting membrane were prepared for each subject. Three of them were attached to the rim of eyeglasses for the calibration of head movements, six of them were placed on the labial surface of the incisal tooth of each denture with a resin crutch, and others were on the metal frame attached to the mandible. The direction and range of denture movements were calculated from movements of each three targets. The relation between lower dentures and the mandibular movements were analyzed with the change of the inner product of normal vectors of denture occlusal planes and mandibular planes because of the calibration of the mandibular movements from lower denture movements. The mandibular movements could be classified into two types. One (80.0%) was the type of normal stroke (the path of closure was on ipsilateral side of mastication : IS) and the other (20.0%) was reversed (the path of closure was on contralateral side : CS). The results are followed: This system could measure the denture mobility within 0.3 mm errors. Upper dentures moved toward the nonworking side in a case of IS (85.6%), and toward the working side in a case of CS (86.4%). The lower dentures moved and inclined toward mastication side (71.8%). The mobility of upper dentures had a correlation to the mandibular movement regardless of working side or nonworking side, and lower dentures to the bolus on the occlusal table.

1. INTRODUCTION

Edentulous persons wear complete dentures on the compressible and movable oral mucosa. Dentures move three dimensionally(3-D) during normal functions, such as chewing, swallowing and pronouncing. A decrease in denture movements have an advantage effect on the maintenance of the retention and stability of dentures, and the rehabilitation of the functions. And then the patients can convalesce more satisfactorily. In this respect, we believe that it is very useful for the evaluation of prosthodontic treatments to measure 3-D denture movements. Though in many studies they measured movements of only upper complete denture, in few studies measured those of the lower ones against the mandible which moves itself during mastication and has very flexible skin so it is difficult to set datum points on it.

The purpose of this study was 1) to assemble and verify the system to measure simultaneously the 3-D movements of the upper and lower complete dentures and the mandible, and 2) to analyze the relation between denture movements and the path of closure of the mandible during functions.

2. MEASURING SYSTEM

2.1 System Arrangements

The measuring system for denture mobility consists of an optical motion capture system with four infrared TV cameras (Elite System, Bioengineering Technology & Systems Co., Italy), stereo photogrammetry system(PGman, the Japan Society of Photogrammetry and Remote Sensing) with two 35 mm SLD cameras (NIKON F3, Nikon Co., Japan) and analyzing computer(Optiplex XMT 590, Dell Co.). Four TV cameras were placed stereographically for 3-D measurement of dentures and the mandibular movements(Fig. 1,2).

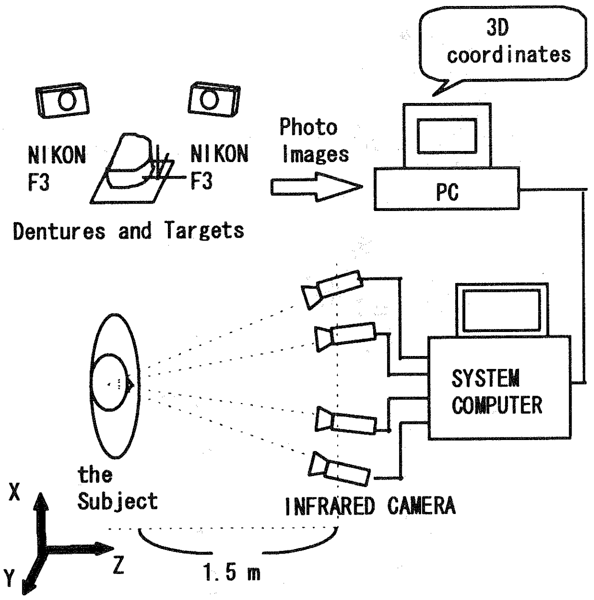

Fig. 1 System Arrangements

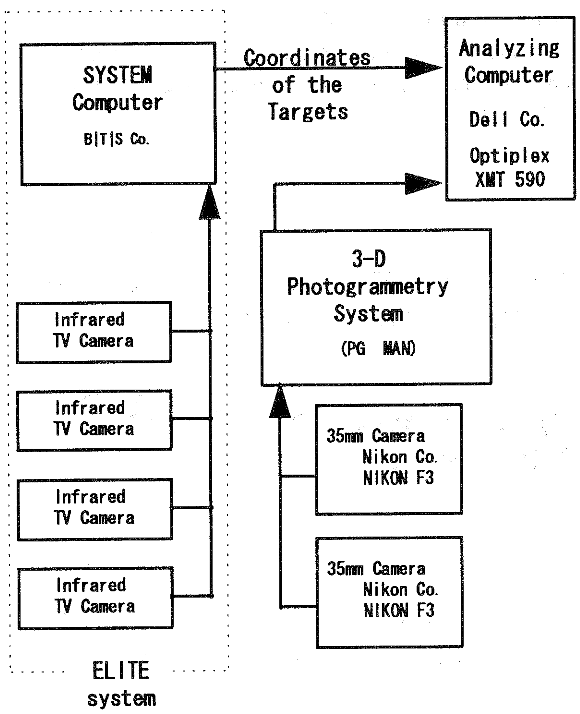

Fig. 2 Data processing

2.2 The Motion Capture System

The Elite system can measure the 3-D coordinates of moving targets in real time with the frequency of 100 Hz. TV cameras equipping with CCD sensor are able to work in the infrared band with an infrared ray filter. The camera emitting a synchronized flush in front of them can detect the reflected light rays, and send the images to the main processor, which finds the coordinates of targets with the practice of the triangulation.

2.3 Targets Construction

Twelve targets were prepared for each subject: For the elimination of the head movement three targets were attached to the rim of eyeglasses; Six targets were placed on the metal frame attached to the labial surface of each denture; For the measurements of the mandibular movements the remains were set on the metal frame (equivalent for the mentum and the mandibular angle), which was adjusted to be in parallel with the mandibular bottom plane and drawn with gum belts in two directions from each side, while the head gear was used as the anchor(Fig. 3).

Fig. 3 One of the subjects in full face

2.4 The Photogrammetry

For the measurement of denture mobility we have to transform because we set the targets in extra oral area. Using stereo photogrammetry system (PGman) the coordinate system on the dentures (representative points: first molars and an incisal point) and the coordinate system of external oral targets on the metal frames were united by the least square method.

These relations were represented by the transforming matrix, with which the loca of the extra oral targets were transformed to the relative movements of the dentures against patients' head on the analyzing computer (Fig. 4). The distance between the subjects and cameras was 40 cm(= h) , and the precision of calculation was 0.0005 x h (= 0. 20 mm).

3. MATERIALS AND METHODS

3.1 The Subjects

Three complete denture wearers (62 ~ 78 years old) were selected. Complete dentures were made in the Department of the Geriatric Dentistry, T.M.D.Univ., and the subjects had been wearing these dentures for at least 3 months.

The subjects were instructed to tap and masticate test foods (carrots, fish paste, and raisins) on the unilateral side until it was ready to be swallowed. The same food was masticated on

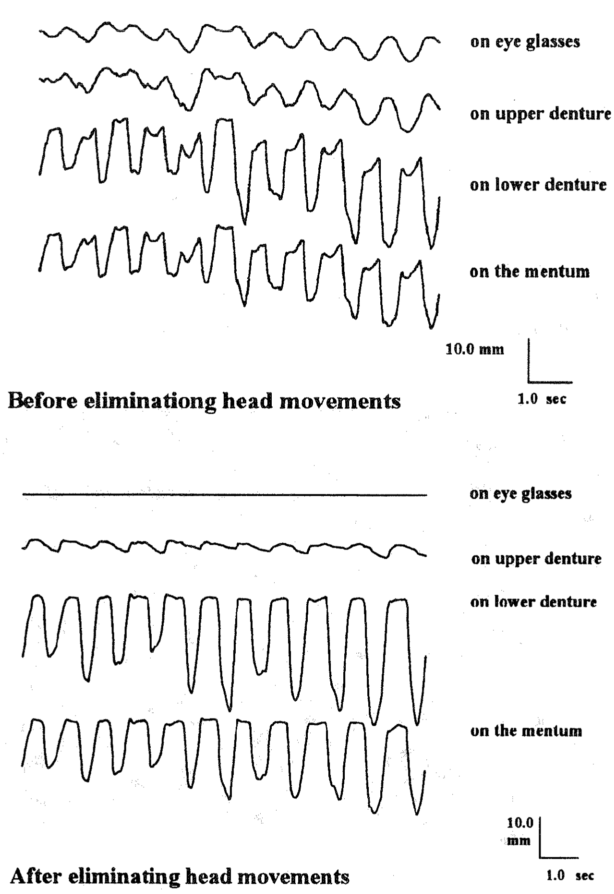

Fig. 4 Loca of the targets before and after eliminating head movements.

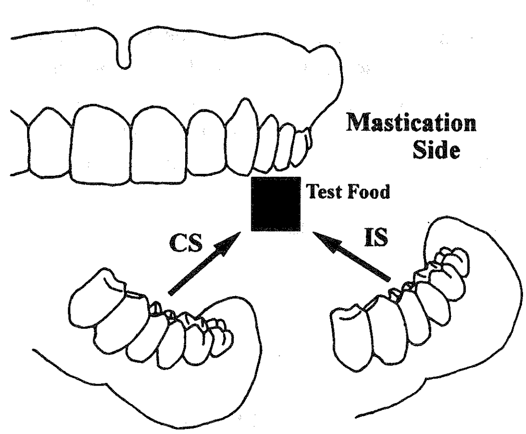

Fig. 5 Division of the path of closure of the mandible

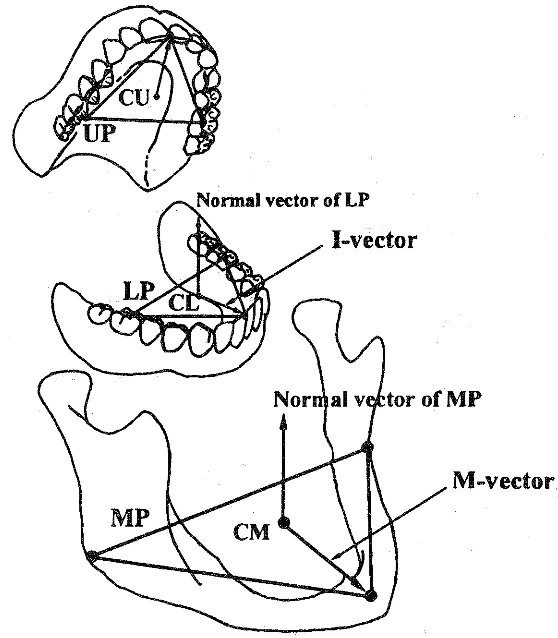

Fig. 6 Relation of the location between the lower dentures and the mandible.
The upward arrows were used to denote normal vectors of each plane, and the sideways arrows were used to denote I-vector and M-vector.

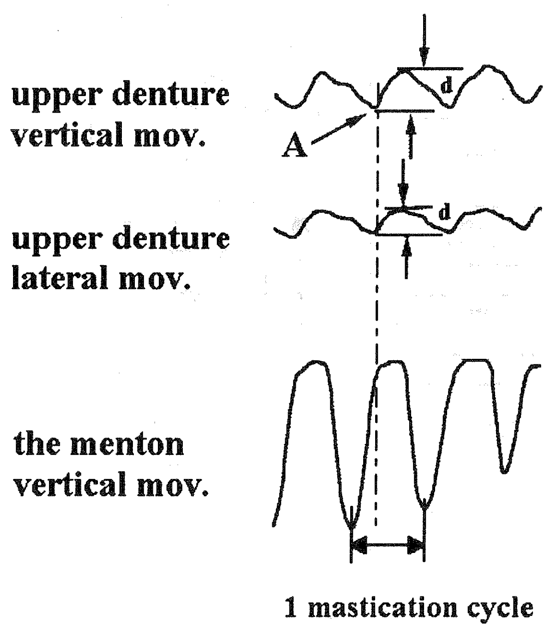

Fig. 7 Measuring method of the amount of the denture mobility.
A: start point of the measurement. d: amount of the movement. One mastication cycle was defined as the duration from maximum opening to next one.

the opposite side. To eliminate the interference by lip functions, they were instructed to keep their lips open during mastication.

3.2 Mandibular Movements

The mandibular movements were classified into two types in the frontal view by its direction at the time when the upper denture began to sink(Fig. 5). One was the type of normal stroke (the path of closure was on ipsilateral working side of mastication : IS) and the other was reversed (the path of closure was on contralateral side : CS).

3.3 Data Transformation

The transformed representative points from the measured targets were followed: the incisal point and the top of mesiolingual cusps of first molars in upper dentures; the incisal point and the central pits of first morals in lower dentures(Fig. 6).

The plane which contains the three points on the upper denture was defined as the upper occlusal plane(UP), and the centroid calculated with these points was defined as the centroid of the upper denture(CU). Similarly the lower occlusal plane(LP) and the centroid of the lower denture(CL) were defined. And with the targets on the metal frame attached to the mandible, the mandibular plane(MP) and the centroid of the base of the mandible(CM) was defined.(Fig. 6)

The vector directed from CL to the lower incisal point was defined as I- vector, and the vector from CM to the mentum was defined as M-vector.

3.4 Measurement of the Denture Mobility

The amount of the vertical denture mobility on the upper incisal points was defined as the distance between the beginning point of the sinking and the maximum point of displacement in one cycle. Lateral and antero-posterior(A-P) movements of the upper dentures were measured similarly on the basis of the timing when the incisal points of the upper denture began to sink(Fig. 7).

The amount of vertical, lateral, and antero-posterior movements of each points on upper dentures were measured. And then, upper denture movements were investigated in the relation to the path of closure of the mandible.

We investigated the movements of lower dentures about following points:

1. Pitching on the lateral axes. The normal vector of LP was project to the plane containing the normal vector of MP and M-vector, and the inner products between the unit normal vector of MP and the unit normal vector of LP were investigated.

2. Rolling on the A-P axes. I-vector was projected to the plane containing the M-vector and crossing MP at the right angles, and the inner products between the unit normal vector of MP and the unit normal vector of LP were investigated.

3. Rotation on the vertical axes. I-vector was projected to MP, and the inner products between the unit I-vector and the unit M-vector were investigated.

Each inner products was investigated frame by frame (Fig. 8).

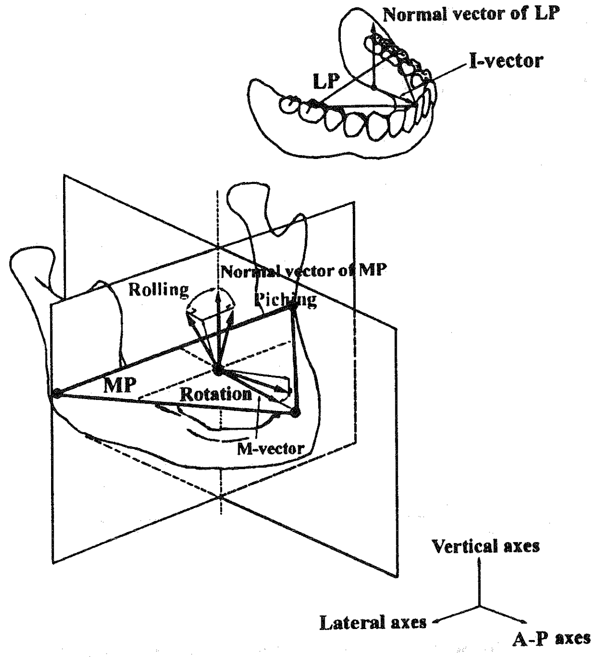

Fig. 8 Relation of the lower dentures' movements and the reference planes.

4. RESULTS

4.1 Accuracy of the System

A computer-controlled XYZ pulse stage was used to verify the accuracy of this system. One target on the pulse stage moved within the range of 20.0 mm cube along each axis at intervals of 5.0 mm, and all of 125 points were measured for calibration. The average of residuals' square sum of 125 points' coordinates from their real coordinates were calculated, and maximum residual was 0.3 mm.

4.2 Denture Movements (Fig. 9)

Table. 1 shows amounts of the upper denture mobility.

In tapping, there was few lateral movements. The incisal points sank more than the molar points and both moved forward. Denture base pitched forward and upper.

In mastication, dentures moved much more than in tapping. Analyzing sequential data on these 3 points, upper dentures intended to pitch upper and forward, and to incline toward the mastication side. In lateral movements, incisal points moved more than molar points. Denture base rotated and moved parallel at the same time.

Table. 2 shows the results of the denture movements related to the path of closure of the mandible.

5. CONCLUSION

Table 1. Amount of the upper denture mobility during tapping and mastication.

	Subject No.	No. 1			No. 2			No. 3		
		6|	1|1	|6	6|	1|1	|6	6|	1|1	|6
Tapping	R(+)-L(-)	0.06	0.02	0.06	-0.09	-0.07	-0.09	-0.01	-0.02	-0.01
	U(+)-D(-)	0.13	0.38	0.05	0.04	0.22	0.10	0.48	0.78	0.48
	P(+)-A(-)	-0.46	-0.24	-0.21	-0.19	-0.18	-0.18	-0.12	-0.05	0.13
Fish paste Left side	R(+)-L(-)	0.34	0.42	0.34	0.25	0.27	0.25	0.29	0.67	0.31
	U(+)-D(-)	0.46	0.63	0.28	0.37	0.43	0.35	0.34	1.03	0.48
	P(+)-A(-)	-0.63	-0.70	-0.64	-0.33	-0.36	-0.42	-0.22	-0.73	-0.95
Fish paste Right side	R(+)-L(-)	0.04	-0.21	-0.02	0.10	0.23	0.13	0.12	0.45	0.16
	U(+)-D(-)	0.39	0.47	-0.29	0.32	0.50	0.28	0.45	0.97	0.30
	P(+)-A(-)	-0.68	-0.61	-0.56	-0.17	-0.31	-0.45	-0.11	-0.52	-0.76
Carrot Left side	R(+)-L(-)	0.37	0.46	0.38	0.42	0.38	0.41	*	*	*
	U(+)-D(-)	0.32	0.50	0.39	0.47	0.53	0.25	*	*	*
	P(+)-A(-)	-0.29	-0.40	-0.49	-0.08	-0.10	-0.11	*	*	*
Carrot Right side	R(+)-L(-)	0.11	-0.19	0.11	0.33	0.44	0.40	0.47	0.78	0.43
	U(+)-D(-)	0.44	0.63	0.20	0.35	0.55	0.22	0.70	1.13	0.18
	P(+)-A(-)	-0.58	-0.47	-0.23	-0.15	-0.37	-0.57	-0.69	-0.90	-1.09
Raisin Left side	R(+)-L(-)	0.37	0.25	0.36	0.08	0.22	0.06	0.32	1.03	0.33
	U(+)-D(-)	0.43	0.57	0.41	0.26	0.43	0.36	-0.02	0.86	0.00
	P(+)-A(-)	-0.55	-0.63	-0.62	-0.30	-0.34	-0.40	-0.17	-0.72	-1.24
Raisin Right side	R(+)-L(-)	0.11	-0.28	0.12	0.20	0.44	0.24	0.37	0.84	0.41
	U(+)-D(-)	0.36	0.57	0.18	0.41	0.66	0.42	0.60	1.24	0.28
	P(+)-A(-)	-0.65	-0.61	-0.52	-0.13	-0.31	-0.62	-0.31	-0.73	-1.12

(unit mm) (* :mastication impossible)

R: right L: left
U: up D: down
A: anterior P: posterior

6| :top of the cusp of the upper right first molar

1|1 :incisal point of the upper central teeth

|6 :top of the cusp of the upper left first molar

Table. 2 Results of the denture movements related to the path of closure of the mandible.

Closure pathway	IS		CS		Total
Direction	WS	NWS	WS	NWS	WS
UD Rotation	12.4	87.6	92.4	7.6	30.1
LD Rotation	81.5	18.5	66.1	33.9	78.4
UD Rollong	7.8	92.2	24.2	75.8	11.4
LD Rolling	78.4	21.6	63.3	36.7	75.7
					Pa
UD Pitching	*	*	*	*	8.6
LD Pitching	*	*	*	*	66.6

(unit %) IS/(IS+CS)=77.9%

UD: Upper Denture
LD: Lower Denture

WS: Working side
NWS: Non-Working side
Pa: Pitch ahead

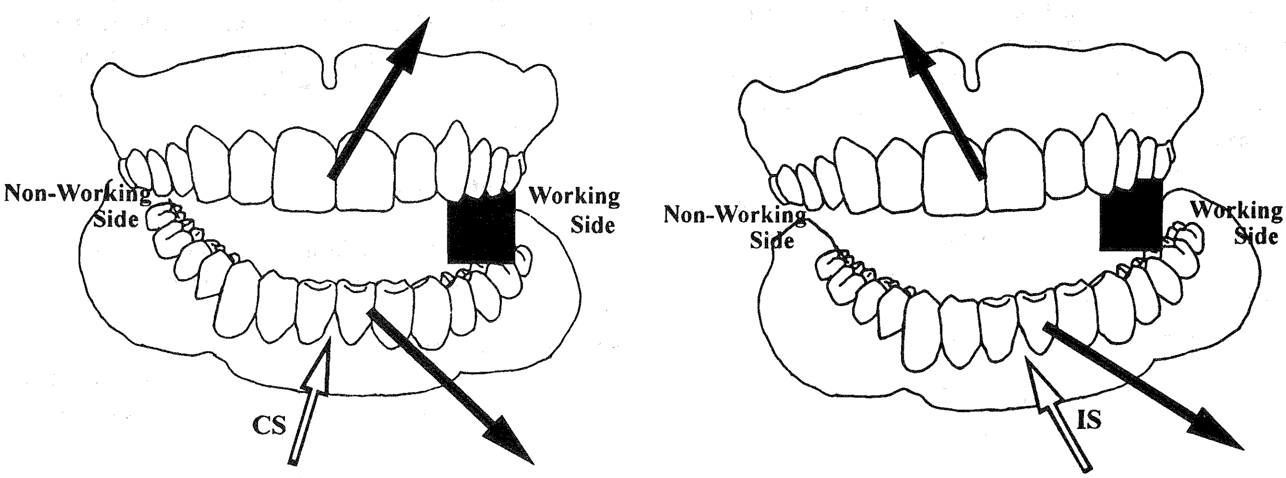

Fig. 9 Denture mobility and the path of closure of the mandible
The results were showed as the schema in the frontal view. The black arrows were used to denote the direction of denture movements, the white arrows were the direction of the path of closure of the mandible and the black squares were test foods.

5.1 Accuracy of the System

We concluded that this system could measure the denture mobility within 0.3 mm errors, and the accuracy of this system meets requirements for the analyzing denture mobility.

5.2 Denture Movements

During mastication the upper dentures inclined to the mastication side and pitched up and moved forward. And the dentures tended to shift toward the same side of the direction of the path of closure of the mandible.

The lower dentures tended to roll toward the working side, to pitch ahead or to be out of the posterior part, and to rotate to working side .

The mobility of upper dentures had a correlation to the mandibular movement regardless of working side, and the lower dentures had a correlation to the bolus on the occlusal table.

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