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A STUDY ON THE EFFECTS OF CHEWING PATTERNS TO OCCLUSAL CONTACT POINTS AND CHEWING EFFICIENCY

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Ⅰ. Introduction

Chewing movements performed with cooperative interactions among stomatognathic system, proprioceptors, and higher brain centers were closely related to a functional occlusion system. There was a number of sutdies that had showed the relationship of chewing patterns and occlusal factors, According to the report of D'Amico, the chewing paths of herbivorous animals clearly differed from those of carnivorous animals(1). As herbivorous animals had degenerated canines and extremely worn posterior teeth, they could easily perform lateral movement. Their chewing paths had almost gorizontal tooth sliding surfaces near centric occlusion and therefore they were suitable for eating grasses, plants, etc. In the case of carnivorous animals, chewing paths were vertical and horizontally very narrow due to sharp canine & posterior teeth. It seemed that the difference between the two types of animal was common to the two typical patterns observed in human beings. Many researchers had made various classifications, but actual chewing paths were complicated and varied(3). However, desipite of the presence of various patterns, two typical patterns had been confirmed. One was more vertical similar to the chopping movement. It had very little sliding of the teeth especially during the opening movement, showing the path only on the chewing side. The other was more lateral(horizontal) type, similar to the grinding movement, with a distinct sliding of the teeth, especially to the non-chewing side during opening movement.

Some of the records during chewing function demonstrated that lateral movements were present in the final phase of natural function(2. 29). Schweitzer found that these movements depended on the nerves and ligaments, the degree of incisal overlap, the cusp height of the posterior teeth, and to some extent the musculature(4).

Many studies had been carried out on the assessment of the masticatory function. Most of these studies measured the chewing ability to break down the test material into a number of grouping. Then, masticatory efficiency was calculated from the broken material. These investigations had been based upon the use of one or more sieves for fractionating the test portion. Chewing efficiency was to be understood as the ability to grind a certain portion of a test food into pieces during a given time. It was affected by many factors ; number of occluding pairs of teeth, number of occluding tooth contacts, number of teeth, number of strokes, chewing time, deformities of the jaw(5, 6, 7, 8). Graber, Astrand discussed the effects of malocclusion on mastication(10, 11). According to their studies, inability to chew properly was associated with maloccusion. Schultz, Helkimo & Carlsson studied the reduced chewing efficiency in edentulous persons with dentures(4, 12).

There was few informations on the effects that relatively minor variations in the natural dentition had on masticatory efficiency. The purpose of this study was to examine relationship between chewing patterns and occlusal factors. A second goal of the study was to investigate the effect of those on the chewig efficiency.

II. Materials and Method

A. Materials

For preliminary purposes, 90 dental students were instructed to chew peanuts at arbitrary rhythms on preferable unilateral side of the mouth. A Saphon-visitrainer Model 3*(Tokyo Shizaisha Co. Tokyo, Japan) was used to record those movements for 20 seconds from five seconds after the atart of chewing(Fig. 1, 2)(37, 38). Reference plane, which was a line between tragus and ala of nose was marked on the skin. LED(Light Emitting Diode) was positioned in the midline of the face, so as to be in parallel to the reference plane. The distance between LED and SPD(Silicone Photo Diode) was fixed at 10cm. The preliminary study showed two typical chewing patterns. One type was a group of having grinding movement path like an herbivorous animal from centric occlusion to the opposite side, corresponding to the final phase of chewing cycle described by Nakazawa(13). This grinding type hereinafter was called G-type(Fig. 3). The other type showed a chopping movement path(like a carnivorous animal) with no slide to the opposite side. This chopping type hereinafter was called C-type(Fig. 4). Of these 90people, 20 people with no temporomandibular disorder and with normal occlusion were selected for this study. Ten had C-type chewing patterns(age 23±2yrs, 8 male and 2 female). Other ten showed G-type patterns(age 23±2yrs, 9 male. 1 fermale).

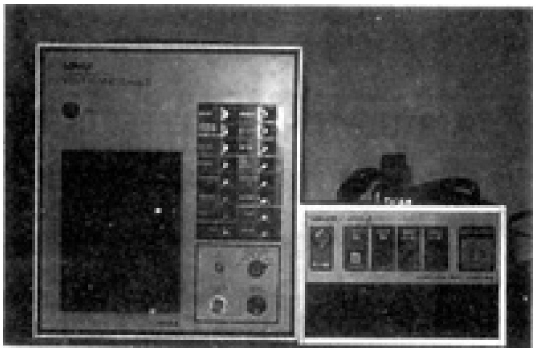


Fig. 1. Saphon Visi-trainer model 3.

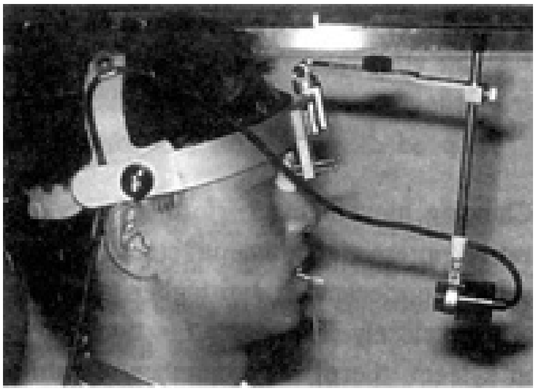


Fig. 2. Attached LED(Light Emitting Diode) and SPD(Silicone Photo Diode).

B. Method

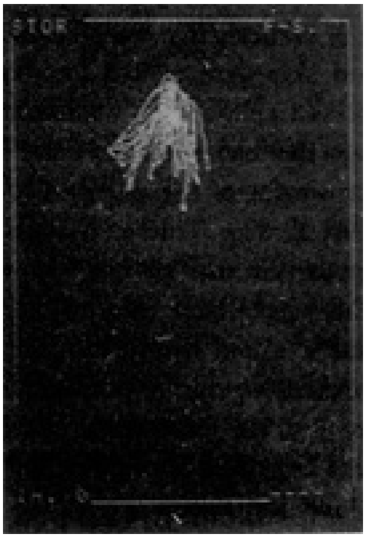


Fig. 3. Grinding type at frontal view(Right side chewing).

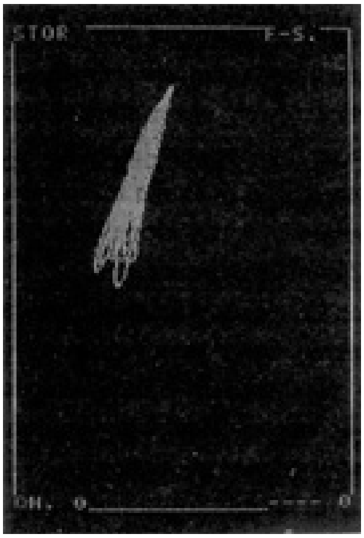


Fig. 4. Chopping type at frontal view(Right side chewing).

(1) occlusal contact point

Occlusal registrations were done in three mandibular positions ; centric occlusion and right, left lateral positions. These positions were registered with polyether rubber bite registration material, Ramited*(ESPE, German) in each subject(35, 36). The Ramitec was mixed and injected onto the occlusal surfaces of the upper dentition with a syringe. The orerator manipulated the mandible to register centric occlusion. To register lateral positions, the lower incisal midline have been moved to horizontal distance of 2㎜ laterally. The operator held each subject' s mandible at this position until the registration material set.

The areas, where the perforations were made through the bite registration materials at each mandibular positions, were regarded as contact areas. Depending upon the contact area, a value of one point was given to those perforations less than 1㎜in diameter, two points to each linear contact area or those 1-2㎜ in diameter, and three points to those areas more than 2㎜in diameter(13). For compareas more than 2㎜in diameter(13). For comparision, the points were added to calculate contact scores for the mandibular first and second premolars and molars on both sides, a total of eight teeth(Fig. 5, 6).

(2) Masticatory Efficiency

The chewing efficiency of the subjects was tested with a method using peanuts and a internationally-accepted standard sieve system with filter paper(Fig. 7)(14). All peanuts were dried under 65℃ in an oven for 3hours. The mean weight of the peanuts used was 3±0.1g. The filter paper and the selected peanuts could be weighed to the nearest 0.001g scale. Each subject was asked to chew an peanuts for 20 masticatory strokes. The chewed test portions were expectorated into a plastic cup and the subjects rinsed their mouth three times with water and spit the remains into a plastic cup again. The chewed samples were washed through a stack of 5 sieves of 4.0, 2.0, 0.85, 0.60, 0.425㎜ aperture. While the particles were being washed through the sieves, the sieves were agitated by a dental vibrator set at half-speed

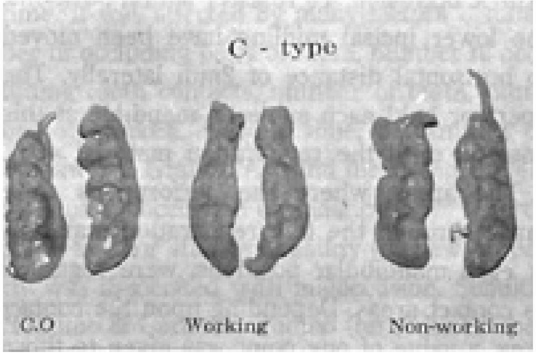


Fig. 5. Examples of Chopping type bite registration

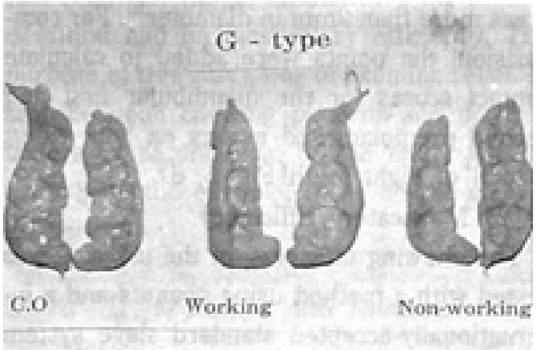


Fig. 6. Examples of Grinding type biteregistration

Fig. 7. Sieve system used in this study

for 2min. Each sieve was then washed individually with a bottle of water. The particles that were in size between two successive sieves that form an upper and lower boundary was collected and called a size fraction. The size fraction of particles was dried in oven set at 65℃ for 3hours and then weighed as before. Cumulative frequency curves were drawn to display the size distributions in which the percentage of the total weight of particles that were below a particular sieve size were plotted for the range of sieve sizes employed(15). It was estimated from the graph the theoretical sieve size that allows 50% by weigth of the particles to pass and used this median value as a measure of the average particle size(16). It had been shown that a median particle size(M_{50}) calculated in this way was a useful measure of the extent of food breakdown during mastication.

Moreover, the masticatory efficiency value(r) was calculated to the method described by Edlund and Lamm(17).

The formula used was $R = 100(1 - \frac{X+Y}{2T-X})$

In order to use this method, the sum of the weight in grams of the chewed material accumulated on the sieve with apertures of 2.0, 0.85, 0.60㎜ was combined and was referred to as the coarsest fraction(X). The sum of the weight in grams of the chewed material accumulated on the sieve with the aperture of 0.425㎜ was referred to as the medium fraction(Y). T was total weight in grams of test portion sfter mastication.

The differnces in contact scores and in R and M_{50} were tested with Student' s t-test to account for unequal variances.

III. Results

(1) Occlusal contact points

Means and standard deviations of contact scores were calculated for each group at each area in the three mandibular positions. These figures were used to compare the difference of occlusal contacts in the posterior teeth between the G-type and C-type subjects.

1. Contact scores in centric occlusion(Table 1)
   The C-type group showed wider occlusal contact areas in #45, 47 than the G-type group(P<0.01).
2. Contact scores on the working side(Table 2)
   The G-type group showed a larger score with wider contact areas on #46, 45. This tendency was more obvious on the right side(P<0.01).
3. Contact scores on the nonworking side(Table 3)
   The G-type group showed wider contact areas than C-type group. There was a tendency that the contact area increased toward the more posterior teeth(P<0.05).

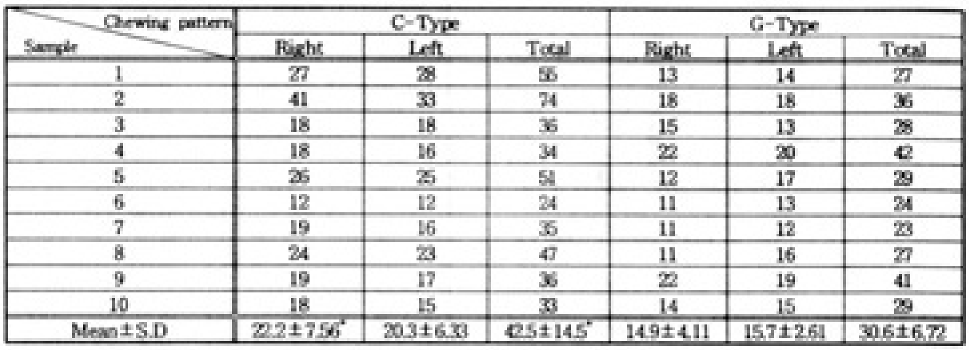
Contact scores in the entire posterior region were shown in Fig. 8.

The C-Type group showed wider contact areas in centric occlusion, while the G-type group exhibited wider contact ranges on the working and nonworking sides.

(2) Chewing efficiency

Means of particle size distributions obtained from C-type group & G-type groups were shown in Table 4, Fig. 9, 10. A characteristic pattern was observed on the cumulative-freguency curves and

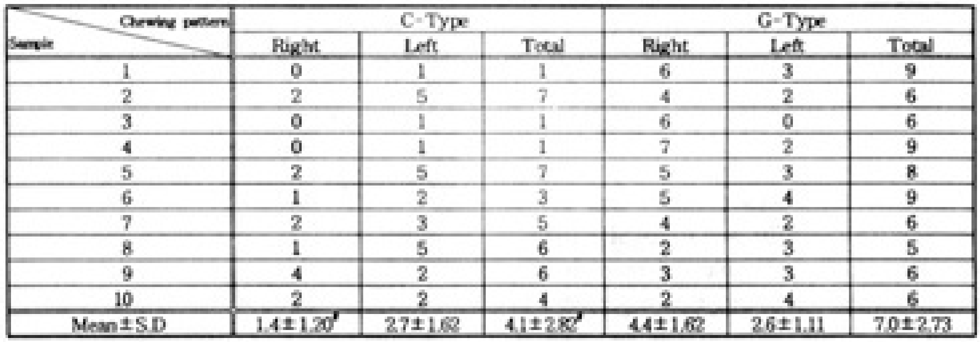
Table 1. Contact scores at C.O



Chewing pattern / Sample	C-Type			G-Type		
	Right	Left	Total	Right	Left	Total
1	27	28	55	13	14	27
2	41	33	74	18	18	36
3	18	18	36	15	13	28
4	18	16	34	22	20	42
5	26	25	51	12	17	29
6	12	12	24	11	13	24
7	19	16	35	11	12	23
8	24	23	47	11	16	27
9	19	17	36	22	19	41
10	18	15	33	14	15	29
Mean±S.D	22.2±7.56*	20.3±6.33	42.5±14.5*	14.9±4.11	15.7±2.61	30.6±6.72

* : $p < 0.05$, $^{\#}$: $p < 0.01$

Table 2. Contact Scores at Working



Chewing pattern / Sample	C-Type			G-Type		
	Right	Left	Total	Right	Left	Total
1	0	1	1	6	3	9
2	2	5	7	4	2	6
3	0	1	1	6	0	6
4	0	1	1	7	2	9
5	2	5	7	5	3	8
6	1	2	3	5	4	9
7	2	3	5	4	2	6
8	1	5	6	2	3	5
9	4	2	6	3	3	6
10	2	2	4	2	4	6
Mean±S.D	1.4±1.20$^{\#}$	2.7±1.62	4.1±2.82$^{\#}$	4.4±1.62	2.6±1.11	7.0±2.73

* : $p < 0.05$, $^{\#}$: $p < 0.01$

Table 3. Contact scores at Non-working

Chewing pattern / Sample	C-Type			G-Type		
	Right	Left	Total	Right	Left	Total
1	0	1	1	4	1	5
2	0	0	0	3	4	7
3	1	1	2	3	5	8
4	1	1	2	3	4	7
5	1	0	1	3	5	8
6	0	1	1	4	1	5
7	0	1	1	2	4	6
8	2	2	4	2	3	5
9	0	0	0	2	4	6
10	2	1	3	3	5	8
Mean±S.D	0.7±0.79$^{\#}$	0.8±0.66$^{\#}$	1.5±1.38$^{\#}$	2.9±0.70	3.6±1.43	6.5±2.13

* : $p < 0.05$, $^{\#}$: $p < 0.01$

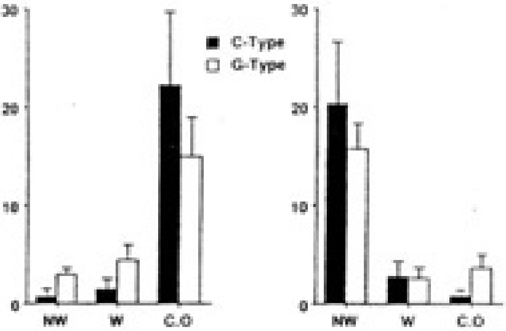


Fig. 8. Contact Scores in the Entire Posterior Region

it tended to show a sigmoid shape. The cumulative freguency curve of C-type group showed a shift towards smaller particle sizes.

Mean of M_{50} obtained from C-type group was 0.557(SD=o.070), and 0.669(SD=0.008) from G-type. Considerable difference in the median particle sizes, M_{50} were observed between two groups with t-test of two sample assuming unequal variances(P<0.01). Moreover, mean of R in C-type group was 82.77.(SD=18.2), 76.99(SD=17.3) in G-type group. Statistically significant differences in masticatory efficiency value(R) were revealed after 20 chews(P<0.05). It was summarized in Table 5.

Table 4. Chewing Efficiency(Median particle size, M_{50})

Chewing pattern / Sample	C-Type	G-Type
1	0.59	0.74
2	0.36	0.65
3	0.60	0.56
4	0.56	0.77
5	0.57	0.70
6	0.70	0.82
7	0.62	0.70
8	0.56	0.69
9	0.48	0.59
10	0.54	0.77
Mean±S.D	0.56±0.09$^{\#}$	0.69±0.08

* : $p < 0.05$, $^{\#}$: $p < 0.01$

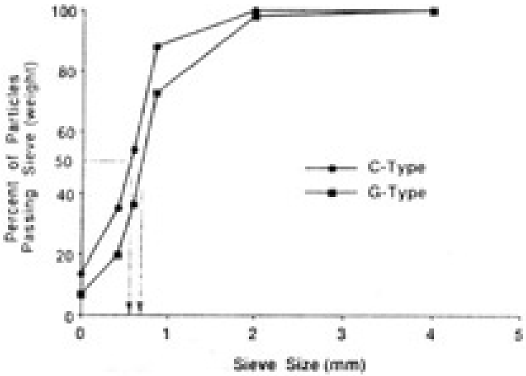


Fig. 9. Cumulative Frequency Curve

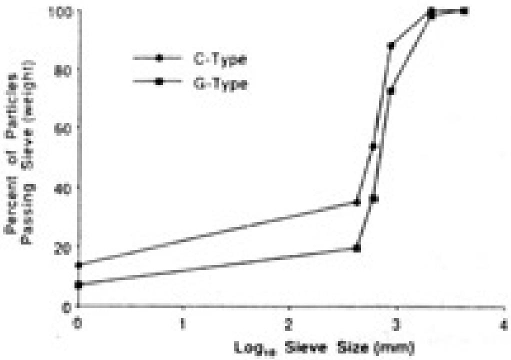
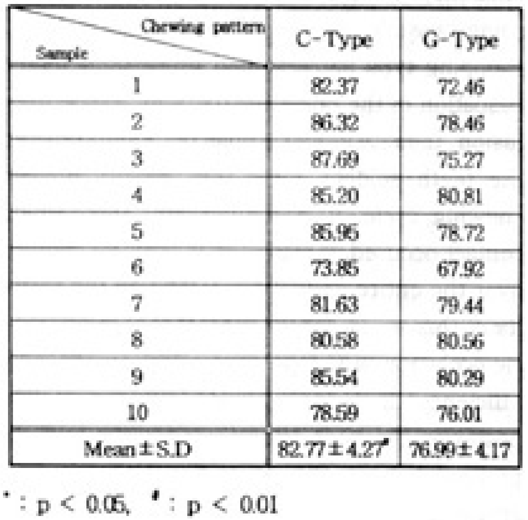


Fig. 10. Log10 Cumulative Frequency Curve

Table 5. Chewing Efficiency(Masticatory efficiency Value, R)



Chewing pattern / Sample	C-Type	G-Type
1	82.37	72.46
2	86.32	78.46
3	87.69	75.27
4	85.20	80.81
5	85.96	78.72
6	73.85	67.92
7	81.63	79.44
8	80.58	80.56
9	85.54	80.29
10	78.59	76.01
Mean ± S.D	$82.77 \pm 4.27^{\#}$	76.99 ± 4.17

* : $p < 0.05$, # : $p < 0.01$

Ⅳ. Discussion

Actual chewing paths were complicated and vary from imdividual to individual. Therefore, it seemed that a detailed classification would complicate the problem. But, two typical patterns were confirmed by other researches(13). One was more vertical type, the other was a more lateral type. Not all subjects belong to these types ; A lot of subjects showed intermediate chewing paths that fall into neither of the two types. Great diversity in chewing patterns was observed, but in general, individual subject exhibited specific and repetitive patterns(8, 18, 23). It was also reported that differnces in the pattern of masticatory muscle activities were observed between two groups of subjects with different chewing patterns(18).

Many researchers stated that those with a steep cuspal inclination showed more vertical type of chewing movement, while those with gentle cuspal inclination showed more lateral type of chewing movements(2, 19). A patient whose chewing movement showed vertical type had occlusion so locked by interfering cusps that he could only chop straight up and down. It was definitely confirmed that it was not the food but the degree of cuspal coordi nation which determined the shearing stroke of the mandible. The character of the food influenced only the character of the food influenced only the forcefulness and perhaps the length of the shearing stroke(20).

Nishio stated that many facets were observed on the inner inclines of functional cusps(13). It was characteristic of the G-type group. In relation to the presence of facets, G-type group exhibited group function type occlusion. In contrast, C-type group showed a pattern of cuspid-protected occlusion(13). In this study. Operator manipulated and held the mandible of subjects, it was thought that contact point was a little different from when there was food bolus between upper and lower teeth. But, when the manipulation was repeated 2-3 times, subjects showed almost constant contact points. So it could be regarded as valuable index.

There were a lot of materials used in the measurement of occlusal contact points. Many studies about occlusal contact points with various materials showed diverse results. Ingervall found a high incidence of full-balanced occlusion with irreversible hydrocolloid indi cators in 3㎜lateral positions(39). It was found that articulating paper. Ehrlich reported variabilities in occlusal contact patterns in lateral movements when a dental mirror and articulating paper were used(40). Technologic advances had encouraged the development of photoelastic instrumentation and electronic sensors for measurement of occlusal contact. Photoelastic and electronic sensors were innovative but were dependent on thick sensors that inhibit dental proprioception. Many studies about reliability of these methods were disappointing(41). Ttakai et al. Compared three occlusal examination methods ; occlusal registrations with a full-mouth articulating paper, a partial articulating paper, a black silicon(42). They reported black silicone recorded more near contacts than articulating paper methods.

Centric occlusion was the intermaxillary tooth relationship most often used during the last stages of chewing. In this study, most subjects who were young dental students with normal occlusion and an absecnce of symptoms of functional disturbances of the masticatory system, had symmetric occlusal contact($P<0.05$). This was opposed by the finding that the asymmetric distribution of contacts in the centric occlusion(21, 22, 23). Riise investigated the number of occlusal tooth contacts in the in adults(23). There were much more contacts It was supposed that the subjects bite the food with hard pressures, which might have been a possible source of differences in the results. There was high frequency of contact on the first molar in this investigation. This explained the importance of the first molar in chewing. Besides, the first molar provided 36.7% of the total effective masticatory area in the complete dentitions, the second molar 28%, third molar 15%, the second premolar 8%, the first premolar 8% of the total area(24).

Chewing efficiency was directly related with potential contact area in a study of complete denture wearer. Reduction in the size of the potential contact areas of artificial posterior teeth caused a loss in chewing effectiveness varied directly, not proportionally(25). In this study, chopping type group had more chwing efficiency than grinding type. There weresome possible source of these results. First, chopping type subjects had more tight inter cuspation of the posterior teeth in centric occlusion than grinding subjects. Even though the teeth seldon com inrto contact during chewing cycle, it was suggested that, when contact occured, it was centric occlusal contrct over the entire arch(30, 32, 33, 34). Based on the results of this study, larger contact scores in centric occlusion of C-type gave effect on chewing efficiency. In C-type group, canine rose the posterior teeth at lateral movement and so protected them. Otherwis G-type group had group function occlusal scheme, not only canine but also molar teeth joined in lateral movement during chewing cycle. The subjects who showed group function occlusion, had the smalll contact areas in centric occlusion, there fore it was expected that the crushing of food bolus was mainly caused by sliding of mandible.

Vertical masticatory cycles, which were differ from horizontal, lateral, and protrusive rubbing movements, were considerecd the functional movements during chewing. It wsa compatible with the finding of yurkstsa ; The first few chewing strokes involved in the brea kdown of food were always in a vertical direction(24).

Chopping type subjects had the posterior teeth with steep cuspal inclinations. It seemed that the pattern of chewing food by points in centric occlusion, which was a terminal position, was a more efficient and rational chewing pattern suited for the occlusal status. Finally, the posterior teeth of chopping type subjects had canine guidance occlusion. So posterior teeth had much less wear, therefore the ability to chew(crushability) improved than the grinding type.

There were many indices to evaluate chewing efficiency ; masticatory performance, mastion using particle coefficient and sieve aperture factors, median particle size, masticatory efficiency value. Masticatory performance and masticatory index were measured with so coarse sieve size ; 10, 20 mesh etc. Median particle size(M_{50}) used in this study, was accurate index to evaluate chewing efficiency, because good reproducibility was obtained for all test food whenever the median particle size(M_{50}) had dropped to about 70% of its starting value. This reduction in the median particle size was acheived after chewing at least 5 time on peanuts(27, 28).

In this study, the higher the contact scores in C.O, the better chewing efficiency was found, But, contact scores in lateral movements were not related with the chewing efficiency. So, the crushing of food was found to be affected by the contact amount in centric occlusion. In procedure of prosthetic restoration, ti was thought that contact points in C.O and contact amounts than the patterns of the lateral movement had greater influence on the chewing efficiency.

It was reported that similar results was obtained in masticatory performance test in regardless of the difference of the test food(25). A natural test food had the advantage that it is normally consumed, and subjects are accustomed to it. The self-correlation coefficient between chewing performance test with peanuts(0.92) was higher than that for carrots(0.84) which indicated that the test with peaunt was more duplicable, presumably because of the greater uniformity in size and texture which was obviously characteristic of peanuts(26). However, the consistency of peanuts might vary due to seasonal and geographical influences. To avoid these variations in consistency, if the artificial test food for example, Optosil, Optocal had been used, more reproducible results could have been obtained(27). In this study, it was suggested that chewing patterns were related to occlusion and chewing efficiency. It is expected that much more researches will be done on the relations between other variations of occlusal factors and chewign efficiency.

V. Conclusion

The subjects with normal occlusion were divided into two groups by analyzing with Saphon visitrainer. Based on the patterns of mandibular movements, chopping type group(C-type) and grinding type group(G-type) were divided. Each group had 10 subjects. The occlusal contact points in centric occlusion and at lateral position were measured with elastic bite registration material and analyzed. Chewing efficiency was tested and compared by using sieving procedure and by median particle size and masticatory efficiency score.

1. The chopping type showed wider occlusal contact areas in centric occlusion than grinding type group subjects, especially right side(P<0.01).
2. The grinding group had a larger contact score

on both lateral position than chopping type, especially right side($P<0.01$).

3. The chopping type group had more the wing efficiency than grinding type in terms of median particle size(M_{50}) and masticatory efficiency value(R)($P<0.05$).

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〈국문초록〉

저작 형태가 교합 접촉및 저작 능률에 미치는 영향에 관한 연구

서울대학교 치과대학 치과보철학 전공

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저작은 교합과 악운동 뿐만 아리라 근신경계, 고위 중추까지 복합적으로 관여하는 기능적 행위이다. 교합 양상은 다양하게 저작 형태에 영향을 끼치며 저작 효율에도 관여한다. 저작 형태는 다양한 모양을 가지나 두가지 전형적인 군 즉, 전방에서 관찰시 그 양상이 수직적이며 chopping운동을 닮은 군과 저작 형태가 주로 측방으로 이루어지며 grinding을 하는 군으로 나눌 수 있다. 본 연구의 목적은 저작 형태의 치아가 교합접촉 및 저작 효율에 미치는 영향을 고찰해 보고자 하는 것이다.

하악운동궤적기록기를 이용하여 정상교합을 가진 치과대학생중 전형적인 2가지 저작형태를 보이는 각 10명씩을 피검자로 선택하였다. 3가지 하악위 즉, 중심위, 작업측 비작업측에서의 교합접촉을 고무형 교합인기재로 기록하여 천공부의 직경이 1㎜이하면 1점, 1-2㎜또는 직선상이면 2점, 2㎜이상이면 3점으로 평가하여 각 점수의 합으로 좌우 소구치 및 대구치의 접촉 지수를 측정하였다. 저작 효율을 평가하기 위해 땅콩 3g(±0.01g)을 20회 저작하게 한 후 3회 입을 헹구어 뱉게 하였다. 체눈 크기가 각 0.425, 0.60, 0.85, 2.0, 4.0인 체에 거른 후 65℃로 오븐에서 세시간 말려 무게를 측정하고 중심 크기(M_{50})과 저작효율치(R)를 계산 비교하여 다음과 같은 결론을 얻었다.

1. Chopping형은 grinding형에 비해 중심위에서 더 넓은 교합접촉을 보였다(P〈0.01).
2. Grinding형은 chopping형에 비해 측방위에서 더 넓은 교합접촉을 보였다(P〈0.01).
3. Chopping형은 중심크기(M_{50})과 저작효율치(R)로 비교하였을 때 더 좋은 저작 효율을 보였다(P〈0.01).

주요어 : 저작 형태, 교합 접촉, 저작 효율, 교합 지수