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The Statistic Analysis of Gothic Arch Records with Tapping Point when Taking the Maxillomandibular Registration for the Complete Denture - The Relation of the Tracing between the Quantitative Evaluation and the Morphological Evaluation by the Gothic Arch Score

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Abstract: The purpose of this study was to clarify relation between the morphology of the Gothic Arch (following GoA) and the Tapping Point (following TP) provided by GoA tracing method with Tapping (following Ta) method which are using for decision of the horizontal mandibular position of the edentulous patient.

Method: 161 records which were gotten by the GoA tracing method with Ta method during 11 years were examined. The evaluations were quantitative and morphological using GoA Score which was contrived newly. These were divided into 4 groups in the distance among the apex (following Ap) / TP and were statistically analyzed.

As results: A group (0 – 0.9mm) was 40.4% (65 patients), B group (1.0 – 1.9mm) was 29.8% (48 patients), C group (2.0 - mm) was 22.4% (36 patients), D group (TP depction only) 7.4% (12 patients). The Ap confirmed in TP (in the A group) was 13.0% (21 patients). There were not either of statistical differences in the front momentum and in the lateral momentum. Among each of the groups, there was no statistical

difference in the spread angle from Ap. The average was $113.54 \pm 7.91^\circ$. The spread angle from TP were $119.51 \pm 9.07^\circ$ in the A group, $121.83 \pm 9.16^\circ$ in the B group, $138.42 \pm 21.06^\circ$ in the C group. There was a statistically difference in the C group to the A group and the B group ($P < 0.05$). The GoA Score was 4.2 ± 2.37 in the A group, 6.01 ± 2.50 in the B group, 7.52 ± 1.93 in the C group. A statistical difference was admitted among each of the groups. (among A - B ? B - C: $P < 0.05$, among A - C: $P < 0.01$). About the number of the denture adjustments, total average was 2.38 ± 1.64 times, 2.28 ± 1.64 times in the A group, 2.92 ± 1.78 times in the B group, 1.83 ± 1.12 times in C group, 1.41 ± 0.76 times in the D group. There was a statistically difference in the B group to the C group and the D group ($P < 0.05$).

From these results: When the distance among Ap/TP increase, there was no change in the functional limit of the mandibular movement from A. On the other hand, the movement from TP was using the area of intermediate movement, therefore, the statistical variance was increasing. Also it found that the GoA Score increased, when the distance among Ap/TP increase, it was proved the dysfunction of the mandibular movement. About the number of the denture adjustments, there was statistical different on the B group, but clinically, there were only a few difference with the other group. At the end, GoA tracing method with Ta method can diagnose whether or not that the TP is appropriate to the mandibular position or the denture.

Introduction

Gothic Arch Tracing (hereafter called GoA) has been broadly accepted clinically until present since A.Gysi¹⁾ advocated it as a mechanical procedure of determining the horizontal mandibular position of an edentulous jaw. Presently this GoA method is applied jointly with record of Tapping Point (hereafter called TP) by the Tapping method (hereafter called Ta), and TP is generally accepted as the position of maxillomandibular registration.²⁻⁸⁾ It is because erroneous registration of maxillomandibular registration can be minimized better by judging from multiple ways of examination rather than a single examining procedure, since individual patient's mandibular position varies too much widely to determine best position of

maxillomandibular registration.^{6,9,10)} Clinical mandibular manipulation in general does not leave any record as an index like a traced graphic, and so it is not known exactly at what point a registration is recorded nor it is not possible to investigate relations with postoperative prediction. It is therefore significantly useful as a method of assessing what point of position a clinical operator has made decision to take the mandibular position when GoA tracing method is used jointly together with Ta method when the maxillomandibular registration is recorded.

Meanwhile, GoA tracing method is an easiest procedure of testing mandibular jaw functions for clinical application, but it will require ample studies to make an interpretation of traced graphics in case where typical examples are not developed or in case where the Apex (hereafter called Ap) does not match with TP. With less study in this regard, clinical evaluation has not yet been highly appreciated.

Furthermore, cases where GoA drawing is typically defined with clear Ap is limited to the normal condition of temporomandibular joint, and it is already known that these drawings would demonstrate deviations among patients of jaw functional disorders. Murakami et al.³⁾ investigate quantitative evaluations of both GoA and T, and they suggest that matching of Ap and TP is limited to 24.4%, while the rest of 75.6% is involved with functional problems, referring to the fact that 9 different morphological patterns are involved. Tanaka et al.¹¹⁾ report that 68.6% of complete denture wearers demonstrate TMJ internal derangement, mentioning that complete denture patients are less associated with normal TMJ. And Abe⁸⁾ concludes that occlusion of dentures are unstable when Ap/TP distance is over 2mm in GoA depiction performed in the passive recording method. And Suzuki et al.¹²⁾ report that denture adjustment is more frequently needed when Ap/TP distance is over 0.6mm. Either report is related with positional and functional relationship between Ap/TP, and the relation of GoA and TP is suggested to be valid enough for functional evaluation, but they are not researched well as far as morphological evaluation is concerned. Suzuki¹²⁾ also confirms that any diagnostic study is not found possible from GoA among reports so far up to the present, and any sufficient research is not yet seemingly done as far as GoA morphology and the maxillomandibular registration are concerned.

In this study, therefore, quantitative and morphological evaluations are made on GoA and TP records of 161 subjects obtained at the maxillomandibular registration for complete dentures at the author's clinics over the period of 11 years. The records are statistically analyzed in association with frequency of denture adjustment, and, as a result, clinically significant conclusions have been obtained and herewith will be reported.

Method

This study is based on the clinical records of "Kunimino Saito Dental Clinic" performed by the same individuals of a clinical operator (the author) and a dental technician, and so procedures of denture construction and methods of maxillomandibular registration are of consistent technique all throughout the clinical cases.¹⁴⁻¹⁶⁾ As the author thinks that this information may have no small effect on research results, procedures of denture construction and method of maxillomandibular registration will be illustrated here as follows.

. Procedures of denture construction

Final impressions are taken on the upper and lower residual alveolar ridges using conventional manners. After working stone models are made, upper and lower bite rims are made joined together with standard wax rims.¹⁶⁻¹⁷⁾ Before taking an maxillomandibular registration using GoA tracing device (H-A Gothic Arch Tracer, Tokyo Shizaisha Co.), a preliminary bite taking is done for fabricating upper and lower jaw stone models that were to be mounted using a split cast method on an average value articulator (Handy Articulator, Shofu Dental Co.) (**Fig.1**) GoA Tracer was assembled with a base plate and the second round of maxillomandibular registration was made through the GoA tracing by the Active Method and Ta motions in order to verify by way of the split cast method whether or not any difference was present from the preliminary registration. And then the mandibular position was finalized for denture construction. (**Fig.2**) (Detailed information will follow later.)

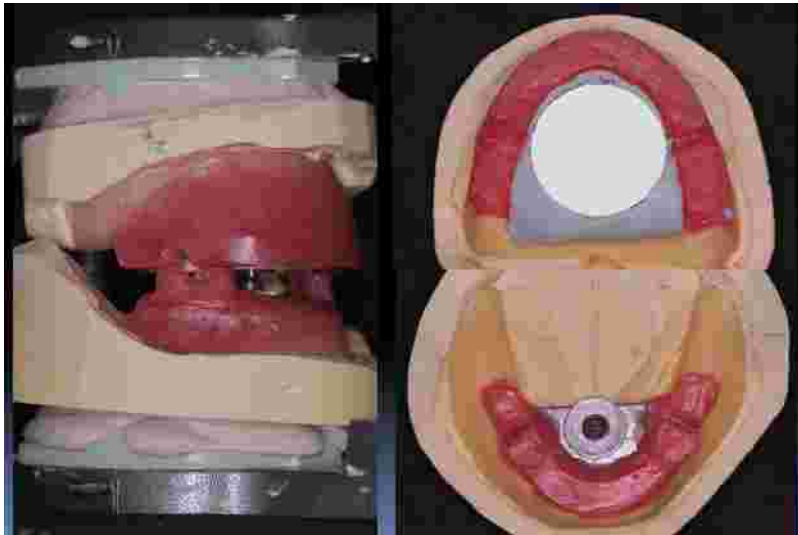


Fig.1 After a preliminary bite taking is done, stone models are mounted on an average value articulator through the split cast method and a GoA Tracer is attached.

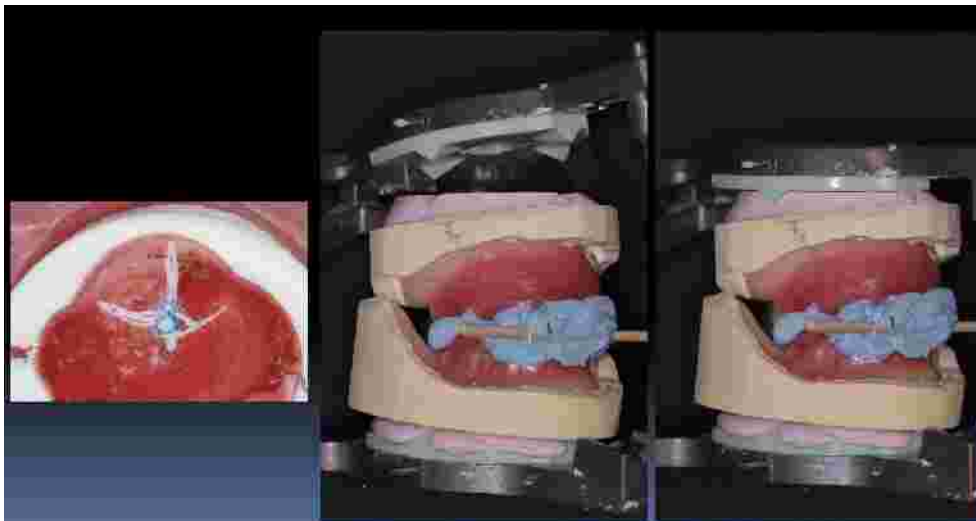


Fig.2 Stable TP is taken as an occlusal position, and comparison is made with the occlusal position taken preliminarily by a clinical jaw e through the split cast method.

And then the stone models were mounted in many cases on an average value articulator (Dental Hoby L, Shofu Dental Co.) or alternatively mounted on a semiadjustable articulator (ProArch EG, Shofu Dental Co.) that had been arranged through the condylar path inclination adjustment with check bite and was attached

with an accessory occlusal plane table. And lingualized teeth (Duradent-Lingualized Teeth, G-C Co.) were adjusted to set up in bilaterally balanced occlusion so that the posterior disclusion could be controlled in eccentric position, and tried in the mouth. After that the polymerization was done to finish the denture.

. GoA recording device and method

1. Assembling the GoA tracer

After a preliminary maxillomandibular registration confirmed an occlusal plane established parallel to Camper's plane, a drawing board of GoA tracer was assembled to meet with an occlusal plane of the upper occlusal rim. And the drawing needle was assembled to arrange vertically toward the drawing board at the central bearing point in the anteroposterior direction on the median line of the lower occlusal rim.

2. GoA and TP records

The GoA drawing method performed in this study is called the Active Method.¹⁸⁻¹⁹⁾ This method does not allow any intentional mandibular jaw manipulation with an operator's fingers and hands, but a patient is advised to draw shapes by his or her own positive motions. In this research a patient was instructed about a brief overview of the tracing method and was limited to trial exercise of tracing as simply as possible. GoA was traced and recorded as the consequence of mandibular jaw movements that were performed by patients themselves under the guidance of the clinician's verbal gestures.

First, TP motions were drawn by lightly and rapidly repeated small opening and closing at the rate of 3~4 Hz frequency. Next the protrusive movement was performed, and immediately afterward the mandible was retruded to reach the most retruded position by patient's own guidance. Thereafter from the most retruded position, the mandible was moved laterally in either one direction and then to return to the most retruded position again. Then after that, the protrusive movement was repeated and again returned to the most retruded position, and then to the other side of lateral movement. By the method described above, TP as well as protrusive and lateral movement tracing paths going back and forth were recorded on the drawing board. One

piece of plastic sheet plate at one tracing was used as the drawing board, mounted on an articulator, and was stored together with patient clinical chart.

3. Establishment of horizontal mandibular position

TP position which was stable was taken as the maxillomandibular registration. Reviewing what position in the GoA graphics TP is corresponding or whether or not it is repeatable and stable, mandibular position is carefully decided for its final denture construction. Especially when TP is shown scattered or is not clearly defined of focusing, points on the protrusive movement path drawn in GoA were taken.

Essential points of maxillomandibular registration by the GoA tracing method are presented here as follows.

- 1) The drawing board is to be set up in parallel to the Camper's plane.
- 2) Patient's active records are to be taken by the Active method.
- 3) Trace practicing is to be limited as least as possible.
- 4) Tracing path records are to be taken both in going back and forth.
- 5) Stable TP is to be taken as the position for the maxillomandibular registration.
- 6) TP on the protrusive movement path is to be taken.

.Graphic measurement

Measurements were made on the distance between Ap and TP, the length of line segment of tracing paths of GoA on the protrusive, right lateral and left lateral movements as well as the angle between these line segments, using 1/20mm reading caliper and 1/2 degree graduations protractor.

.GoA Score evaluation method (GoA point rating evaluation)

GoA Score evaluation method, which the author has uniquely developed by himself, is in an object to evaluate GoA shapes as objectively as possible. Components of the graphics are classified into four groups, and scores are counted by adding each one point depending on the grade of disorders of each segment. And these points are totaled for evaluating as GoA Scores. These components of the graphics and elements of count addition will be shown in the followings.

1.Ap

Each line segment under the length of 3mm from the point that is estimated as Ap is used for evaluation.

- In case when Ap is not in a pointed shape but rounded.
- In case when lateral movement paths, either side of right or left, are not focused into Ap. (2 points will be added when both right and left sides bilaterally are involved.)
- In case when the protrusive movement is not focused into Ap. (It is understood as only TP depiction for evaluation, when not defined on either right or left as well as protrusive path graphics.)

2.Protrusive movement path

- In case when line segments are plural in number.
- In case when line segments are curved.
- In case when line segments are short. (less than 5mm)

3.Right lateral movement path

- In case when line segments are plural in number.
- In case when line segments are curved.
- In case when line segments are short. (less than 3.8mm)

4.Left lateral movement path

- In case when line segments are plural in number.
- In case when line segments are curved.
- In case when line segments are short. (less than 3.8mm)

“Short line segment” is defined from length measurements of total records taking the length of standard error deducted from mean values as minimum parameter, and also it should be under 1 SD and under 5mm for the protrusive movement and under 3.8mm for the lateral movement. (**Table 1**)

Apex	Protrusive movement path	Right lateral movement path	Left lateral movement path	Maxillomandibular registration position
Not pointed but round	Plural line segments	Plural line segments	Plural line segments	Ap = TP Ap TP
Lateral movement paths are not focused	Line segment is curved	Line segment is curved	Line segment is curved	Ap/TP distance
Right side				
Left side				mm
Protrusive movement paths are not focused	Line segment is under 5.0mm	Line segment is under 3.8mm	Line segment is under 3.8mm	GoA Score Total points
0 1 2 3	0 1 2 3	0 1 2 3	0 1 2 3	

Table 1. GoA Score check chart. Enter total count of each component as to matching and unmatching of Ap/TP, and Ap/TP distance as GoA Score. Evaluate both going back and forth of movement paths. Count over 3 points in the Apex column is taken as Score 3.

Every time when point addition scoring is needed, one point is added as score, and maximum value should be 3 points as per each component. Total scores for these four different components are evaluated as total GoA Scores to each patient. If GoA tracing is clear, the score will be zero point, and as the GoA shapes becomes the less clearly defined, the score will be the higher, and finally the highest scores will become 12 points as in the table shown separately. (Table 2)





	Ap score	Protrusivescore	Right \score	Left /score	GoA score
	0	1	0	0	1
	0	1	2	0	3
	1	2	1	2	6
	2	3	2	2	9

Table 2. Example of GoA Scores

.Denture adjustment frequency

From patient's medical chart, data of patient's visit frequency for denture adjustment was extracted.

.Statistical analysis

For statistical analysis, EXCEL and JSTAT softwares were used to test the significant difference of mean values through calculating of basic statistics, F-test, Student's t-test, Pearson's correlation coefficient and through processing Kruskal-Wallis test from Scheffe's method. Especially comparisons were made from the following two viewpoints.

1. Test subjects

Total number of subjects and number of males and females (male-female ratio), Mean ages \pm 1 SD value (lowest values – highest values) and mean values \pm 1 SD values as for ratio of age group.

2. Analysis of groups of Ap/TP distance

After basic statistic analysis is processed, subjects were classified in 4 groups from distance differences between Ap/TP. Group A defines 0 ~ 0.9mm of Ap/TP distance.

Group B 1.0 ~ 1.9mm, Group C over 2.0mm, and Group D showed only TP depiction. And all measurements, GoA Scores, and denture adjustment frequency were analyzed statistically.

Results

. Regarding subjects

1. Total number and male-female ratio and ages

Number of subjects: 161 subjects

Male-female ratio: 58/103 subjects (36.0/64.0%)

Overall mean ages: 73.8 ±9.6 years (46 – 94 years)

Mean male ages: 72.3 ±10.6 years (48 – 90 years)

Mean female ages: 74.6 ±8.9 years (46 – 94 years)

2. Ratio of age group

46 – 59 years: 10.6% (17 subjects)

60 – 69 years: 15.5% (25 subjects)

70 – 79 years: 47.2% (76 subjects)

80 + years: 26.7% (43 subjects)

. Analysis of groups of Ap/TP distance

Among total number of 161 subjects, 149 subjects could be discriminated between Ap from TP. And only TP depiction was found in 12 subjects.

Mean values were calculated per each measurement exceptionally without Group D as measurements were not available with this group. And highest GoA Scores showed 12 points in Group of only TP depiction, and so this group was eliminated from the calculation of mean values. So the highest GoA Scores were 11 points among the rest of 149 subjects combined together of Groups A, B and C. As for the denture adjustment frequency, records of all 161 subjects throughout the Groups were taken. (**Table 3**)

Ap/TP Groups	Group A 0-0.9	Group B 1.0-1.9	Group C 2.0-	Group D (only TP)	Overall means
Rate of Appearance % (n)	40.4 (65)	29.8 (48)	22.4 (36)	7.4 (12)	100
Amount of protrusive movement (mm)	7.53 ± 2.27	8.02 ± 3.12	8.86 ± 2.78		8.01 ± 2.75
Amount of right lateral movement (mm)	6.38 ± 2.35	6.72 ± 2.73	7.44 ± 3.06		6.74 ± 2.70
Amount of left lateral movement (mm)	6.51 ± 2.24	6.47 ± 2.66	7.05 ± 2.90		6.63 ± 2.57
Spread angle from Ap (°)	114.38 ± 7.54	112.67 ± 7.45	113.17 ± 8.83		113.54 ± 7.91
Spread angle from TP (°)	119.51 ± 9.07	121.83 ± 9.16	138.42 ± 21.06		124.83 ± 15.22
GoA Score (point)	4.2 ± 2.37	6.01 ± 2.50	7.52 ± 1.93	(12 ± 0)	5.62 ± 2.69
Denture adjustment frequency (round)	2.28 ± 1.64	2.92 ± 1.78	1.83 ± 1.12	1.41 ± 0.76	2.38 ± 1.64

Table 3. Groups and movements of the Ap/TP distance

1. Rate of appearance in each group

Rates of appearance in Ap/TP distance of each Group were analyzed as 40.4% in the Group A (0 – 0.9mm) (65 subjects), 29.8% in the Group B (1.0 – 1.9mm) (48 subjects), 22.4% (2.0+ mm) (36 subjects) and 7.4% in the Group D (only TP depiction). In the Group A, 13.0% of the total where Ap and TP coincided, or 21 / 65 subjects.

2. Amount of protrusive movement

As for the amount of protrusive movement, $7.53 \pm 2.27\text{mm}$ was in the Group A, $8.02 \pm 3.12\text{mm}$ in the Group B and $8.86 \pm 2.28\text{mm}$ in the Group C. And as the Ap/TP distance became larger, some amount of increasing tendency showed, but there was no significant difference among groups.

3. Amount of lateral movement

As for the amount of right lateral movement, mean value was $6.74 \pm 2.70\text{mm}$. On the left lateral movement, it was $6.63 \pm 2.57\text{mm}$, and there was no significant difference. Or no significant difference was confirmed among Groups A, B and C.

4. Spread angle from Ap

The spread angle of right and left lateral movement paths from Ap was in the mean of $113 \pm 7.91^\circ$. No significant difference was confirmed among Groups A, B and C.

5. Amount of spread angle from TP

The spread angle of right and left lateral movement paths from Ap was in the mean of $124.83 \pm 15.22^\circ$. That of Group A was $119.51 \pm 9.07^\circ$, Group B was $121.83 \pm 9.16^\circ$ and Group C was $138.42 \pm 21.06^\circ$. And as the Ap/TP distance became larger, the spread angle increased, and Group C showed significantly larger than Group A or B. ($P < 0.05$)

6. GoA Score

GoA Scores were in the mean value of 5.62 ± 2.69 points in the Groups A, B and C where Ap and TP were clearly defined. As TP was only depicted in the Group D, it showed 12 ± 0 points. That of Group A was 4.2 ± 2.37 , Group B was 6.01 ± 2.50 and Group C was 7.52 ± 1.93 , and GoA Scores between Groups A, B and C were not confirmed with significant difference. ($P < 0.05$ as for Groups A – B and B – C. $P < 0.01$ for Groups A - C)

(Fig.3)

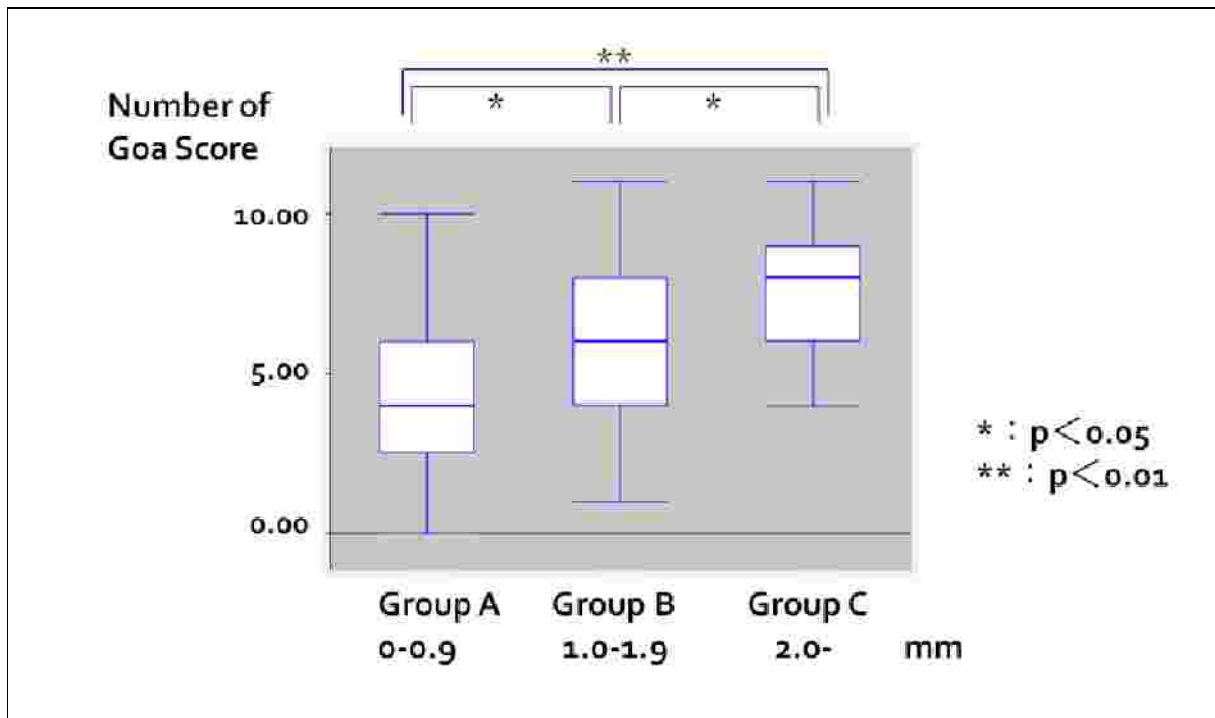


Fig.3 GoA Score according to the Ap/TP distance

And also the correlation coefficient of the Ap/TP distance and GoA Scores were found to be +0.50817, and moderately positive linear correlation was confirmed. (**Fig.4**)

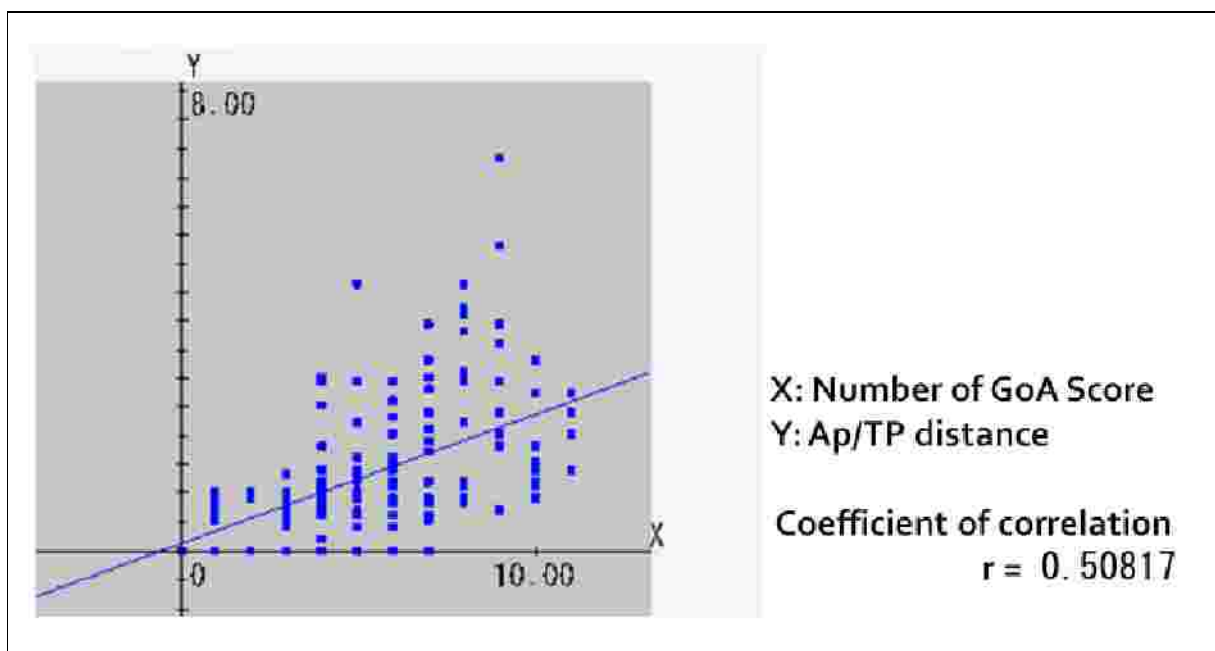


Fig.4 Correlation between Ap/TP distance and GoA Score

7. Denture adjustment frequency

As for the denture adjustment frequency, total average frequency was 2.38 ± 1.64 rounds, Group A average was 2.28 ± 1.64 rounds, Group B 2.92 ± 1.78 rounds and Group C 1.83 ± 1.12 rounds and Group D 1.41 ± 0.76 rounds. Adjustment frequency in the Group B was significantly higher than Groups C and D. ($P < 0.05$) No significant difference was confirmed among other Groups. (Fig.5)

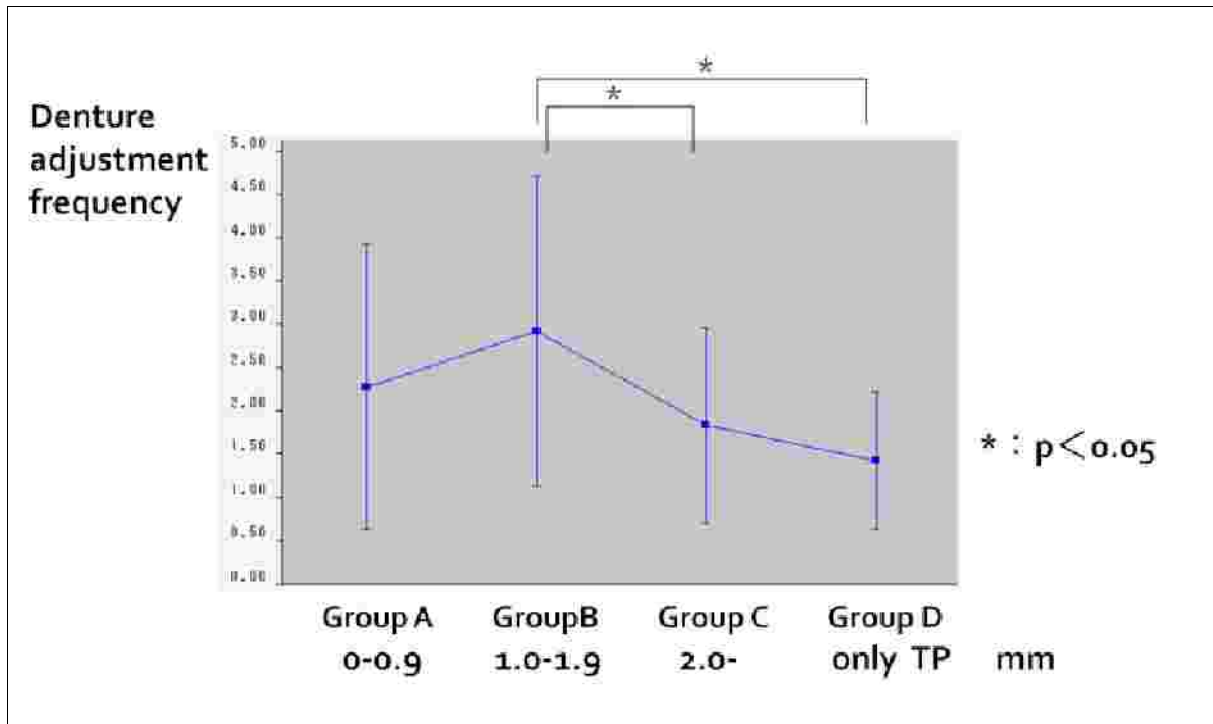


Fig.5 Denture adjustment frequency according to Ap/TP distance

Discussion

Totalling 161 pieces of GoA measurements used in this study were all traced graphics taken clinically at the time of complete denture construction. When patient's graphic was taken originally in the past, data collection was not intended for processing like this study but was intended to find out repeatable and stable TP positions in order to prevent errors from recording final maxillomandibular registration. Now the purpose of the study this time is to research clinical significance of GoA by analyzing relationship between GoA and TP.

The maxillomandibular registration in complete denture construction is a procedure to

find out a single point of TP over the intermaxillary relation is the masticatory terminal position after the occlusal vertical dimension and the plane are determined. This TP position must be certainly a consolidated point of the neuromuscular mechanism and the bilateral status of TMJ that are related with the patient's own specific stomatognathic system at this point of moment. And also this point should be repeatable and consistent within reasonable range of the living body, even though it is a compromised one when patient's dental history is taken account.

Meanwhile, as far as Ta method is concerned without using GoA tracing method in order to fix the maxillomandibular registration, there is no index existing as to how to correct any error if it happens, because such a Ta method does not permit relations clearly with the mobility of TMJ in visual form like the GoA method.

For this reason, combined use of the GoA tracing method and TP method is capable of clarifying the mobility of TMJ in form of traced graphic at this point of moment of an individual patient, and it is objectively able to know in what way the TP is positioned. So it is thought effective that the maxillomandibular registration can be processed more precisely. And even if any error occurs in the maxillomandibular registration, it is possible to understand in what way errors have been modified and corrected through the GoA processes. And so the GoA tracing technique is excellent in this regard.

. Organizing GoA

The GoA tracing method is most familiar and simple recording method of jaw movement for a practitioner, but the interpretation is mostly complicated. There is no question about a basic and beautiful shape. But when the drawing is in disorderly manner, sufficient researches have not been conducted so far in the past for reasoning with excuses that 'there is no information available'. So for better interpretation of GoA tracing method, factors of this complicated background will be elaborated and organized.

1. GoA and posterior guidance

GoA tracings are recorded with three points of support. Two points are supported in the back by TMJ bilaterally, and the recording apex is the front support. The tracing

needle works to record three-dimensional movements of bilateral TMJ onto the two-dimensional flat plate in certain level. On the other hand, posterior guidance is an element that defines the jaw movement as TMJ morphological factors.²⁰⁾ And so, GoA tracings are drawn by the posterior guidance that is guided by the TMJ architectures including joint ligaments and discs on both sides, and they are expressed in graphics of movements of bilateral mandible condyles. For this reason, this is thought as one of recording methods of jaw movements. If any organic change is present, therefore, including an eccentric displacement of mandible condyle or disc like TMJ internal derangement, it will become an impaired posterior guidance, and GoA will not be traced smoothly. As a result, disorderly GoA will be drawn, indicated as a tracing disorder. In other words, it is known that GoA analysis is a recording method of mandibular jaw movement that can detect any presence of organic change in the posterior guidance.¹⁰⁾

2. GoA and neuromuscular mechanism

In practical clinics, there is another reason for inhibiting the smooth tracing of GoA other than organic dysfunctions of the posterior guidance as described above. That is related with inhibition of smooth working of neuromuscular mechanism. Furthermore, this kind of tracing disorders caused from neuromuscular mechanism will be divided into two groups. First one refers to a case of essential cause like after-effects from brain damages. **(Fig.6)**

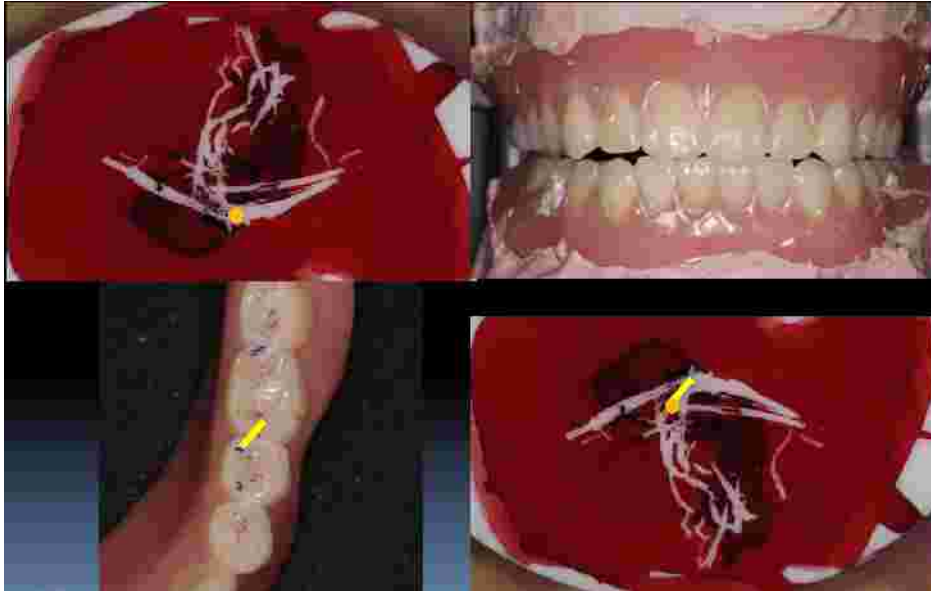


Fig.6 GoA depicted by a patient suffering from partial paralysis after stroke. It was estimated that Ap and TP would be matched at first of the construction but after the insertion, the intercuspation of artificial teeth were found in discrepancy, and remounting was done after new maxillo registration taken at the TP position on the protrusive movement path.

The next one refers to a problem of tracing the mandibular jaw movement smoothly as a voluntary movement, even if simply trying to follow an operator's request. It may not be an easy task for an elderly people who often are complete denture wearers to do the right and left lateral movements voluntarily without lifting up the tracing needle from the drawing board. In the latter case, it may often be nominated as the tracing disorder even without any problems involved with TMJ. In this case, a patient is suggested to do a free moving horizontally forward, backward, right and left from TP. Then, it may be possible to take the component of involuntary motion into an examination supplementary.

This kind of involvement of neuromuscular mechanism might have made the understanding of GoA more complicated, and so there may be major reasons of background that there has not been good enough research in many reports on GoA reasoning of excuses that "Individual patients variety are many." ¹³⁾

3. GoA tracing method is a loading test

GoA is usually recorded under certain height of occlusal vertical dimension on an imaginary occlusal plane in parallel to the Camper's plane. But it is more flattened with no inclination than the sagittal condylar path inclination of the posterior guidance, and so the mandible condyle would be forced to rotate in the negative direction at the protrusive movement. (Fig.7,8) ^{21,22}



Fig.7 When GoA is to be drawn on the board parallel to Camper's plane, TMJ is forced to rotate conversely.

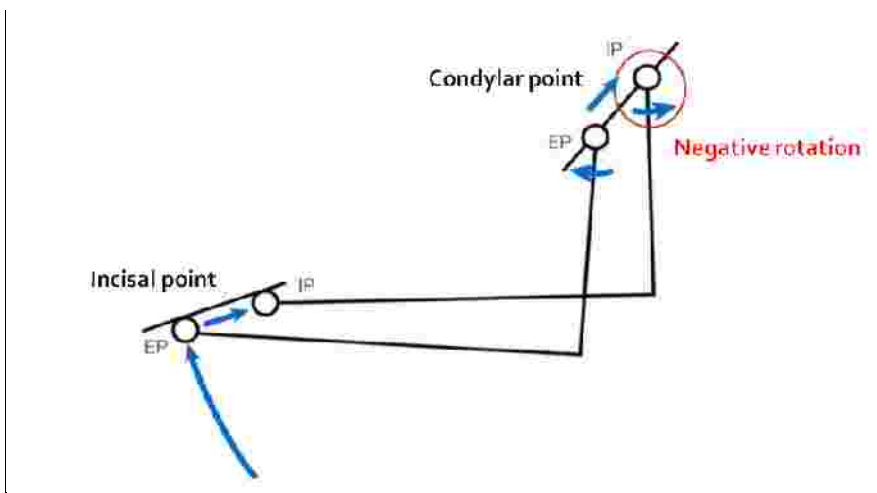


Fig.8 IP: Intercuspal position, EP: Edge-to-edge occlusal position. If the incisal path angle < the condylar path angle, the movement from EP to IP would rotate the

condyle conversely and would adversely affect TMJ. And so, it would be preferable if the incisal path angle be larger than the condylar path angle (quoted from the reference literature number 21 and 22).

From this viewpoint, it would be understood that GoA tracing method has a component of a loading test. In order to reciprocate this negative rotation, it is proposed whether the tracing should be initiated under increased vertical dimension to provide the positive rotation, or alternatively the tracing board should be tilted anteriorly along with about equivalent amount to the sagittal condylar path like a supplemental element of anterior guidance. From this measure, there might be an improvement depicted on the drawing board. If there happens to be any clicking or crepitus sounding or any catching, the mandible condyle will detect this problem not to move smoothly under loaded condition like this. In case the condyle cannot climb over this drawback, GoA depiction will become extremely small, or even if it can climb over it, the tracing will become discontinued or will not be coincided on the way going back and forth. (Fig.9.10)

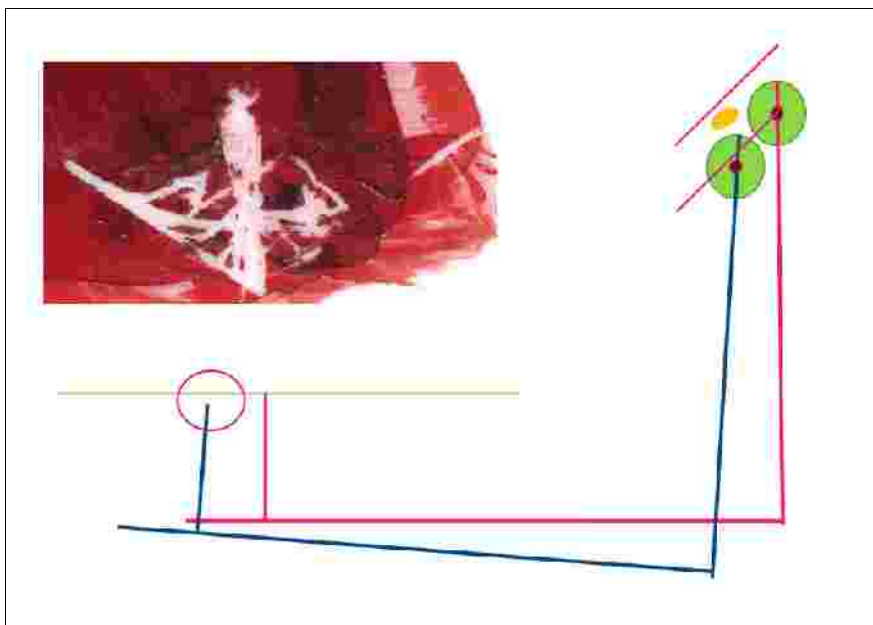


Fig. 9 If any interference is present on the posterior guidance, smooth mandibular movement is inhibited. The needle will lift off from the board when it climbs over and its drawn line will become a broken line.

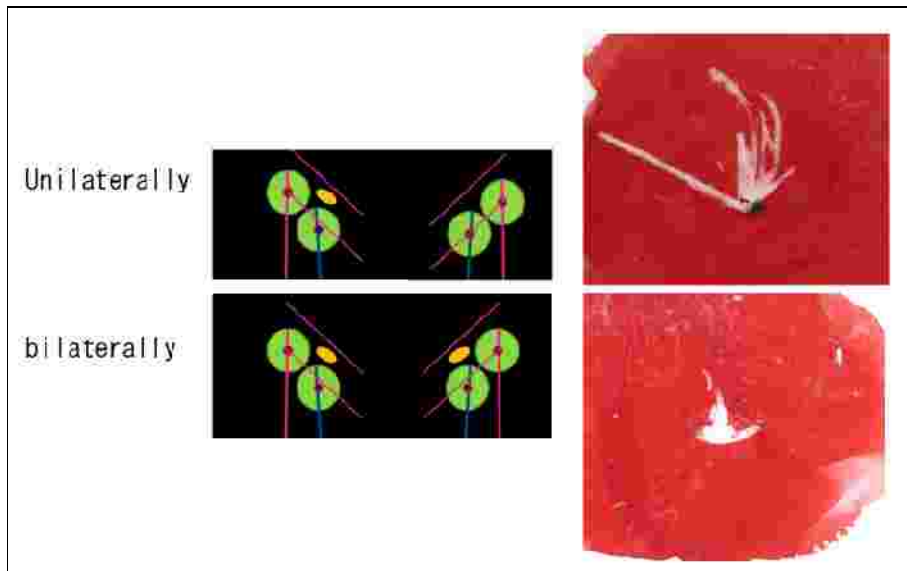


Fig.10 If any interference is present on the posterior guidance, and when it cannot climb over it, the drawn path will become shorter in a unilateral case, as the movement on the troubled side is controlled and the balancing side is largely affected. In a bilateral case, all the movement paths, protrusive or lateral, will become shorter.

4. Intended use of GoA

From research reports so far to the present, there may be grouped about in two different intended uses of GoA. The first one is to use it to determine preoperative horizontal mandibular position in relation to the TP d a. The second one is to obtain functional status of TMJ.

In the latter use, pre- and post-operative comparisons of GoA will be conducted. It is reported that functional improvement like masticatory efficiency may be confirmed from changes of GoA graphics depending on consequences of provision of treatment denture and other treatment measures.^{13,23,24)} Even if there may be, however, any graphic changes confirmed, it is still unknown to what degree of changes some organic problems in the TMJ area or some muscle tissues problems have been involved.

As described above, GoA tracing method as for recording mandibular jaw movements can be obtained from the mandible condyle translation on the posterior guidance. And

so it is an objective method of graphics to show the degree of functional status of mandibular jaw movement. Its drawn graphic is a comprehensive record of patient's complicated background including patient individual TMJ organic status, neuromuscular mechanism and tracing condition. For this reason it is difficult to appreciate any single significance of graphic, but it is rather helpful for us to obtain patient special information on TMJ functions by studying to break down the components. It is not, however, well established on procedures for analyzing the components, or yet sufficiently organized currently. In this study, therefore, if procedure of scoring like GoA Scores this time can be taken as objectively as possible and can compare the degree of pre- and post-operative improvement in numerical values, then clinical significance of GoA tracing method may be enhanced.

. Discussion on method

1. Regarding GoA records that were evaluated

As described above, GoA tracings that were evaluated in this study were taken in our practice for determining the maxillomandibular registration of denture construction in practice, and they were not intended for statistical study or not based on precise research protocol. Furthermore, many subjects of them had resorbed residual alveolar ridges and some of recording bite plates were troubled with problems of stability from mobility or displacement on the mucosa, and so it is necessary to understand the measurements roughly as to the line segment length and the angle data. In practical case, a practitioner needs to recognize that such records might be always accompanied with problems of bite plate displacement.

2. Regarding installation method of GoA tracing unit

In this time of GoA tracing method, following the method of Nanami's et al. ⁵⁾, an intraoral recording method was taken with the drawing board on the maxilla and the needle on the mandible. The author considers that the bite plate would not dislodge easily with pressure loading in the center of the plate even at eccentric displacement by setting the tracing needle on the mandible. And it is pointed out that GoA tracer would block physiological shape of the tongue as its tracer interferes with the anterior

portion of tongue space whether or not the needle is set up on either side of upper or lower device. ^{6,25)} We think it rather beneficial to control the tongue posteriorly to some degree in order to inhibit the anterior projection of the mandible that occurs often at the time of maxillomandibular registration of edentulous patient and to prevent the lift-up of mandibular bite plate as well.

3. Regarding GoA tracing method and position of maxillomandibular registration

GoA tracing method in this study is called the Active method. ^{18,19)} This method does not permit the operator's manipulation with fingers and hands but a patient's own positive actions. The operator's manipulation with fingers and hands as called the Passive method⁸⁾ is to record the intrinsic range of movement composed with the TMJ structure. Researches up to the present ^{18,19,26)} report that about 0.6mm~1.0mm of positional differences of the mandible condyle are measured between the Active and Passive methods. But in a study like this time where denture is constructed without using a treatment denture, the Active method is estimated most appropriate in order to determine the mandibular position which position is repeatable to produce by patient oneself. And a briefing to patient is made only about the tracing method, and a simple exercise is suggested in order to see mandibular jaw movement more naturally. An appropriate mandibular jaw position that is acceptable to a patient can be taken successfully by the guidance of clinician's verbal gestures.

Even when TP depiction is scattered within some certain range without focusing on a single point, any point on the protrusive movement path is understood to retain well balanced with both right and left sides of TMJ status as well as neuromuscular mechanism, and so they are determined as the position of maxillomandibular registration. This method is thought appropriate even from the results of denture adjustment frequency throughout all the cases in this study. So it is significant enough to trace the protrusive movement paths.

4. Regarding GoA Scores

In the beginning of this study, groupings were studied according to the shapes of GoA tracings, but the whole images were thought difficult to evaluate objectively. So the four different components of graphics were separated indicating respectively zero

point for clearly drawn trace, and 1~3 points given on the traces depending on the degree of disorder so that graphics could be evaluated as objectively as possible. As this evaluation did not include the Ap/TP distance or the spread angle of right and left lateral movement paths, it should be noted that significant difference was confirmed in the relation of these results and GoA Scores.

. Discussion on the results obtained

1. Regarding patient subjects

Among total number of 161 subjects, males belong to 35.0% (58 subjects) and females to 64.0% (103 subjects), and females are more in number than males as in 1.78 times. And mean age was 73.8 ± 9.6 years and no difference between males and females.

Although there were not mentioned in the chapter of results here, no significant difference was confirmed between age differences regarding the amount of protrusive and right-left lateral movements, the spread angle from Ap or TP, GoA Scores and denture adjustment frequency. From this fact, therefore, it is known that favorable prognosis may be predicted with any degree of certainty as far as this procedure of denture construction is concerned.

2. Regarding analysis of Ap/TP distance groups

1) Regarding amount of movement

The amount of protrusive movement showed 7.53 ± 2.27 mm in Group A, 8.02 ± 3.12 mm in Group B and 8.86 ± 2.78 mm in Group C. And as far as mean values were concerned, the more anteriorly the TP was positioned, the greater the movement amount would tend to be. No significant difference was found among each Group. As long as Ap was well defined, the amount of protrusive movement of the mandible condyle from Ap did not exhibit any greater change even though TP was positioned anteriorly. Meanwhile if the maxillomandibular registration is fixed in TP position, the amount of protrusive movement will become less than in case of that amount from Ap, and the mobile range in the forward direction will become limited within small area.

And as for the amount of lateral movement, the right lateral movement showed 6.74 ± 2.70 mm and the left lateral movement showed 6.63 ± 2.57 mm and no significant

difference was found between the right and left sides or among Groups A, B and C. And it is known that, even if the Ap/TP distance becomes larger, the lateral movement amount will not change. Likewise in case of the protrusive movement, the range of lateral movement from TP is thought to be limited to some extent.

For this reason, when TP is taken for the maxillomandibular registration as occlusal position, it is considered to increase the freedom from the posterior direction, or the freedom in the movement range from Ap to TP. But it is also considered that the movement amount from TP toward protrusive and lateral directions may be limited.

2) The spread angle of lateral movement path

The spread angle between the right and left lateral movement paths from Ap showed $113.54 \pm 7.91^\circ$ and no significant difference was found among Groups A, B and C. These values were confirmed consistent approximately with the report from Murakami et al.³⁾ When this is put together with the movement amount as described above, it shows that TMJ natural structures of individual subjects are not different basically and that functional structures of natural anatomy represent similarity regardless of Ap/TP distance.

Meanwhile, the spread angle between the right and left lateral movement paths from TP showed $124.83 \pm 15.22^\circ$ at an average rate. Group A showed $119.51 \pm 9.07^\circ$, Group B $121.83 \pm 9.16^\circ$, Group C $138.42 \pm 21.06^\circ$, and the larger the Ap/TP distance became, the spread angle showed the greater, and Group C showed significantly larger than Group A and B ($P < 0.05$), and at the same time it showed larger deviation and variance. This means that the spread angle of the lateral movement from TP is performed in the range of intermediate movement as the mandible condyle is already positioned in the forward position, and it is thought that it showed rather larger values at standard deviation as the terminal position of lateral movement is located somewhere within the path of border movement. Therefore the spread angle of lateral movement path from TP showed largely different behaviors among individuals and so the variance is thought to become larger. In clinical practice, a check bite is taken and an articulator is adjusted, and it can be confirmed that the working side lateral condylar movement (a rear wall) has produced larger values. In pursuit of more precise

denture construction, it will need to have a semiadjustable articulator coordinated with this information and to select and setup the artificial teeth based on this adjustment.

3) Regarding GoA Scores

GoA Scores showed 5.62 ± 2.69 in Groups A, B and C at an average rate when Ap and TP were discriminated. In Group D, only TP was depicted, showing 12 ± 0 points. Group A showed 4.2 ± 2.37 , Group B 6.01 ± 2.50 and Group C 7.52 ± 1.93 , and significant difference was found in GoA Scores in each Group of A, B and C. ($P < 0.05$ as for A – C and B – C, $P < 0.01$ for A – C)

This shows that GoA Score became higher as the Ap/TP distance was larger, and TP was positioned more anteriorly. In addition to this, the correlation coefficient of the Ap/TP distance and GoA Scores were found to be +0.50817 and moderately positive linear correlation was confirmed. And so, it also suggested that the higher GoA Scores became, the more possible TP was positioned in the forward direction.

When GoA Score is the higher as the Ap/TP distance is the larger, it means that the mandibular movement under the leading role of TMJ will become less smooth accordingly as TP is positioned in the forward direction from Ap, and there may be seemingly any presence of TMJ organic alteration or neuromuscular disharmony.

In the followings, items of clinical observation of GoA Score will be described.

Ap

Consolidated point of the right and left lateral movement paths and protrusive movement path are determined as Ap. And, since the Active method was adopted, the most retruded position was demonstrated available for individual patient's own neuromuscular mechanism and TMJ status, but it is not definitely the most retruded position generated by intrinsic architecture of TMJ under the guidance of the Passive method. In case the shape of Ap is not pointed and is rounded, a presence of immediate side shift or Bennett movement is known, and, generally speaking, it is owing to looseness of TMJ^{13,23)}. The non-pointed Ap is drawn at the time when both the working and balancing condyles move simultaneously at the initial stage of the lateral movement. And when the lateral and protrusive paths are not consolidated, causes

may be possible in case when neuromuscular mechanism cannot work well to express with voluntary movement, or alternatively in case when organic alteration of T J is presented as dysfunction surrounding Ap position.

Protrusive movement path

Normal protrusive movement is to be generated in balanced TMJ motion bilaterally, and their paths going back and forth should be matched clearly in straight line. In case protrusive movement paths are in plural lines, according to our observation, these paths going back and forth are not matched, or initial and terminal points of line segment are plural in number.

In case these line segments are curved, it is understood that amounts of movement of the right and left condyle are different. If any grave dysfunction is present in one of TMJ, only the other side of normal TMJ is mobile and the depicted line will be largely curved toward the side in dysfunction. This kind of curvature will become an important index to detect whether or not any disorder of unilateral side of TMJ itself is present in addition to some problem involved with lateral movement path. **(Fig.9,10)**

Cases where the line segment was short were based on the length less than 5mm after standard deviation was deducted from total mean values of measurements. Since any decreased amount of movement caused by aging is not confirmed, it is significantly important that the length of line segment should be to indicate the degree of recording disorder.

As described above so far, evaluation of the protrusive movement path will be expressed as recording disorder when any trouble is present on the movement path of uni- or bi-lateral TMJ and when any avoidance or interference are underway.

Right and left lateral movement paths

In cases where the line segment is in plural lines, like in the case of protrusive movement, it is frequent that many paths going back and forth are not matched. And, in general, cases were seen more often when paths going back return to TP, although paths going forth were initiated from Ap.

Cases where the line segment was curved were observed when paths going back were shown consolidated toward TP in mid-course of the way in spite of the forth record

showing straight linear border movement path, or alternatively when movement was inhibited by any TMJ disorder on one side contrary to the movement direction (e.g. left side TMJ disorder in case of right lateral movement). This might be considered that the mandible condyle is not able to move on the border movement path for some reason or other and only is allowed to move in the intermediate moving area.

Cases where the line segment is short were based on the length value less than 3.8mm after standard deviation was deducted from total mean values of measurements. In general, check bite is taken at about 5mm of eccentric translation amount in order to adjust the condylar inclination path of an adjustable articulator, and if the line segment is short with the minimum movement amount, correct check bite cannot be taken and so its clinical significance is grave.

4) Denture adjustment frequency

As for denture adjustment frequency, total average showed 2.38 ± 1.64 rounds, Group A 2.28 ± 1.64 rounds, Group B 2.92 ± 1.78 rounds, Group C 1.83 ± 1.12 rounds and Group D 1.41 ± 0.76 rounds. Significant difference was found in Group B in relation with Group C and D respectively. No significant difference was found among other Groups. It is known from these data that denture adjustment frequency was highest in Group B where the Ap/TP distance showed 1.0 – 1.9mm and that it was lowest in Group C where the distance was over 2mm. So far to the present, Suzuki et al. reports that denture adjustment frequency increases as the Ap/TP distance is over 0.6mm¹²⁾, and Abe reports that the mandibular positions will become unstable in the groups where the Ap/TP distance is over 2.0mm under the manipulation of the Passive method⁸⁾. It is already known that Ap is positioned rather anteriorly in case like this study of the Active method with patient's positive tracing than in case of the Passive method with patient's passive tracing with the help of an operator.^{18,19,26)}, and so not only the Ap/TP distance but also its performed method should be taken into account for studying comparisons. The results obtained, therefore, indicating increased rounds of denture adjustment frequency, when the Ap/TP distance is positioned more anteriorly to certain degrees, are thought to be compatible with their results.

In this study, furthermore, denture adjustment frequency decreased in Group C

where the Ap/TP distance was over 2.0mm and in Group D of only TP depiction without graphic evaluation available. This might mean that GoA Scores are significantly higher in these Groups and higher of degree of recording disorder, and that the mandibular position was clearly defined for necessary treatment especially in Group D. In considering this fact, it is estimated that highly repeatable masticatory terminal position has been obtained and simultaneously function of movement during mastication have been controlled. In other words, it is also estimated that, as the TP depiction is largely positioned in the protrusive direction, masticatory functions involved with TMJ have been controlled and that TP as masticatory terminal position have been limited to a smaller area.

Denture prognosis will need to be evaluated comprehensively depending on the adjustment degree, its frequency as well as its necessary duration, but the position of maxillomandibular relation will be the greatest factor of all. Suzuki et al. determines that prognosis would not be good enough for the frequency over 6 rounds and the duration over a period of one month¹²⁾. Someya states that Ta motion is one of clinical skills to determine the mandibular jaw position and that the denture prognosis will be influenced when clicking is detected in the way of the movement path of mouth opening and closing, when any eccentric deflection is present or when any hesitation or looseness in the Ta motion is present. He also states that, if occlusal relationship is to be corrected properly, open-close motion with smoothness and without looseness will be resulted within around one month²⁷⁾. After all, adjustment duration within one month would be favorably indicated.

In practical cases of Group B (1.0 – 1.9mm) of GoA Scores of 6.04 ± 2.21 , it is known from these results above to have a tendency to increase denture adjustment frequency with possible errors raised in the maxillomandibular registration.

. Regarding clinical significance

1. GoA and maxillomandibular registration

As long as Ap and TP are matched, recording of the mandibular position might be an easy procedure, but this matching of both points were seen only in 21 subjects (13.0%)

in Group A. It is compatible with the report from Mizokami et al. ²⁸⁾ stating that clinical cases of Ap and TP matching were found in about 10%. Meanwhile, even in case of only TP depiction with 12 subjects (7.4%), it is rather difficult to find proper horizontal mandibular position exceptionally in the point where TP are focused. There is no other way but to take this position as the horizontal mandibular position. Accordingly the rate of patients where mandibular positions are exactly identifiable in clinical cases would be thought 20.4% combined together with both groups, or about two out of ten cases.

Oshima et al. ³⁾ are suggesting that, when Ap is not matched with TP, the mandible condyle positions are greater in degree of horizontal deviation. Furthermore, deviations of the mandibular positions are suggested extremely high with lower consolidation rate of TP.

And also Kobayashi ²⁹⁾ demonstrates that the degree of functional disorders along the masticatory system will become advanced progressively as the degree of mandibular deviation increases. From these viewpoints, GoA Scores that evaluate GoA shapes are considered effective for objective evaluation of individual subjects' organic status of TMJ as well as the capability of neuromuscular mechanism.

If any occlusal position is deflected in practical cases for denture construction, rearrangement of artificial teeth and denture remaking will have to be needed. In this case it will be clinically necessary to study how to take or change new mandibular position by understanding graphic status and its relation with TP by the use of GoA Scores.

2. Regarding clinical diagnosis

As described above, GoA is drawn with the support of the tracing needle in the front and bilateral TMJ in the back. Its graphic is drawn as a tracing graph of the needle as a result of the simultaneous motion of bilateral TMJ. In other words, GoA is the movement of the mandible condyle drawn on a plane surface under the posterior guidance. While governed by the neuromuscular mechanism, the drawing is processed with the reflection of the protrusive movement of the lateral mandible condyle with similar amount of moving at the same time, with the reflection of the left border

movement of the left mandible condyle with smaller motion on the left side and large scale of motion on the right side, and with the reflection of the right border movement of the right mandible condyle with smaller motion on the right side and majority of motion on the left side.

Consequently if any dysfunction is present on either side of TMJ, right or left, some disorder is detected on a drawn line on the opposite direction^{25,26)} Like this from the drawn graph, it is possible to judge whether or not any trouble on either side of TMJ structures are present, and GoA Scores in this study have demonstrated the grade of abnormality objectively. And the fact that significant relationship has been confirmed with the Ap/TP distance has made us possible to grasp more precise status of jaw functions from both of these diagnosis results, and furthermore it has made us possible also to judge whether or not a certain result of TP is appropriate to take as the horizontal mandibular position.

That is to say, GoA drawing method is possible to overview the TMJ organic status and neuromuscular mechanism comprehensively through observing the mutual relationship of the whole overviews of the drawing as well as each component in it. And also it is a diagnostic method to decide whether or not the results of TP can be taken as the mandibular position for therapeutic means.

Conclusion

Quantitative and morphological evaluation were processed on the records of GoA and TP of 161 subjects collected over a period of 11 years when taken at the maxillomandibular registration for complete denture construction in practical cases. And relations of these evaluations and denture adjustment frequency were studied and discussed. As for quantitative study, amount of the protrusive and right-left lateral movement and the spread angle of lateral movement composed from Ap and TP were measured. As for morphological study, new development of GoA Score method was applied. This GoA Score method is to count scores on 4 different components grouped from GoA, and their total score was taken as scores of morphological evaluation of relevant graphics to ensure the objectivity. 4 kinds of groups were classified by the

Ap/TP distance, and these elements and denture adjustment frequency were analyzed statistically and following results were obtained.

1. Classification according to the Ap/TP distance

Group A (0 – 0.9mm) was 40.4% (65 subjects), Group B (1.0 – 1.9mm) 29.8% (48 subjects), Group C (2.0mm+) 22.4% (36 subjects) and Group D (only TP) 7.4%(12 subjects). And in Group A, matching of Ap and TP was 1 .0% of the total and 21 subjects.

2. Amount of the protrusive movement

Group A showed 7.53 ± 2.27 mm, Group B 8.02 ± 3.12 mm, Group C 8.86 ± 2.78 mm, and no significant differences were confirmed among each Goup.

3. Amount of the right and left lateral movements

The right lateral movement showed means of 6.74 ± 2.70 mm, and the left lateral movement showed means of 6.63 ± 2.57 mm, and no significant differences were confirmed between the right and left sides, or among G oups A, B and C.

4. The spread angle of the right and left lateral movement paths from Ap

The average values showed 113.54 ± 7.917 ° and no significant differences were confirmed among Groups A, B and C.

5. The spread angle of the right and left lateral movement paths from TP

The average values showed 124.83 ± 15.22 ° and Group A showed 119.51 ± 9.07 ° , Group B 121.83 ± 9.16 ° , and Group C 138.42 ± 21.06 ° . The greater the Ap/TP distance became, the larger the spread angle became, and Group C showed significant difference in comparison with Groups A and B. ($P < 0.05$)

6. GoA Score

Group A showed 4.2 ± 2.37 , Group B 6.01 ± 2.50 , and Group C 7.52 ± 1.93 , and

significant differences of GoA Scores were confirmed among Group A, B and C. ($P < 0.05$ between A – B, and B – C, $P < 0.01$ between A – C)

7. Denture adjustment frequency

Total average showed 2.38 ± 1.64 rounds, Group A 2.28 ± 1.64 rounds, Group B 2.92 ± 1.78 rounds, Group C 1.83 ± 1.12 rounds and Group D 1.41 ± 0.76 rounds. Significant difference was found in Group B in relation with Group C and with Group D. ($P < 0.05$) No significant difference was found among other Groups.

As mentioned above, it is suggested from the statistic analysis results of GoA drawing method under the Active method that no alterations have been made for the movement distance from Ap or the spread angle of later movement nor any difference from the border movement function of TMJ itself, even when the Ap/TP distance becomes larger. But from TP, it is suggested that the movement path is taken on the intermediate movement path and that the spread angle as well as the deviation are grown larger significantly. And the larger the Ap/TP distance becomes, the higher the GoA Score becomes significantly. So the more anteriorly TP is positioned, the more often the recording disorders are raised, and the more the function is inhibited. On the other hand, as for denture adjustment frequency, in the group of the Ap/TP distance with 1.0 – 1.9mm, the frequency increases significantly but in small difference from the total average. It is therefore clarified that adopting proper TP by the use of the proposed method as the mandibular position for complete denture construction would be the means of minimum errors. Accordingly in order to diagnose TP appropriately as for the position of maxillomandibular registration, procedures of GoA drawing method (under the Active method) combined with the use of Ta method would be thought extremely significant from clinical practice.

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