行政院國家科學委員會補助專題研究計畫成果報告

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※ 咀嚼效率與功能性咬合面積相關關係之研究 ※
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※ Chewing efficiency and functional occlusal contact area ※
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計畫類別：☑個別型計畫 □整合型計畫

計畫編號：NSC 91－2314－B－002－341

執行期間： 90 年 8 月 1 日至 91 年 7 月 31 日

主持人：蕭裕源 教授 台灣大學醫學院口腔生物科學研究所

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行政院國家科學委員會專題研究計畫成果報告
咀嚼效率與功能性咬合面積相關關係之研究
Chewing efficiency and functional occlusal contact area

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一、中文摘要

以咬合面積評估軟食之咀嚼效率

處理硬質食物咀嚼功能已於以前之研究計畫中觀測完成，至於軟性食物之咀嚼效率則尚未徹底研究過。本研究之目的即在利用含氫氧磷石灰(HA)細粒之口香糖做軟食之咀嚼效率之觀測。含 HA 之口香糖經咀嚼後 HA 顆粒之分布均勻度應與咀嚼之效率成正比。根據此觀點，以正常齒列而無顎關節肌肉問題之年輕男女各 10 人(年齡自 18 至 25 歲）為對象，觀察咀嚼含 HA 口香糖 10 次，15 次，20 次，25 次及 30 次之後口香糖食團切面在 X 光照片上分布均勻情形。另外以缺一至二顆大小臼齒之無症狀同年齡及性別群者 20 人做相同之咀嚼測試以資對照。結果顯示咬合面積並不因習慣側面有顯著差異，但與牙齒存在數目有正相關。咬力之施出於習慣側較強，男性之咬力明顯大於女性之咬力，但咬肌之肌電圖表現上完整與不完整齒列之差異不大也不與咬合面積有相關關係（P>0.05），但不完整側之顳肌則明顯低於完整側之顳肌肌電表現（P>0.05）。咀嚼效率隨咀嚼次數而增高，但至 25 嚼次後效率之增加即不明顯。在 25 嚼次以前，不完整齒列者之咀嚼效率明顯低於完整齒列者。咬力與咀嚼效率無正相關關係，完整齒列者之咬合面積與其咀嚼效率無明顯相關（r<0.13）但在不完整齒列者則相關性較高（r=0.24，p<0.05）。咬力與咬合面積之相關性甚高（完整齒列，r=0.42；不完整齒列，r=0.42，p<0.05）。

根據以上發現，可以推論軟食如口香糖者其咀嚼效率較不受咬合力及咬合面積之影響，但缺牙則明顯減低咀嚼效率。可見口香糖之咀嚼不需太多的施力與研磨，但牙齒數所提供之研磨平台可因缺牙而減少。咀嚼口香糖旨在混勻內含物，此功能可能由舌及頰部之肌收縮負責，咬力施出及較大咬合面積之咬合接觸則較無關聯。

二、關鍵詞：口香糖咀嚼，咀嚼效率，咬力，咬合面積，肌電圖。

Abstract

The chewing efficiency of hard food mastication had been studied in our previous projects. However, that of soft food chewing has not been intensively studied. The purpose of this study was to apply a hydroxyapatite crystals containing chewing gum to observe the chewing efficiency of soft food in human subjects.

Twenty young subjects (10 males and 10 females, aged from 20 to 29 years old) having complete dentition and healthy TMJ and facial muscles were observed.

They were asked to chew an HA containing chewing gum block 10, 15, 20, 25, and 30 times. The gum boluses were then frozen and sectioned and the distribution the HA in a bolus section was observed and compared. Another 20 subjects having missing one or two posterior teeth in one guardant were also observed for comparison.

It was found that difference in occlusal contact area was not related to the chewing side of preference, although the biting force was better at side of preference. The masseter muscle EMG was not significantly related to occlusal surface area in both complete and incomplete dentitions. However, temporalis EMG was higher in complete dentition side ($p<0.05$).

Increase of HA homogeneity was related to the increase of chewing stroke number before 25 chewing strokes. In 30th chewing stroke, no more increase of HA homogeneity was found. The difference in chewing efficiency between complete and incomplete dentition was evident ($p<0.05$) before 25 chewing strokes. The occlusal contact area had minor significant correlation with chewing efficiency in incomplete dentition group while not in complete dentition group. Based on those findings, it can be concluded that chewing gum chewing efficiency was not affected by occlusal contact area when there is no missing tooth. The mixing ability of a subject on chewing gum is basically related to the tongue, cheek and lip manipulation ability instead of powerful chewing strokes on wide occlusal tables.

Keywords: Chewing gum chewing，Chewing efficiency，bite force，occlusal contact area, EMG

I. Introduction

Human chewing ability can be defined as the ability of minimizing the food in the oral cavity before swallowing. Chewing efficiency can then be defined as the time or chewing strokes used to obtain the minimized food before swallowing. Many methods have been proposed to observe hard food chewing function, e.g., sieve method (Manly R.S. & Braley L.C., 1950 ; Helkimo E. et al, 1978), colorimetric analysis (Kayser A.F. & van der Hoeven J.S., 1977), photometric analysis (Nakasima A., 1989), and computer image analysis methods (Shi C.S., 1990 ; Mowlana F. et al, 1995) etc. Among them, sieve method was more often used. For hard foods like peanuts or almonds, it was generally believed that the wider the occlusal contact area, the higher the chewing efficiency (Russell M.D. & Grant A.A., 1983; Gazit E. & Lieberman M.A., 1985; Kydd W.L. & Bingham V.F., 1962; Lambercht J.R., 1965; Woda A. et al, 1979; Wilding R.J.C., 1993). The linear correlation was said to be high (Yurkstas A.A. & Manly R.S., 1949; Gazit E. & Lieberman M.A., 1985). However, similar correlation was not found in soft food chewing.

Soft foods like agar or “toufu” can be “chewed” without using teeth (Arai E. & Yamada Y.1993). Human subjects without teeth can do as good as completely dentate subjects. However, soft food like chewing gum is chewed for fun without swallowing it. The ability of mixing the ingredients of the chewing gum after chewing has been regarded as the chewing efficiency of gum chewing (Liedberg B. & Owall B., 1995; Matsui Y. et al, 1995; Prinz J.F., 1999). Previous studies on gum chewing concluded that presence of teeth is necessary for gum chewing, but bite force does not strongly related to the gum chewing function. However, the effects of occlusal contact area and the number of teeth remained on such function have not been well documented.

The purpose of this study was to observe chewing gum chewing efficiency of complete and incomplete dentition subjects with a newly developed test food and technique. The test food contains radio-opaque particles (Hydroxylapatite, HA), which can be seen clearly in the X-ray image of the chewed chewing gum bolus. The homogeneity of HA particles in the gum bolus after chewing can be related to the occlusal contact area of the subjects. Although no soft tissues like the tongue and cheek movement was observed in this study, the effect of occlusal contact area on gum chewing ability can still be evaluated. The findings on the occlusal contact area effects on soft food chewing can then be applied on the design of denture prosthesis.

II. Materials and methods

1. Fabrication of standardized soft test foods：

Fresh sugarless chewing gum, Extra (Wrigley's sugar free chewing gum 7.2×1.8 cm), was used as base material of the test food. The gum strip was equally divided into three parts with two depression lines. In the center of the middle part, a 0.5 cm diameter depression was formed with a round wood stick. In the depression, 0.02 g HA particles (Hydroxylapatite, HA, Calcitite 4060-2, Calcitek, 40-60 mesh, Sulzer, Carlsbad, CA, USA) were inserted. The two side parts were then folded on top and bottom of the central part with a gentle pressure. The border of the three-layered gum blocks was sealed by finger pressure. The HA containing gum blocks were then stored in a 20℃ incubator before use.

2. Subjects：

Twenty subjects with complete dentition (10 males, and 10 females, aged from 18 to 25 years) were included as the complete dentition group. They had no missing teeth except third molars. No evident TM joint and masticatory muscle pain or dysfunction during and before examination was found. Another 20 subjects (10 males and 10 females of the similar age group) who had one or two missing molars in a quadrant before reconstruction were collected as incomplete dentition group. They did not have TMJ and muscle problems either. Both of the two group subjects were well informed with the procedures of this human experiment protocol approved by the committee of medical ethics of the National Taiwan University Hospital.

3. Observation of the bite force：

The bite force was obtained by using a piezoelectric force transducer (Model A04PCB, Piezoelectric Inc., Depew, NY USA), which was inserted between upper and lower molars of habitual and non-habitual side (Fig. 2). The thickness of the sensor was 0.9 cm and was dressed with two layers of gauze and housed in a plastic sac. The gauze and sac were replaced after use of each subject. The subject was asked to bite the sensor at the first molar area with the maximum force for 3 times with an interval of 1 min. The maximum value of the three trials was regarded as the bite force value of that subject (Fig. 3).

4. EMG of masticatory muscles：

Biopak system (Bioresearch Assoc Inc, Milwaukee, WI. USA) was used to obtain the muscle activity of the right and left masseter and anterior temporalis muscles during gum chewing. Two Ag / AgCl bipolar surface electrodes were adhered to the skin surface of each muscle. The distance of the two electrodes was constant, i.e., 2.0 cm center to center. The electrode pairs were attached to the central part and 1.5 cm from the anterior border of the anterior temporalis and masseter muscles. The skin was cleaned thoroughly with alcohol sponge before electrode attachment.

During chewing, the EMG signals were collected and amplified with the Biopak electrode connection box and were recorded and analyzed in a personal computer equipped with Biopak software (Bioresearch Assoc Inc, Milwaukee, WI. USA). The integrated muscle activity of those muscles was obtained.

5. Occlusal contact area evaluation：

Fuji Prescale pressure sensitive film (Fuji Prescale film, LLW 0.5-2.5 MPa, Fuji Photo Film Co. Ltd. Tokyo, Japan) was used to demonstrate the occlusal contact area during centric occlusion clenching (Fig. 4). The thickness of the film was 98 ì m, and its pressure / mark threshold was 5 kgf/cm2. The intensity of the red marks revealed after compression was linearly related to the amount of the force. The color spots shown on the film after being bitten at centric position for 5 seconds was photographed with a digital camera (Cyber-shot, 2.1 mega pixels, Sony DSC-F505, Sony Co., Tokyo, Japan), and the image was then loaded in a PC and calculated with Ulead Photoimpact 5.0 (Ulead systems Inc., USA). The total occlusal contact area of right and left posterior teeth in centric occlusion was then obtained. (Fig. 5)

6. Evaluation of chewing efficiency：

The subject was asked to chew a chewing gum block firstly with his / her habitual side teeth and then the non-habitual side teeth. The subjects were asked to chew the gum block 10, 15, 20, 25 and 30 times respectively. The chewed gum bolus after each of the five chewing sessions was spat out and immersed in a glass of ice water. Before spitting out, the gum bolus was roughly rounded by the subject with his / her tongue, teeth and lips.

A pin was inserted in the approximate center of the chilled gum bolus, which was then embedded in a self-cure resin block (Temporon, GC Corporation. Tokyo, Japan). The gum bolus containing resin block was then sectioned with a low speed saw (Isomet, Buehler Co. Ltd. Illinois, USA) on a reference plane parallel to the pin. The middle most section of 0.5 mm thickness was obtained for radiography with a digital X-ray system (Digora digital image system, Soredex Orion Co., Helsinki, Finland). The HA particles were found in the film of that section. A 100 cells overlay square was inserted in the round image to its maximum, and the distribution on the 100 cells was measured. The number of cells containing one or more HA particles was regarded as the percentage of HA homogeneity in that section of gum after chewing. The chewing efficiency of that subject in each chewing session was represented by the percentage of HA homogeneity.

7. Statistical treatment：

Data of bite force, occlusal contact area, EMG and chewing efficiency obtained from the two groups were compared with ANOVA and paired t test. Significance level was set at $P<0.05$. Pearson’s correlation was used to obtain the relationship between chewing efficiency and occlusal contact area, bite force and chewing EMG.

III. Results

No significant difference in occlusal contact area was found between habitual and non-habitual side of teeth in complete dentition group ($P>0.05$), while significantly smaller area was found in non-habitual side of incomplete dentition group whose non-habitual side was also the side with missing teeth ($P<0.01$). In complete dentition group, bite force seems stronger in habitual side although no statistic significance ($P>0.05$). In incomplete dentition group, complete side bite force was much stronger than in incomplete side ($P<0.01$). In both complete and incomplete group, females had weaker bite force than males ($P<0.05$). (Table 1)

Significant difference in masseter and temporalis muscle activity during gum chewing was found between males and females ($P<0.05$). The difference in EMG between habitual and non-habitual sides in complete dentition group was not significant ($P>0.05$). In incomplete dentition group this difference was not significant ($P<0.05$). However, significantly weaker EMG of anterior temporalis was found in missing side of the incomplete dentition group ($P<0.05$).

Chewing efficiency of both males and females with or without intact dentition revealed a positive correlation with the number of chewing strokes. However, when the chewing stroke number increased up to 30 times, the increase of chewing efficiency became less evident. (Table 3)

Chewing efficiency of 20 and 25 chewing strokes in complete dentition group with either habitual or non-habitual side teeth was significantly higher than in incomplete dentition group ($P<0.05$). However, no significant difference was found in sessions of 30 chewing strokes.

(Table 2)

The correlation between chewing efficiency and bite force and EMG was not evident (r<0.15 in both males and females). The correlation between chewing efficiency and occlusal contact area was moderate in incomplete dentition group (r = 0.24, P<0.05) while not in complete dentition group (r<0.13, P>0.05). There was a strong correlation between biting force and dental occlusal contact area (r = 0.42 in complete dentition group and r = 0.67 in incomplete dentition group, P<0.05). The correlation was very weak (r<0.1) between chewing efficiency and EMG in both complete and incomplete dentition groups of both males and females. (Table 3)

IV. Discussion

The detection of occlusal contact area was previously done with direct measurement of the wearing facet areas on dental casts (Luke D.A. & Lucas P.W., 1985). Their method was not physiological because the facets were not always reflecting the contact situation during chewing. Parafunctional wear on the occlusal surface can not be excluded. Image analysis of the occlusal surface (Takenoshita et al, 1991) provided a convenient way of occlusal contact surface observation. Again, the image may also include the contact area caused by parafunctional contact. This study obtained the occlusal contact area found in centric occlusion, and was more physiological and not related to parafunctional wear. The centric contact area during the observation period was then more accurately obtained. However, eccentric contact area during chewing should be wider than at centric occlusion position and it was unable to observe and calculate in this study. Therefore the effect of eccentric contact surfaces on gum chewing function requires further studies.

The findings in centric occlusal contact area by using Fuji Prescale film can also be obtained by using T-scan (Tekscan, Inc. Cambridge, MA, USA) or Occluzer (Fuji Prescale Occluzer, Fuji Dental Occlusion Pressuregraph, Fuji film Co. Ltd., Tokyo, Japan)(Suzuki et al, 1997). However, this study did not use expensive equipment for the measurement of contact area. The software applied in this study (Ulead Photoimpact 5.0) provided similar function with even wider selection of pressure area measurement. For this purpose, the ability of the pressure sensitive film to reveal contact area during eccentric movement should be verified first because the eccentric contact time on the film might not be long enough to show the pressure marks.

In this study, we found that only weak correlation existed between occlusal contact area and chewing gum chewing efficiency. It can be concluded that chewing gum minor occlusal contact area difference dose not change the gum chewing efficiency significant. The lack of teeth and subsequently the major loss of occlusal contact area will minimizing the platform for pulverizing and squeezing activities with the help of the tongue and check. In this study, no observation was made on the gum chewing efficiency of complete denture wearers or partial denture wearers. The demands of the number of teeth or the retention of the dentures for a specific chewing efficiency need be clarified as well.

1. The effects of bite force on soft food chewing efficiency

Stronger bite force can be found in males, short face, big masseter and medial plerygoid muscles, and complete dentition with flat occlusal surface (Profitt W.R. et al, 1983; Hsu C.W. et al, 2001). Stronger bite force may enhance the hard food chewing efficiency (Shiau et al 2002). In this study, chewing gum chewing efficiency was not related to the bite force. It seems only minimum jaw muscle activity was needed to manipulate or press the gum bolus, therefore The role of the tongue and cheek might be more important which was not detected in this study. The findings of similar jaw chewing muscle activity for gum chewing in different bite force groups also suggested the insignificant role of bite force on gum chewing. The demands of jaw closing muscle activity seems just for raising the jaw to meet the chewing gum while not to exert force to crash or bite through the food.

2. Efficient chewing stroke number for the observation of gum chewing efficiency

Based on the findings on Table 1 and Fig. 7, it can be clearly seen that the distribution of HA particles in a section of gum bolus became maximum at 30 chews. Before 30 chews, the homogeneity of HA was increasing. This finding suggested that for saving material and time, comparison of different situations on gum chewing efficiency should be obtained before 30 chews. However, significant difference was not evident either if the chewing strokes were less than 20 times. Because in 10 and 15 chew session, the variation was too wide to tell the difference between means (Fig. 7). It can be concluded that for soft food like chewing gum, the efficient observation can be based on 20 to 30 chews. Too many means waste while too few makes comparison difficult.

Acknowledgement

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V. References

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Table 1. Bite force, occlusal area, and EMG of complete and incomplete dentition subjects

		Complete dentition		Incomplete dentition	
		Habitual	Non-habitual	Habitual	Non-habitual
Bite force	Male	73.6±16.1	66.7±9.1*	80.5±11.1	47.8±8.2*▼
(kgf)	Female	46.8±14.1	44.8±20.1	56.7±11.1	35.9±5.2*▼
Occlusal	Male	14.8±2.1	14.5±2.0	13.6±2.1	8.0±1.6*▼
(cm^2)	Female	13.6±1.5	13.0±1.5	13.0±1.1	7.3±1.2*▼
Masseter	Male	6183±1016	5926±968	5950±1042	5444±942
EMG (mV)	Female	5069±662	5072±644	4917±888	4758±791
Temporalis	Male	5275±1017	5159±1185	5279±763	4698±677*
EMG (mV)	Female	4474±784	4363±639	4356±1117	4124±879

* Habitual vs. Non-habitual $P < 0.05$

▼ Complete dentition Habitual vs. Incomplete dentition $P < 0.01$

§ Male vs. Female $P < 0.05$

Table 2. Chewing efficiency of complete and incomplete dentition subjects

	Complete dentition		Incomplete dentition	
Stroke numbers	Habitual	Non-habitual	Habitual	Non-habitual
10	20.9±6.7	21.2±6.0	20.5±5.1	18.1±4.8
15	30.7±4.7	33.3±6.0	34.6±5.1*	28.6±6.9*
20	41.9±6.8#	40.1±6.5▼	43.9±3.5*	33.6±7.9*#▼
25	48.5±5.7#	49.2±5.3▼	51.0±4.8*	42.6±5.3*#▼
30	54.6±4.7	55.9±5.6	54.2±7.7	52.1±5.7

* $P < 0.05$ between incomplete dentition habitual and non-habitual side.

\# $P < 0.05$ between complete dentition habitual side and incomplete non-habitual side.

▼ $P < 0.05$ between complete dentition non-habitual side and incomplete non-habitual side.

¥ Non-habitual of incomplete dentition was the side of missing teeth.

Table 3. Correlation of chewing efficiency and bite force and occlusal contact area in complete and incomplete dentition subjects

(Pearson’s correlation coefficients，$P < 0.05$)

	Complete dentition	Incomplete dentition
Chewing efficiency vs. Bite Force	0.02872	0.14991
Chewing efficiency vs. Occlusal contact area	0.12698	0.24159*
Bite force vs. Occlusal contact area	0.41603*	0.69572*

Legend of figures：

Fig. 1 Standardized test food, chewing gum with HA particles

Fig. 2 Piezoelectric force transducer

Fig. 3 EMG assembly for anterior temporalis and masseter muscles

Fig. 4 Fuji Prescale film before and after biting

Fig. 5 Photoimpact contact force analysis on a PC monitor

Fig. 6 Sectioned gum bolus showing HA particles (black) under a 100 cell overlay

Fig. 7 Chewing efficiency of complete and incomplete dentitions with habitual and non-habitual side teeth

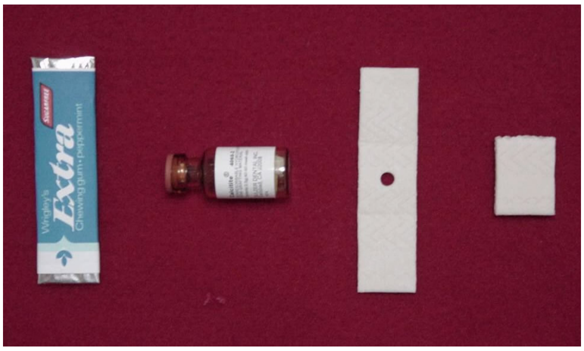

Fig. 1

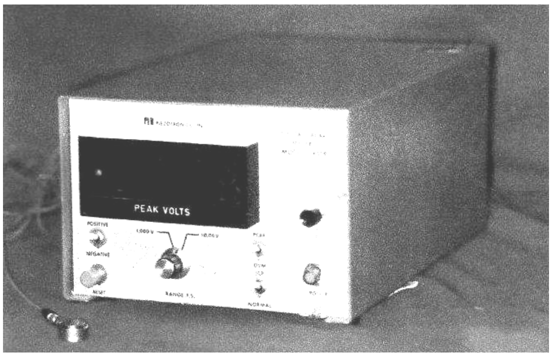

Fig. 2

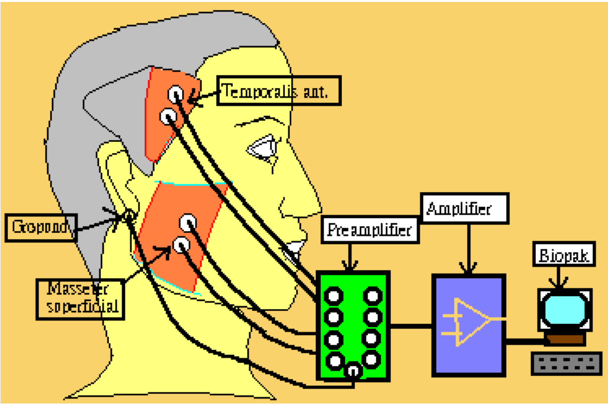

Fig. 3

Fig. 4

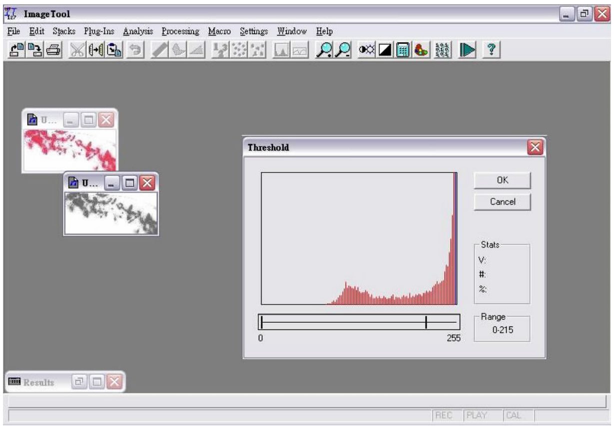

Fig. 5

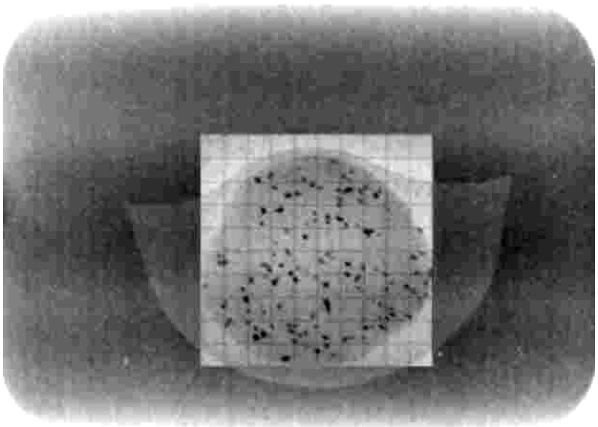

Fig. 6

Fig. 7