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김 경 화

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치간 접촉이란 동일 악궁에서 인접 치아와 연결 또는 접촉되는 치아의 한 부분으로 적절한 치간 접촉은 악궁의 연속성 유지 및 안정에 기여한다. 그러나 과도한 치간 접촉은 바람직하지 않은 치아이동 및 치주조직의 외상을 일으키고 반대로 약한 치간 접촉은 치아우식 및 치주질환 등을 야기할 수 있다. 따라서 적절한 치간 접촉을 유지하는 것이 중요하나 그 접촉 강도를 정량적으로 평가한 논문은 많지 않다. 본 논문에서는 새로 개발한 장치를 이용하여 영구 치열에서 전 치간부의 접촉 강도를 측정하였다. 이 장치는 치간부에 삽입된 얇은 금속판을 전기모터를 이용하여 일정한 속도로 제거하고, 그 때 발생하는 마찰력을 측정하여 치간 접촉 강도를 평가하는 장치이다. 성인 10명(남 : 5명, 여 : 5명, 나이 : 25-29세)을 피험자로 선정한 후 각 치간부의 접촉강도를 5회 측정하였으며 이 중 최대값과 최소값을 제외한 나머지 값의 평균값을 그 치간부의 대푯값으로 결정하였다. One-way ANOVA test와 independent samples T-test를 이용하여 각 측정값을 비교하였다. 그 결과 같은 악궁에서는 전치부에서 구치부로 갈수록 접촉강도가 증가하는 양상을 보였으며, 1/4악당 나누어 전치부와 구치부의 평균 치간 접촉 강도를 비교 한 결과 4부위 모두에서 통계적으로 유의한 차이를 보였다. 상하악간에는 대체로 하악에서 더 높은 치간 접촉 강도를 보였으나 어느 부위에서도 통계적으로 유의한 차이를 보이지 않았다. 또한 남녀 간에 비교 한 결과 남성이 여성보다 더 높은 치간 접촉 강도를 보였으나 상악 우측 제1소구치와 제2소구치간 접촉부 및 하악 좌우측 제 1대구치와 제 2대구치간 접촉부를 제외하고는 유의한 차이를 보이지 않았다.

Ⅰ. *INTRODUCTION*

Under physiological conditions, teeth are stabilized in the dental arch by making occlusal contacts with opposing teeth and proximal contacts with adjacent teeth[1]. Proximal contact has been defined as the area of a tooth that is in close association, connection or touch with an adjacent tooth in the same arch[2]. The proper proximal contact plays an important role in the stability and maintenance of the integrity of the dental arches[3]. However, a weak or slightly open proximal tooth contact would permit food impaction and cause subsequent dental caries, halitosis, periodontal disease, or drifting of teeth. On the other hand, excessive proximal tooth contact would results in wedging of teeth and undesirable tooth movement and trauma of periodontium[4-9]. Therefore, it is important to maintain proper proximal tooth contact.

Alexander D et al.[10] reported that the proximal contact is maintained by the next two conflictive theories. : The first theory, compression theory, is that the compression force occurs proximal surface between adjacent teeth and keeps an active proximal contact. The second theory, resistance theory, is that teeth touch each other passively in a non-force mode, but resisting any force which tries to separate them.

Tightness of proximal tooth contact(TPTC) is conventionally checked with dental floss[11,12]. It is considered that such a contact allow floss to pass with a snap[13]. Although this method is simple and easy, it is inaccurate to record slight change of TPTC[14]. If the assessment is performed using a thin metal strip, more reliable information about the contact state may be acquired[15,16].

Osborn[17] was the first who constructed a device based on the theory of frictional force to quantify the TPTC by inserting a thin metal strip interdentally which is pulled out with a spring balance in horizontal direction. When a strip is slipped between two adjacent teeth, each tooth is displaced and exerts a force against the strip. The maximum frictional force(F_f) that resists withdrawal is a value for the TPTC. With a known coefficient of dynamic friction(μ) between tooth enamel and metal strip material, TPTC is related to F_f by the following equation: Contact tightness = $F_f/2\mu(N)$. Modifications of this device were described in several other studies. Southard et al.[18] used a digital tension transducer to measure the frictional force occurred at pulling metal strip of 0.038mm-thickness, whereas Oh et al[19] constructed a device equipped with a digital strain gauge designed to convert the frictional force into compressive force using a hinge. Dörfer et al.[20] developed a device which the metal strip of 0.05mm-thickness was fixed in a special holder, which was prepared with strain gauges to register the bending action of the holder during removal of the strip. TPTC was measured by device as stated above quantitatively, nevertheless, the data are not enough yet.

The objectives of this study was to measure the TPTC of all proximal contact using a novel device in permanent dentition.

Ⅱ. *MATERIALS AND METHODS*

A. Subjects

Ten healthy young adults(5 males and 5 females) with class I normal occlusion consented to participate in the study. The mean age of the subjects was 26.1 years (range : 25-29 years), and informed consent was obtained from all participants. All subjects had complete dentitions from the second molars forward and the third molar did not visually existed. None of the subjects had received prosthodontic or conservative treatment of the proximal surface and orthodontic treatment during the past year. No signs or symptoms of food impaction or temporomandibular disorders were present in any of the subjects. None of the subjects had periodontal disease. At rest, contact tightness was considered appropriate if a 0.05mm stainless steel strip (Contact gauge : GC Co., Tokyo, Japan.) could be inserted with some resistance, but a 0.11mm strip could not[21].

B. Measuring device

The measuring device used for recording TPTC has been described previously[22]. Briefly, the measuring device(Figs. 1,2) is consisted of sensor part, motor part, body part and measuring part.

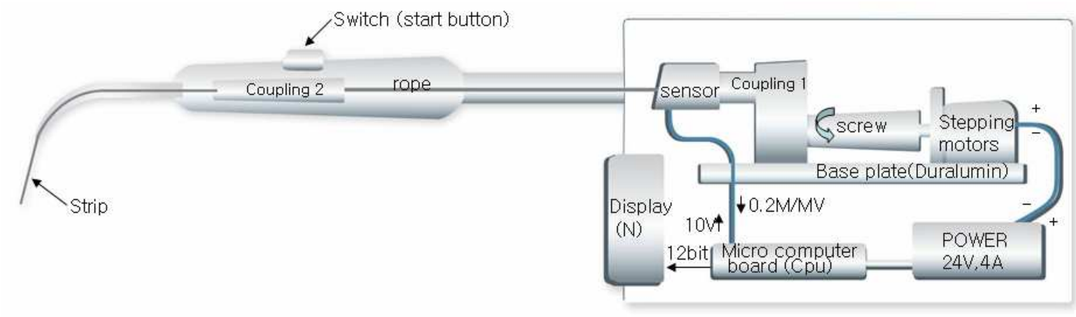


Fig. 1. Diagram of measuring system.

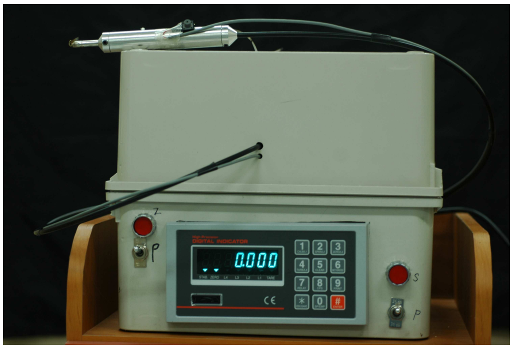


Fig. 2. Measuring device.

Sensor part operates amplifying and filtering of the output voltage that occurred from strain gauge sensor. The output voltage of the sensor is converted into newton(N) and it could measure up to 98N. The motor part is the stepping motor. Each parts of this device are fixed to the body part that consists duralumin alloy. For the structure of the measuring part, the outer pipe(handle) and inner part was manufactured by processing duralumin pipe. On the inner pipe, steel wire from the body part and metal strip(2mm width, 0.03mm thickness) which was inserted to the proximal surface was fixed by the screw(Fig. 3).

Fig. 3. Measuring part of the device.

Right after pushing the starting button, the metal strip was pulled by constant speed of 8mm/s. The measuring part was equipped automatic reverting limit switch(LS) for convenience and 90 degrees curvature of the measuring part tip was manufactured for the approach to the posterior teeth.

C. Measurement of TPTC

Due to unfavorable approach of the posterior teeth in an upright posture, experiment was operated in a supine posture. Each subject was seated in a dental chair in an supine posture with head support and all muscles of the subjects were relaxed and maintained rest state. After turning on the device, zero degree was controlled. Before each test, the proximal contact areas were dried with an air syringe and the metal strip was inserted to proximal surface(Fig. 4).

Fig. 4. Measurement of the tightness of proximal tooth contact between the left second premolar and first molar in mandible.

As pushing the starting button, the metal strip was removed by constant speed. The highest value of the frictional force which was occurred during removal was considered the TPTC. This trial was repeated five times at same proximal contact area. Among these values, the highest and the lowest values were excluded, then the mean value of the other three measured values was determined as the representative value in each contact area. Measurement was operated at rest state and the subjects were restricted not to be occlusion during measurement. Between each measurement, there was more than 2 minutes of rest intervals[23]. All experiments were conducted around 4 PM, allowing sufficient rest time after the lunchtime meal.

D. Statistical analysis

The statistical evaluation of the data was performed using the software package SPSS version 12.1(SPSS Inc., Chicago, USA). One-way ANOVA test was used to compare the values in all measuring area. When a statically significant difference was calculated, Bonferroni correction was applied. Independent samples t-test was used to compare the TPTC between male and female subjects, and between anterior teeth(from mesial contact area of central incisor to mesial contact area of canine) and posterior teeth(from distal contact area of canine to distal contact area of first molar). A value of $p<.05$ was considered as statistically significant.

Ⅲ. *RESULTS*

The lowest TPTC and the highest TPTC was measured between the central incisiors(0.88±0.37N), and between the right second premolar and first molar(1.94±0.76N) in maxilla(Table 1), respectively. Also, the lowest TPTC and the highest TPTC was measured between the central incisiors(0.43±0.20N), and between the lower left first molar and second molar(1.99±0.68N) in mandible(Table 2).

(Unit : N)

Contact area	Mean	SD
#17-16	1.73	±0.62
#16-15	1.94	±0.76
#15-14	1.53	±0.40
#14-13	1.28	±0.49
#13-12	1.12	±0.47
#12-11	0.94	±0.41
#11-21	0.88	±0.37
#21-22	1.01	±0.48
#22-23	1.09	±0.41
#23-24	1.36	±0.49
#24-25	1.49	±0.75
#25-26	1.73	±0.71
#26-27	1.65	±0.53

Table 1. Proximal contact tightness in maxilla.

(Unit : N)

Contact area	Mean	SD
#47-46	1.83	±0.52
#46-45	1.93	±0.64
#45-44	1.60	±0.43
#44-43	1.38	±0.48
#43-42	1.04	±0.40
#42-41	0.91	±0.28
#41-31	0.43	±0.20
#31-32	0.89	±0.20
#32-33	0.92	±0.18
#33-34	1.18	±0.42
#34-35	1.43	±0.45
#35-36	1.85	±0.63
#36-37	1.99	±0.68

Table 2. Proximal contact tightness in mandible.

All TPTC per quadrant demonstrated a similar pattern of a continuous increased gradient in a anterior-posterior direction(Fig. 5).

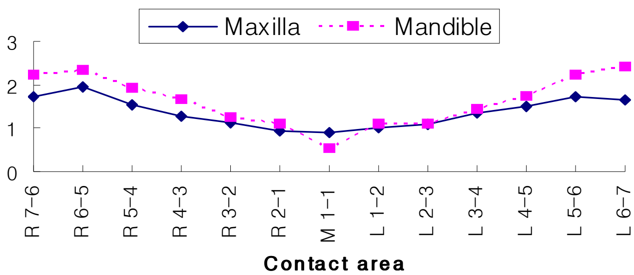
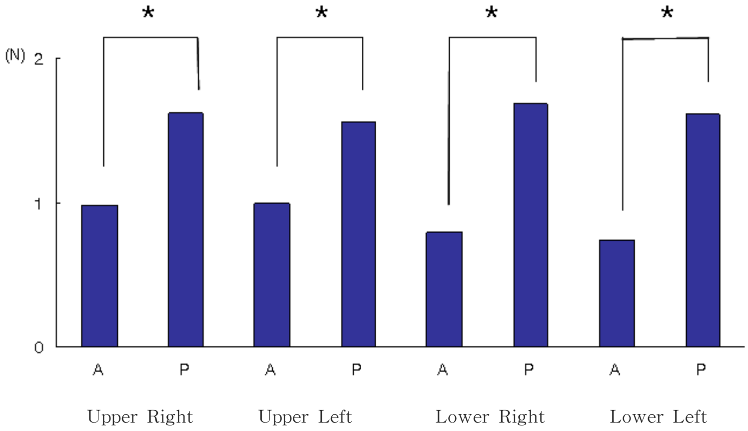


Fig. 5. Diagrammatic presentation of the proximal contact tightness in maxilla and mandible.

In both the maxilla and mandible, the TPTC was less in the anterior teeth than in the posterior teeth(Fig. 6).



(*P< 0.05, Independent samples t-test)

Fig. 6. Comparison of the proximal contact tightness between anterior teeth and posterior teeth(A : Anterior teeth, P : Posterior teeth).

There are no significant difference between the maxilla and mandible at opposing area.

Differences between male and female subjects failed to be statistically significant except upper right first premolar and second premolar, lower left first molar and second molar, lower right first molar and second molar(Tables 3,4)(Figs. 7,8).

(Unit : N)

Contact area	Male		Female		p values
	Mean	SD	Mean	SD	
#17-16	1.94	±0.38	1.52	±0.77	
#16-15	2.14	±0.61	1.76	±0.92	
#15-14	1.79	±0.29	1.27	±0.34	*
#14-13	1.48	±0.61	1.09	±0.26	
#13-12	1.32	±0.54	0.88	±0.24	
#12-11	1.09	±0.43	0.79	±0.37	
#11-21	1.04	±0.42	0.72	±0.25	
#21-22	1.26	±0.53	0.76	±0.29	
#22-23	1.24	±0.40	0.93	±0.41	
#23-24	1.37	±0.42	1.36	±0.60	
#24-25	1.50	±0.61	1.50	±0.94	
#25-26	1.96	±0.67	1.51	±0.75	
#26-27	1.90	±0.28	1.40	±0.63	

(*P<0.05, Independent samples t-test)

Table 3. Proximal contact tightness of male and female subjects in maxilla.

(Unit : N)

Contact area	Male		Female		p values
	Mean	SD	Mean	SD	
#47-46	2.24	±0.34	1.44	±0.31	*
#46-45	2.26	±0.44	1.60	±0.67	
#45-44	1.76	±0.31	1.44	±0.50	
#44-43	1.43	±0.66	1.27	±0.28	
#43-42	1.07	±0.50	1.00	±0.33	
#42-41	0.92	±0.25	0.90	±0.34	
#41-31	0.87	±0.16	0.98	±0.27	
#31-32	0.81	±0.16	0.98	±0.22	
#32-33	0.88	±0.17	0.96	±0.20	
#33-34	1.09	±0.34	1.27	±0.52	
#34-35	1.41	±0.48	1.44	±0.46	
#35-36	2.09	±0.62	1.60	±0.60	
#36-37	2.44	±0.64	1.54	±0.36	*

(*P<0.05, Independent samples t-test)

Table 4. Proximal contact tightness of male and female subjects in mandible.

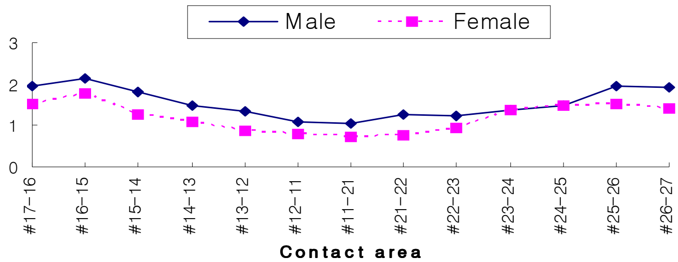


Fig. 7. Diagrammatic presentation of the proximal contact tightness by sexes in maxilla.

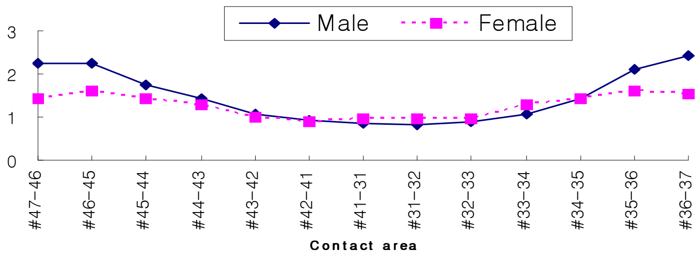


Fig. 8. Diagrammatic presentation of the proximal contact tightness by sexes in mandible.

IV. DISCUSSION

Traditionally, dentists have believed that teeth make contact with adjacent teeth in the rest state. Southard et al.[24] reported that teeth made contact with some pressure at rest. Therefore, in constructing cast restorations, it was considered desirable to have proximal contacts[25-27]. However, some studies reported that human tooth possesses a small range of movement at resting position by pulsation in alveolar socket[28-30]. Especially, Kato[29,30] reported that the range of demonstrable space was from 0.25㎛ to 0.70㎛ resulted from measurement by displacement transducer. These reports supported that there is no proximal contact in the rest state in order to adaptation to pulsating action[31,32]. Kasahara et al.[21] observed spaces ranging from 3㎛ to 21㎛ between adjacent teeth at rest, using a charge coupled device microscope.

The device that used for this study is to measure the TPTC from the frictional force occurred during pulling the thin metal strip by electric motor after inserting the thin metal strip to proximal surface. When the strip is inserted between two adjacent teeth, micro-displacement of teeth and reaction force from the strip contacts to each proximal surface occurs. As pulling out the strip parallel to the proximal surface, the frictional force occurs to the opposite to the pulling direction. The strain gauge of the device converts frictional force to compression force and the frictional force gradually increases until the strip moves, and the frictional force is maximal at the starting point of movement of the strip. This maximum frictional force is the TPTC of the proximal contact area. This force is recognized to electrical signal and displays on micro-processor. Especially, the removal speed of the metal strip was controlled constantly in order to except the effect of removal speed to frictional force. The metal strip was removed through the horizontal direction, not the occlusal direction, therefore, it was be able to measure the TPTC not only in rest state but also in occlusion. The maximum measurement range of this device was 98N and statistical difference was ±0.02N. Oh et al[19] reported that the range of the TPTC was 0.1-23N at rest and 50% MVC (maximum voluntary contraction) clenching level of masseter muscle. Therefore, it could be considered that the accuracy of this device for measuring TPTC was favorable. If the metal strip of the thickness over interdental space is inserted between two adjacent teeth, the teeth is slightly displaced. Therefore, as the metal strip becomes thinner, more accurate measurement could be possible. However, too thin strip could be easily tear and there is a problem to control it intraorally. So, we used 0.03mm-thickness metal strip. Metal strip of 0.03mm-thickness is not only durable but also easy to use for clinicians[33]. This device was controlled that the metal strip could be removed at constant speed of 8mm/s. Fuhrmann et al[33]. reported that there was no significant correlation between TPTC and removal speed of metal strip in the velocity range of 0.83-8.33mm/s. For convenience, there was a limit switch which could make the metal strip return right after measurement. In our study, the TPTC was measured in all dentition using this devices. We statistically compared value of TPTC of all measured area. Also, TPTC was compared between maxilla and mandible in opposing area, between males and females in same area. The results were as follows.

First, the TPTC was observed to be decreasing from posterior to anterior teeth in same arch. In the results of the statistical analysis, there were statistically significant differences between anterior area and posterior area. This result supported the previous studies[10]. The proximal contact of anterior teeth was unstable and resulted in spacing or crowding. The size, number, and divergency of the roots of anterior teeth can result the decreased resistance force. This can be explained by the resistance theory that we mentioned for the second theory of maintenance of the proximal tooth contact tightness[10].

Second, as we compared the TPTC between maxilla and mandible, a higher TPTC was observed in the maxilla compared with the mandible. However, there were no statistically significant differences. Proffit[34] explained it by the balanced TPTC system, similar to oral muscle balancing theory. Exactly, the TPTC is increase when the muscle functions like mastication and this effect is distributed equally to both arches. Therefore, the TPTC between maxilla and mandible becomes similar.

Third, we compared the TPTC between male and female. As a result, there were no statistically significant differences except upper right first premolar and second premolar, lower left first molar and second molar, lower right first molar and second molar. However, opposing to our study, Alexander et al.[10] reported that the TPTC was higher in male than in female. They considered that the masticatory force of male is stronger than that of female[35,36]. Even though, there were no statistically significant differences in this study. It is considered to be needed more studies which works with more subjects.

We measured at the same time of the days. Dörfer et al.[20] reported that the TPTC at rest increase from morning to noon, and then decrease in the afternoon, and it was explained by fatigue and mucoelastic characteristic of periodontal ligament. However, the differences were very small. Throughout the day, most of the high activity levels of the masticatory muscle appear mainly during meals[37]. Considering these variations, all measurement were conducted around 4 PM, allowing sufficient time after the lunchtime meal.

Teeth displace thorough each different directions according to the direction of functional force. Vertical factor of the force tends to intrude tooth to alveolar socket, and horizontal factor, to displace tooth mesially. The mesial force distributed to the proximal contacts of many teeth and affects the TPTC[38,39]. Not only tooth, but also alveolar bone tends to be displaced, especially in the mandible[40]. Korioth et al.[41] analyzed the change of the TPTC occurred due to deformation of the mandible, and observed the higher TPTC of balancing side, compared with working side. Therefore, we limited food ingestion for one hour before measurement in order to except effect of tooth displacement and mandibular deformation during function. But the tooth contact or occlusal force occurred during function like swallowing or clenching was not controlled. There was resting time of more than 2 minutes at every measurement. This resting time was for recovering previous position of tooth after measurement[24].

In our study, we measured the TPTC at rest state without any tooth contact. However, Kato[29] reported that teeth displace during occlusion and it affects to the TPTC. Oh et al[19] reported that TPTC was higher during occlusion than at rest. Therefore, it is considered to be needed analyzing the TPTC during not only resting state but also function state.

V. *CONCLUSION*

In this study, we measured the frictional force which occurred when the metal strip(stainless steel strip - 2mm width, 0.03mm thickness) was inserted to the proximal surface and was removed at constant speed by the electric motor, then we obtained the value of the TPTC in all contact areas. As a result, in both maxilla and mandible, the TPTC was less in the anterior teeth than in the posterior teeth. However, there were no significantly difference between maxilla and mandible, and between sexes.

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