Table 1 Comparison of anthropometric variables (adjusted mean ± standard error) for the two occlusal groups

	Retained contact group (n = 138)	Lost contact group (n = 44)	P-value
Body mass index (BMI, kg/m^2)	22.8 ± 2.8	21.9 ± 2.4	0.075
Upper arm circumference (AC, cm)	25.8 ± 2.3	24.7 ± 2.1	0.004*
Triceps skin fold (TSF, mm)	16.1 ± 5.7	12.7 ± 5.1	0.000*

P-value by multivariate ANOVA for comparison between groups adjusted for sex and age (*P < 0.05).

Table 2 Selected food group intakes (g/1000 kcal, adjusted mean ± standard error) for the two occlusal groups

Food group	Retained contact group	Lost contact group	P-value
Meat	34.1 ± 2.9	30.4 ± 3.7	0.507
Fish	64.5 ± 4.6	64.1 ± 5.9	0.632
Egg	19.6 ± 1.8	19.7 ± 2.3	0.821
Soy products	43.6 ± 3.0	35.4 ± 3.8	0.162
Vegetables	179.4 ± 9.9	144.4 ± 12.8	0.048*
Fruits	68.5 ± 6.0	52.6 ± 7.8	0.096
Cereals	136.5 ± 8.8	147.9 ± 11.3	0.561
Confectioneries	22.8 ± 2.7	35.8 ± 3.4	0.005*

P-value by multivariate ANOVA for comparison between groups adjusted for sex and age (*P < 0.05).

Table 3 Macronutrient intakes (adjusted mean ± standard error) for the two occlusal groups

Variable	Retained contact group	Lost contact group	P-value	Standard Tables of Food Composition in Japan (5th ed.)
Protein (% of energy)	17.4 ± 0.5	17.0 ± 0.6	0.317	<25
Fat (% of energy)	25.8 ± 0.6	25.9 ± 0.8	0.971	15–25
Carbohydrate (% of energy)	53.5 ± 0.9	54.4 ± 1.2	0.461	50–70
Dietary fiber (g/1000 kcal)	8.49 ± 0.28	7.36 ± 0.37	0.036*	10

P-value by multivariate ANOVA for comparison between groups adjusted for sex and age (*P < 0.05).

Japan, whereas fat was slightly over the standard range in both groups. Dietary fiber consumed by the lost contact group was significantly lower than for the retained contact group and, furthermore, intake of dietary fiber for both groups was lower than the recommended amount (Table 3). The lost contact group also consumed significantly less vitamins including carotene, vitamin K, vitamin B_1, vitamin B_6 and vitamin C (Table 4).

Discussion

The results from this study suggest that occlusal status based on natural tooth loss is associated with nutritional intake in dietary fiber and vitamins from food in Japan.

Chewing efficiency, for example, the rate of breakdown of food during mastication, is clearly correlated with features of the dentition such as number of posterior teeth and occlusal relationships.[17] As chewing efficiency declines, individuals report increasing difficulty chewing and may avoid difficult-to-chew foods and prefer soft and easy-to-chew foods.[18] The most pronounced difference in intake involves hard-to-chew foods such as vegetables and some fruits and a higher consumption of confectionaries, which are likely to be most affected by tooth loss.[19] The findings of this study are almost the same results as those of previous studies, and therefore may support a reasonable consensus that tooth loss affects elements of nutritional intake such as dietary fiber and vitamins in Japan.

Because all subjects in the lost contact group in our study had removable dentures, it was impossible to compare the difference in nutritional intake with and without dentures. Many previous studies have reported no significant difference in nutrient intake between patients retaining their own teeth and those with dentures, however.[20,21] Wöstmann *et al.*[22] reported that despite the highly significant improvement in masticatory ability after the optimization of dentures,

Table 4 Vitamin intakes (adjusted mean ± standard error) for the two occlusal groups

Variable	Retained contact group	Lost contact group	*P*-value
Retinol (μg/1000 kcal)	412.0 ± 85.6	496.9 ± 110.3	0.455
Carotene (μg/1000 kcal)	2475 ± 150	1790 ± 193	0.014*
Vitamin D (μg/1000 kcal)	11.8 ± 0.9	12.1 ± 1.2	0.882
Vitamin E (mg/1000 kcal)	4.42 ± 0.13	4.09 ± 0.17	0.193
Vitamin K (mg/1000 kcal)	242.0 ± 12.1	200.8 ± 15.6	0.039*
Vitamin B_1 (mg/1000 kcal)	0.48 ± 0.01	0.43 ± 0.02	0.029*
Vitamin B_2 (mg/1000 kcal)	0.87 ± 0.03	0.83 ± 0.04	0.141
Niacin (mg/1000 kcal)	10.9 ± 0.4	10.3 ± 0.5	0.182
Vitamin B_6 (mg/1000 kcal)	0.83 ± 0.02	0.74 ± 0.03	0.009*
Vitamin B_{12} (μg/1000 kcal)	7.44 ± 0.51	7.59 ± 0.66	0.750
Folate (μg/1000 kcal)	239.1 ± 9.8	212.0 ± 12.6	0.104
Pantothenic acid (mg/1000 kcal)	4.12 ± 0.11	3.93 ± 0.14	0.146
Vitamin C (mg/1000 kcal)	75.7 ± 3.3	60.2 ± 4.3	0.013*

P-value obtained by multivariate ANOVA for comparison between groups adjusted for sex and age (*$P < 0.05$).

no general improvement in nutritional status was observed. Our finding supports these previous studies that the lost contact group was associated with the lower amount of hard-to-chew foods such as vegetables that individuals consume even though they used their dentures during food intake. These results may indicate that denture use is not enough to compensate for natural teeth. Recently, Bradbury *et al.*[23] demonstrated that food instruction encourages an increase in the consumption of vitamins and minerals among new denture wearers. These results should suggest to all dentists that proper nutritional counseling is needed for the edentulous elderly in routine dental practice to prevent not only inadequate nutrition but also systemic diseases such as cerebrovascular disease.[8]

Muscle function is essential for masticatory efficiency. As individuals age, there is a significant decrease in the cross-sectional area and density of the masticatory muscles.[24] These observations are consistent with general age-related changes in skeletal muscle tissue throughout the body. Anthropometric measurements are indicators of muscle mass and subcutaneous fat.[25] Therefore, the significant decrease in AC and TSF observed among members of the lost contact group may also be associated with a reduction in masticatory function, resulting in increased difficulty chewing hard food. We did not evaluate such masticatory function elements as occlusal force and chewing efficiency in this study, however. Kikutani *et al.*[26] reported that oral function training can improve nutritional status in institutionalized elderly people. Further study will be needed to compare not only tooth contact but also masticatory function to evaluate the effects of nutritional status.

Acknowledgments

This study was supported by a Grant-in-Aid from the Ministry of Health, Labor and Welfare (#H19-tyoujyu-ippan-011) and a Grant-in-Aid for Scientific Research from the Japan Society for the Promotion of Science (#19592241). We address special thanks to Professor Sasaki for the analysis of BDHQ.

References

1 Yukawa H, Suzuki T. Aging-related changes of food intake in elderly subjects living in an urban community and relation with vital prognosis: results of an 8-year longitudinal study (TMIG-LISA). *Geriatr Gerontol Int* 2003; **3**: S55–S62.
2 Joshipura KJ, Willett WC, Douglass CW. The impact of edentulousness on food and nutrition intake. *J Am Dent Assoc* 1996; **127**: 459–467.
3 Krall E, Hayes KC, Garcia R. How dentition status and masticatory function affect nutrient intake. *J Am Dent Assoc* 1998; **129**: 1261–1269.
4 Mojon P, Budtz-Jorgensen E, Rapin CH. Relationship between oral health and nutrition in very old people. *Age Ageing* 1999; **28**: 463–468.
5 Sheiham A, Steele JG, Marcenes W *et al.* The relationship among dental status, nutrient intake, and nutrirional status in older people. *J Dent Res* 2001; **80**: 408–413.
6 Walls AWG, Steele JG, Sheiham A. Oral health and nutrition in older people. *J Public Health Dent* 2000; **60**: 304–307.
7 Nowjack-Raymer RE, Sheiham A. Association of edentulism and diet and nutrition in US adults. *J Dent Res* 2003; **82**: 123–126.
8 Joshipura KJ, Ascherio A, Manson JE. Fruit and vegetable intake in relation to risk of ischemic stroke. *J Am Med Assoc* 1999; **282**: 1233–1239.
9 Steinmetz KA, Potter JD. Vegetables, fruit, and cancer prevention: a review. *J Am Diet Assoc* 1996; **96**: 1027–1039.
10 Yoshihara A, Watanabe R, Nishimuta M, Hanada N, Miyazaki H. The relationship between dietary intake and

the number of teeth in elderly Japanese subjects. *Gerodontology* 2005; **22**: 211–218.
11 Suzuki K, Nomura T, Sakurai M, Sugihara N, Yamanaka S, Matsukubo T. Relationship between number of present teeth and nutritional intake in institutionalized elderly. *Bull Tokyo Dent Coll* 2005; **46**: 135–143.
12 Wakai K, Naito M, Naito T *et al.* Tooth loss and intakes of nutrients and foods: a nationwide survey of Japanese dentists. *Community Dent Oral Epidemiol* 2010; **38**: 43–49.
13 Eicher K. Uber eine Gruppeneinteilung des Luckengebisses fur die Prothetik. *Dtsche Zahnarztl Z* 1955; **10**: 1831–1834.
14 Sasaki S, Yanagibori R, Amano K. Self-administered diet history questionnaire developed for health education. *J Epidemiol* 1998; **8**: 203–215.
15 Sasaki S. Serum biomarker-based validation of a brief-type self-administered diet history questionnaire for Japanese subjects. A research for assessment of nutrient and dietary habit in "Kenko Nippon 21". Tokyo. Ministry of Health, Labor and Welfare of Japan. 2005: 10–42 (in Japanese).
16 Resources Council. *Science and Technology Agency: Standard Tables of Food Composition in Japan*, 5th edn. Tokyo: The Printing Bureau, The Minister of Finance, 2000; (in Japanese).
17 Carlsson GE. Masticatory efficiency: the effect of age, the loss of teeth and prosthetic rehabilitation. *Int Dent J* 1984; **34**: 93–97.
18 Chauncey HH, Muench ME, Kapur KK *et al.* The effect of the loss of teeth on diet and nutrition. *Int Dent J* 1984; **34**: 98–104.
19 Sheiham A, Steele JG, Marcenes W *et al.* The impact of oral health on stated ability to eat certain foods: findings from the National Diet and Nutrition Survey of Older People in Great Britain. *Gerodontology* 1999; **16**: 11–20.
20 Marshall TA, Warren JJ, Hand JD, Xie XJ, Stumbo PJ. Oral health, nutrient intake and dietary quality in the very old. *J Am Dent Assoc* 2002; **133**: 1369–1378.
21 Sahyoun NR, Krall E. Low dietary quality among older adults with self-perceived ill-fitting dentures. *J Am Diet Assoc* 2003; **103**: 1494–1499.
22 Wöstmann B, Michel K, Brinkert B, Melchheier-Weskott A, Rehmann P, Balkenhol M. Influence of denture improvement on the nutritional status and quality of life of geriatric patients. *J Dent* 2008; **36**: 816–821.
23 Bradbury J, Thomasson JM, Jepson NJA, Walls AWG, Allen PF, Moynihan PJ. Nutrition counseling increases fruit and vegetable intake in the edentulous. *J Dent Res* 2006; **85**: 463–468.
24 Newton JP, Yemm R, Abel RW, Menhinick S. Changes in human jaw muscles with age and dental state. *Gerodontology* 1993; **10**: 16–22.
25 Okada K, Enoki H, Izawa S, Iguchi A, Kuzuya M. Association between masticatory performance and anthropometric measurements and nutritional status in the elderly. *Geriatr Gerontol Int* 2010; **10**: 56–63.
26 Kikutani T, Enomoto R, Tamura F, Oyaizu K, Suzuki A, Inaba S. Effects of oral functional training for nutritional improvement in Japanese older people requiring long-term care. *Gerodontology* 2006; **23**: 93–98.

結果と考察：実験1における血中カテコールアミン濃度は，アドレナリン，ノルアドレナリン濃度ともに，飼料変更後7日目以降，固形飼料群に比べ，液体飼料群で有意な増加傾向が認められた（$p<0.05$）。好中球のスーパーオキシド産生能は，飼料変更後7日目から21日目まで，固形飼料群に比べ，液体飼料群で有意な増加傾向が認められた（$p<0.05$）。また，血清SOD様活性は，飼料変更後21日目から84日目まで，固形飼料群に比べ，液体飼料群で有意な低下傾向が認められた（$p<0.05$）。実験2における血清SOD様活性は，液体飼料から再び固形飼料へ戻した7日目以降，両群に差は認められなかった。

以上より，噛むことが習性であるラットの液体飼料飼育がストレッサーとなり，その結果，生体が酸化ストレス状態へ誘導されていることが示唆された。

38. 要介護高齢者における原始反射の再出現と摂食機能および予後との関連

Relationship among the Primitive Reflexes, Feeding Function and Survival Prognosis in Elderly in Need of Care

川瀬順子，菊谷　武，高橋賢晃
福井智子，西脇恵子，田村文誉
Junko Kawase, Takeshi Kikutani
Noriaki Takahashi, Tomoko Fukui
Keiko Nishiwaki, Fumiyo Tamura

日本歯科大学附属病院
口腔介護・リハビリテーションセンター
Rehabilitation Clinic for Speech and Swallowing Disorders,
The Nippon Dental University Hospital

目　　的：原始反射は，認知症などにみられる前頭葉の障害により再び出現するとされている。口腔関連の原始反射に，吸啜反射，咬反射，口尖らし反射があり，これらの反射の出現により，要介護高齢者の食事場面において，食事介助に難を示すことがある。これまでの研究において，原始反射の出現が，摂食機能および食事場面での行動に影響することを報告してきた（2009，日摂食嚥下リハ）。今回，介護老人福祉施設入居者において，1年の追跡調査により原始反射の出現と摂食機能や栄養状態との関連性，さらには予後に及ぼす影響について検討した。

方　　法：東京都内の介護老人福祉施設（2施設）に入居している要介護高齢者127名のうち，経口摂取をしている，121名，平均年齢86.3±7.8歳（男性32名・女性89名）を対象とした。平成21年4月より1年間を調査期間とした。対象者に対し，吸啜反射，咬反射，口尖らし反射の有無を調査開始時，6カ月後，12カ月後での調査を行った。発症の有無と，ADL（Barthel Index），認知機能評価（CDR），食形態，栄養状態（体重，BMI），肺炎発症について検討した。さらには，1年後の栄養状態，肺炎発症との関連を検討した。

結　　果：対象者のうち，38名31%にいずれかの原始反射が認められ，吸啜反射，咬反射，口尖らし反射が認められた者はそれぞれ，31名，28名，15名であった。6カ月後の評価では，新たに12名で反射が認められた。さらに，12カ月後では，8名の者に新たに反射が認められた。1年間の観察期間に，25%の者に反射の出現が認められた。ADL（維持・低下），CDR（維持・低下），食形態（常食・刻み食，ペースト食・ミキサー食）と反射出現頻度との間に有意差が認められた。口尖らし反射とBMIとの間に有意差が認められた。6カ月後，12カ月後の体重減少率を検討したところ，ともに咬反射において有意差が認められた。さらに，観察期間365日の肺炎発症についてカプランマイヤー法を用いて検討した。いずれかの反射がなかった者の肺炎発症は17.8%に対し，反射がみられた者は35.5%であり，肺炎発症までの推定平均日数は反射ありで300±16.7日，反射なしは338.1±8.0日で，2群間に有意差を認めた。咬反射においても，反射がなかった者の肺炎発症は18.5%に対し，反射がみられた者は39.1%であり，反射ありは298.8±18.2日，反射なしは334.8±8.2日で，2群間に有意差を認めた。

考　　察：1年間の観察期間に，新たに約1/4の者に原始反射の出現が認められた。原始反射の出現が栄養状態に影響を及ぼすことが示唆された。さらには，肺炎発症を引き起こす要因のひとつと考えられた。今後は，原始反射の出現時期とこれらの低栄養や肺炎の発症との関連を検討し，予防に資する介入法について検討する予定である。

39. 咀嚼能力の国際比較調査をするための食品群リストの作成，フィリピンとシンガポールの場合

Making the Lists of Foods to Evaluate Ability to Chew for International Comparative Studies, in the Cases of Philippines and Singapore

那須郁夫[1)]，斎藤安彦[2)]
Ikuo Nasu[1)]，Yasuhiko Saito[2)]

【考　察】
上述の内容は，そのほとんどが，機種更新時の入札仕様書に明記があれば解決できるものであり，実例を提示しながら，その重要性を報告する．

1-2-11

嚥下造影検査用動画サーバーの構築　第1報

社会医療法人生長会愛風病院放射線室
岡田秀人

【はじめに】
近年医療画像の一元管理が進む中，嚥下造影検査の保存は他の放射線検査とは別に独自の保存方法を行っているのが現状である．嚥下造影検査と他の放射線検査との大きな違いは，嚥下造影検査がエックス線透視による動態検査であり，他の放射線検査は静止画検査である点と考えられる．今回，動態検査である嚥下造影検査を他の放射線検査画像と共に一元管理が可能となる検査画像サーバーを構築したのでここに報告する．
【方　法】
エックス線TV装置から検査モニターと今回開発したキャプチャー装置へ信号を分岐させ，検査画像サーバーへの保存を行った．キャプチャー装置では専用のアプリケーションを起動させ入力された動画をWMVファイルで圧縮し画像サイズを1280×1024，画素数を1.3メガピクセルとした．また嚥下造影検査を視聴するときには，自動的にウインドウズメディアプレイヤーが起動するようにしている．今回の検査画像サーバーに保存された動画が嚥下造影検査に重要な喉頭蓋や舌骨の動き，また喉頭侵入などの判別が可能かをオリジナルと比べての判定を普段検査に携わる医療従事者による検証も行った．
【結果および考察】
今回の医療画像の一元化により各診察室やカンファレンス室等での検査動画の閲覧が可能となった．また圧縮による動画のコマ落ちや劣化を検証した結果，改善事項が生じている．保存媒体においてもHDDの信頼性が懸念されてはいるが現状の画像一元化ではHDDへの保存が主流となっているため今後はDVDやコンパクトメディア等への自動保存や自動バックアップ等の改良を続けていく予定である．

1-2-12

要介護高齢者における原始反射の再出現が予後に与える影響

日本歯科大学附属病院口腔介護・リハビリテーションセンター[1)]
日本歯科大学大学院生命歯学研究科臨床口腔機能学[2)]
高橋賢晃[1)]，町田麗子[1)]，川瀬順子[1)]，
田村文誉[1)]，菊谷　武[1), 2)]

【緒　言】
原始反射とは，新生児における発達過程において一定の順序で出現し，大脳の発達とともに大脳皮質や錐体路といった上位より抑制がかかるために消失する反射である．一方，中枢神経系における何らかの病的状態の存在が示唆される時，この原始反射は再出現することが報告されている．口腔に見られる主な原始反射に，吸啜反射，口尖らせ反射，咬反射がある．これらの反射は，食事の際にも認められることから，摂食機能に与える影響は無視できないと考えられる．しかし，これまで原始反射と栄養摂取および予後との関連を検討したものは少ない．そこで，本研究の目的は，要介護高齢者の原始反射の出現頻度を知るとともに，それらが，栄養状態および予後に及ぼす影響について知ることである．
【対象および方法】
2009年8月から2010年1月までの期間において，介護保険施設71施設に入居している要介護高齢者のうち胃瘻による栄養管理を受けている者を除く2187名（男性430名，女性1757名，平均年齢85.7±8.3歳）を対象として，原始反射発現の有無を調査し，ADL，認知機能，栄養状態（BMI，体重減少率），口腔ケアリスク（開口保持の有無），嚥下機能との関連を検討した．さらに，6カ月間追跡し予後との関連を検討した．
【結果および考察】
吸啜反射，口尖らせ反射，咬反射の出現頻度は，それぞれ297名（14%），326名（15%），310名（14%）であった．これらの反射出現頻度とADL，認知機能，肺炎既往，口腔ケアリスク，嚥下機能，BMI，体重減少率との間に有意な関係が示された．さらに，追跡調査の結果，肺炎発症との間に有意な関係を示した．原始反射の発現は，低栄養のリスクと関連し，肺炎発症との関連が示された．本研究は，平成22年度厚生労働科学研究費補助金（H21-長寿一般-003）によった．

P108 Relationship between primitive reflexes and malnutrition of the elderlies under long-term care

Kikutani T, Kawase J, Takahashi N, Hirabayashi M, Tashiro H, Fukui T, Tamura F

Rehabilitation Clinic for Speech and Swallowing Disorders, The Nippon Dental University School of Life Dentistry at Tokyo, Dental Hospital, Tokyo, Japan

Introduction: Whenever the presence of some type of pathological condition in the CNS is suggested, primitive reflexes that disappear in the course of normal development can reappear. The purpose of the present study is to identify the frequency at which primitive reflexes reappear in elderly patients living in nursing homes and to determine the effects that such reflexes have on eating function, nutritional status and prognosis.

Material and Method: Subjects were 127 elderly patients who require care (mean age, 86.1±7.9 y) from two nursing homes; they were examined for the presence of sucking reflex, snout reflex and phasic bite reflex and the associations between these reflexes and ADL, cognitive function and nutritional status were investigated. Subjects were then followed for six months in order to determine the associations with prognosis.

Results and Conclusion: Sucking reflex was confirmed in 31 patients (25.6%), snout reflex in 15 patients (12.3%) and phasic bite reflex in 28 patients (23.1%). One or more of these reflexes was identified in 38 patients (31.4%). A relationship between the appearance of a primitive reflex and serum albumin was indicated. An association with the onset of pneumonia after 6 months was also confirmed. The appearance of primitive reflexes was shown to be associated with the risk of malnutrition and to be relevant to the question of whether oral ingestion is advisable after the onset of pneumonia.

P109 Prediction of dysphagia outcome in elderly patients receiving long-term care using videoendoscopic evaluation of swallowing

Takahashi N, Kikutani T, Tohara T, Tamura F

Rehabilitation Clinic for Speech and Swallowing Disorders, The Nippon Dental University School of Life Dentistry at Tokyo, Dental Hospital, Tokyo, Japan

Aim: To examine effectors for the prediction of dysphagia outcome using videoendoscopic evaluation (VE) of swallowing in dependent elderly people at nursing care facilities.

Material and Method: The study was performed at six nursing care facilities during a 2-year period (March 2007 to February 2009). The subjects comprised 148 (43 men and 105 women; mean age 85.1±8.0 years) of 176 people requiring evaluation of feeding and swallowing function. Twenty-eight people requiring tube feeding were excluded at the initial evaluation. Subjects' feeding and swallowing movements were evaluated by observation and VE during a regular meal, and subjects received diet modification according to the evaluation results. Evaluation items included oral movement during eating (evaluated by observation) and food residue in the pharynx, food penetration, food aspiration and saliva aspiration (evaluated by VE). Variation in body weight and outcome (presence or absence of pneumonia) were compared after three months on the modified diet. In addition, we analysed the relationship between the evaluation items and variation in body weight and outcome after three months.

Results and Conclusion: Twelve (8.1%) of 148 subjects developed pneumonia after three months. Significant correlations between saliva aspiration and development of pneumonia ($p=0.04$) and between saliva aspiration and variation in body weight after three months ($p=0.03$) were observed. The results suggest that saliva aspiration may be a predictive factor for the development of pneumonia and weight loss in patients with dysphagia.

LIP-CLOSING FUNCTION OF ELDERLY PEOPLE DURING INGESTION: COMPARISON WITH YOUNG ADULTS

FUMIYO TAMURA, DDS, PHD, TOMOKO FUKUI, DDS, PHD, TAKESHI KIKUTANI, DDS, PHD, REIKO MACHIDA, DDS, PHD, MITSUYOSHI YOSHIDA, DDS, PHD, TAKEYOSHI YONEYAMA, DDS, PHD, AKIRA HAMURA, DDS, PHD

ABSTRACT

In this study the relationship between the functional vertical labial pressure and aging during ingestion in the elderly is examined. The subjects were 84 community-dwelling elderly (mean: 79.4 years old), 109 elderly needing long term care (mean: 81.3 years old), and 59 healthy young adults (mean: 32.0 years old) as control. Labial pressure was measured with a pressure sensor embedded in acrylic plate. There was no correlation between age and labial pressure or the coefficient of variation of labial pressure during ingestion. In people with a history of "choking on food", labial pressure was, however, significantly lower ($p<0.01$) than people without a history of "choking on food", while the coefficient of variation of labial pressure was significantly higher ($p<0.05$). Poor labial pressure and movement were noted in subjects who experienced "choking on food", suggesting that lip-closing function also plays an important role in the pharyngeal stage of feeding/swallowing. On the other hand, the coefficient of variation of labial pressure during ingestion was not changed in the elderly group in comparison to the control group. These results showed that skilled movement of lip-closing might be compensated by labial pressure. Labial pressure and skilled movement were, however, decreased in the elderly needing care because of "choking on food".

Key words: Lip-closing Function; Elderly; Ingestion; Labial Pressure

INTRODUCTION

Body functions including feeding/swallowing are susceptible to change with aging (Baum, & Bonder, 1983; McHenry et al., 1999; Sheth, & Diner, 1988; Tomita et al., 2002). Feeding or swallowing function occurs through the coordinated movement of various organs such as the tongue, lips, and pharynx. Among the organs associated feeding/swallowing, the function of the tongue and masticatory muscles decreases with aging (Baum, & Bonder, 1983; McHenry et al., 1999; Sheth, & Diner, 1988). Feeding/swallowing function consists of a series of processes starting with the anticipatory stage when food is taken into the mouth by the lips, and concluding when food reaches the stomach (Leopold, & Kagel, 1983). Lip-closing movement plays an important role in these processes, from ingestion to swallowing (Kaneko, Mukai, & Omoto, 1987). The lips are closed by vertical and horizontal muscle pressure. However, the majority of previous studies investigated only the horizontal labial pressure, which is related to preservation of tooth alignment or denture stability (Floystrand, 1986; Newman, Barnes, & Newman, 1983), and few studies have elucidated the relationship between labial pressure and feeding/swallowing function (Chigira et al., 1994; Takahashi, & Mukai, 2002; Tamura et al., 2004; Tomita et al., 2002). Swallowing is associated with mandibular-closing movement, but the

relationship between mandibular-closing movement and lip-closing movement is unknown. We previously reported that lip-closing pressure of people with an edentulous jaw at the time of swallowing was greater without dentures compared with the pressure when they wore dentures (Tamura et al., 2004).

Baum et al. (1983) reported that the number of people who experienced decreased functional changes in the lips increased with aging. On the other hand, Fucile et al. (1998) reported that functional eating ability did not decrease in healthy elderly people aged 60 to 97 years old. Furthermore, Tomita et al. (2002) reported in their study of the vertical labial pressure that there was no difference in labial pressure and the maximum labial pressure during swallowing between an elderly group with a dentulous jaw and a young adult group.

However, it has not been elucidated how lip-closing function correlated with aging. Thus, the relationship between lip-closing function and aging in the elderly during ingestion was examined in this study.

METHODS

Subjects

The subjects were 84 community-dwelling elderly people who participated in a health seminar (Elderly group: 27 men and 57 women with mean age of 79.4 years old) and 109 elderly people needing care and living in a nursing care facility in Tokyo (Elderly needing care group: 41 men and 68 women with mean age of 81.3 years old). The criteria for the levels of nursing care set by the Japanese Ministry of Health, Labor and Welfare, which are shown in Table 1, were employed. The control group consisted of 59 healthy young adults who had no stomatognathic abnormality (Young adult group: 23 men and 36 women with mean age of 32.0 years old).

This study employed the Eichner classification (Eichner, 1955). The selected subjects were classified into level A1 - B1, in which three or more occlusal supporting areas in both jaws were preserved.

Prior to this study, the objective, method, and expected outcome of this study was explained to the subjects orally and in writing. Their consent was obtained. The procedures used comply with the protection of human rights. This study was approved by the Ethics Committee of the Nippon Dental University, School of Life Dentistry at Tokyo.

Measurement method of labial pressure during ingestion

A strain gauge type of pressure sensor was employed in this study. This sensor was originally developed to measure pressure of fluid and pressure in containers, also widely used in dental research. A strain gauge pressure sensor is appropriate for measurement of the pressure of soft tissue such as the lips and tongue (Chigira et al., 1994; Floystrand, 1986; McHenry et al., 1999; Ono, Hori, & Nokubi, 2004; Takahashi, & Mukai, 2002; Tamura, & Suzuki, 2004).

A measurement device made of acrylic plate with 20 mm width, 150 mm length, and 2 mm thickness, in which a strain gauge type of pressure sensor was embedded, was used to measure labial pressure. The center of the pressure sensor of labial pressure measurement system was embedded 20 mm from the end of the oral cavity side of the plate, and fixed with wax. The sensor was connected to an instrumentation amplifier (WGA-710A, Kyowa Electronic Instruments Co., Ltd., Japan) using a waterproof small pressure transducer with 6 mm diameter and 0.6 mm thickness (PS-2KA, Kyowa) (Chigira et al., 1994) (Fig. 1). Labial pressure during ingestion was measured at the center of the lips. The system was soaked in a water bath at 37°C just before measurement to prevent any effect of temperature change on the pressure sensor. Figure 2 shows the measurement method of the vertical labial pressure between upper and lower lips. The examination was performed while the subjects were sitting. Before starting the examination, the subjects were asked to "eat 1 g of yogurt placed at the end of the measurement device 'as usual', and the vertical labial pressure was measured five times In terms of the measurement method used in this study, it was expected that the state of mind of the

subjects may significantly influence lip-closing function during ingestion, because the function is voluntary. For this reason, attempts were made to make the subjects feel as relaxed as possible and encouragement was given to them by saying, "Please eat the yogurt as usual", to reassure them and allow them to eat calmly. Furthermore, the yogurt on the measurement device was brought to their mouths horizontally. The device was then withdrawn without changing the angle after the yogurt was eaten, because labial pressure might be influenced by the angle of the device on the lower lip

Data Analysis

In order to examine the skilled movement of lip-closing function during ingestion, the mean of the 5 repetition was represented as a reading from each subject. The coefficient of variation was obtained to indicate the data variation. Poor skill of movement is indicated by a lower coefficient of variation (Chigira et al., 1994).

Using the data obtained, the statistical significance of differences between the age groups and sex was analyzed using Mann-Whitney U-test, and the correlation between the measurement values was analyzed using Spearman's rank correlation coefficient. Statistical analysis was conducted using SPSS version 9.0J. The significant level in this study was $p<0.05$.

Table 1. Certification of eligibility for long-term care

Care level	Criteria for care level
Needing support 1	Slight decline in physical function in some activities of daily living due to impairment, but will improve with preventive support.
Needing support 2	Partial decline in physical function in some activities of daily living due to impairment, but will improve with preventive support.
Needing care 1	Observation and/or assistance needed for all activities of daily living. Support needed for standing up and walking.
Needing care 2	Observation and/or assistance needed for all activities of daily living. Support needed for standing up and walking. Observation and/or assistance needed for eating and toileting.
Needing care 3	Cannot take care of oneself or stand up by oneself. General care needed for toileting, etc.
Needing care 4	Considerable decrease in activities of daily living. General care often needed. Problematic behavior or decreased comprehension.
Needing care 5	Significant decrease in activities of daily living. General care needed. Much problematic behavior or significantly decreased comprehension.

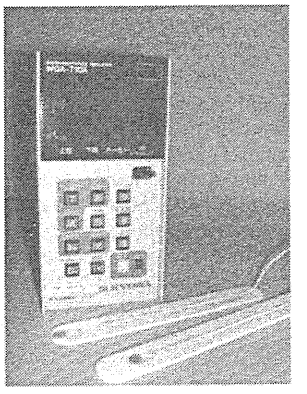


Figure 1 Pressure transducer and instrumentation amplifier to measure labial pressure. An acrylic plate, in which a strain gauge type of pressure sensor was embedded, was connected to an instrumentation amplifier.

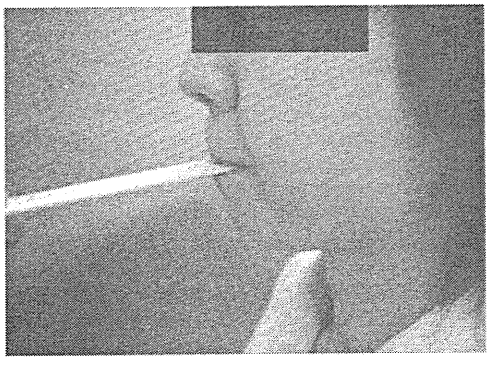


Figure 2 Measurement of labial pressure. The subject was seated and the examiner helped the subject to eat, in order to measure labial pressure during ingestion.

RESULTS

Relationship between measurement results and age

There were no significant differences between the under age of 65-year old group and aged 65 or over group (unpaired t-test) (Fig. 3-A and 3-B). The relationship between age and labial pressure during ingestion or the coefficient of variation of labial pressure during ingestion was investigated in all subjects using Spearman's rank correlation coefficient. There was no correlation between age and labial pressure.
Neither was there a correlation for the coefficient of variation of labial pressure during ingestion.

Difference in sex in labial pressure during ingestion and coefficient of variation of labial pressure during ingestion

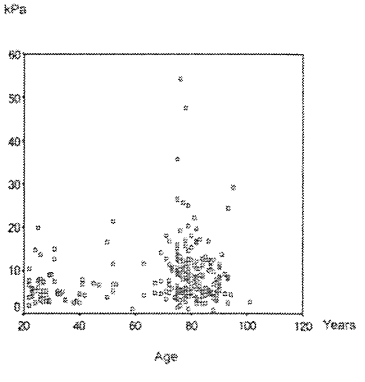
1) Labial pressure during ingestion
The mean value of labial pressure during ingestion was 6.6 ± 4.2 kPa in the control group (men: 8.0 ± 5.3, women: 5.7 ± 3.2), 11.2 ± 8.9 in the elderly group (men: 10.5 ± 8.7, women: 11.3 ± 8.9), and 7.9 ± 4.8 in the elderly needing care group (men: 8.5 ± 5.0, women: 7.6 ± 4.7). There was no significant difference in sex among all groups (Fig. 4).

2) Coefficient of variation
The mean value of the coefficient of variation of labial pressure during ingestion was 0.26 ± 0.14 in the control group (men: 0.25 ± 0.12, women: 0.27 ± 0.21), 0.34 ± 0.17 in the elderly group (men: 0.37 ± 0.21, women: 0.32 ± 0.14), and 0.34 ± 0.19 in the elderly needing care group (men: 0.36 ± 0.18, women: 0.34 ± 0.21). There was no significant difference in sex among all groups (Fig. 5).

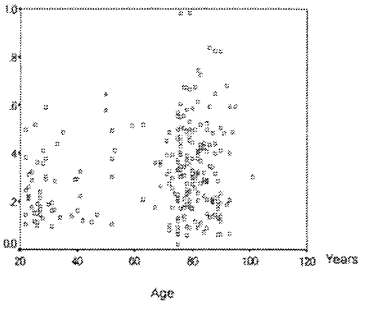
Figue 3-A Labial pressure during ingestion and age. There was no significant difference between under age of 65-year old group and aged 65-year old or over group in labial pressure during ingestion.

Figure 3-B Coefficient of variation of labial pressure during ingestion and age. There was no significant difference between under age of 65-year old group and aged 65-year old or over group in coefficient of variation of labial pressure during ingestion.

A



B



Relationship between lip-closing function and "spilling food" and "choking on food" in elderly people during ingestion

The relationship between events such as "spilling food" and "choking on food" and labial pressure during ingestion or the coefficient of variation of labial pressure during ingestion was investigated in the elderly group. No significant relationship between "spilling food" and labial pressure during ingestion or the coefficient of variation of labial pressure during ingestion was noted. However, labial pressure during ingestion and the coefficient of variation of labial pressure during ingestion were significantly lower ($p<0.01$) in subjects with "chocking on food"; and significantly higher ($p<0.05$) in subjects without "choking on food" (Fig. 6-A and 6-B).

DISCUSSION

Labial pressure during ingesting yogurt and the coefficient of variation of labial pressure were determined and discussed in order to elucidate the effect of aging on labial pressure in this study. The variability in the distribution indicated individual differences in labial pressure. Labial pressure during ingestion during the developmental stage increases with age (Chigira et al., 1994; Floystrand, 1986), and therefore, it was expected that labial pressure would decrease from its peak in adulthood, in a manner similar to other physical organs. However, in contrast to this assumption, the results of this study revealed that the vertical labial pressure during mastication was less likely to be influenced by aging. Considering that tongue pressure decreases with age (Fucile et al., 1998), it is speculated that labial pressure might be maintained to compensate for the weakness of tongue pressure.

Before commencement of this study, it was postulated that labial pressure during ingestion in the elderly group would be lower than that in the young adult group because of decreased function with age. However, the results showed that labial pressure in the elderly subjects was similar to that in young adults. The results suggested that lip-closing function would be maintained during the aging process to preserve feeding/swallowing function in place of the weakened tongue function because tongue function could decrease with age.

The coefficient of variation of labial pressure during ingestion did not change in the elderly group in comparison to the control group. The elderly group even demonstrated a higher coefficient of variation than the control group although a significant difference was not found. It was suggesting that the reduced skilled movement of lip function with aging was compensated for by the increase in labial pressure. The elderly might have used their lips as an instrument to catch and hold food. Inagaki (1993), reported that young people in recent years have decreased in their physical strength, which may have an effect on their labial pressure and resulted in their demonstrated labial strength similar to the labial strength showed by the elderly.

The elderly needing care group had relatively lower labial pressure during ingestion and poorer skilled movement. This was also indicated by the low coefficient of variation compared to that in the control group and the elderly group, although no significant difference was found. Once the elderly fall into a state of needing care, their worsened general status may have an influence on lip-closing function.

A limitation of this study was not determining interlabial maximal pressure. If maximal interlabial pressure during ingestion of food was low, especially in the young subjects, it could indicate that those subjects may have very efficient mechanisms. If this happens in the elderly, it could mean that they might use a larger percentage of their total lip-strength capacity, which might result in fatigue.

In a previous study the authors reported that events such as "spilling food" and "choking on food", which may involve lip-closing function, influence life prognosis (Kikutani et al., 2006).

Figure 4 Effect of sexual difference on labial pressure during ingestion. There was no significant difference in sex among all groups.

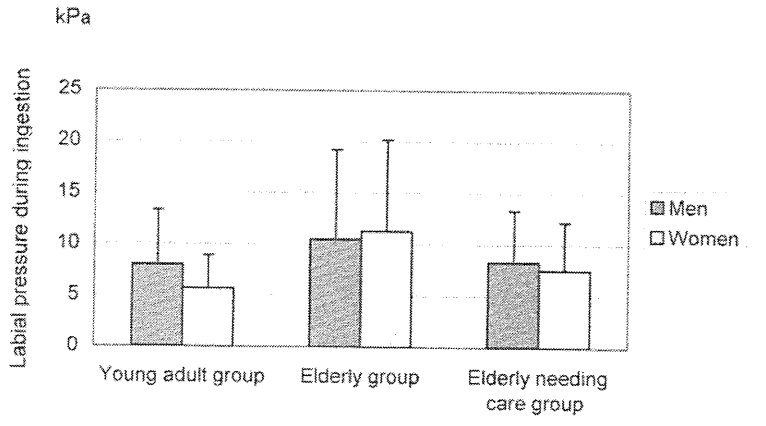


Figure 5 Effect of sexual difference on coefficient of variation of labial pressure during ingestion. There was no significant difference in sex among all groups.

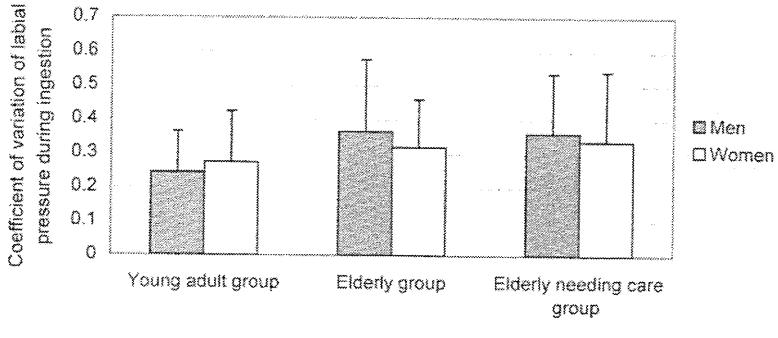


Figure 6-A Relationship between "spilling food" and lip-closing function during ingestion in elderly group. No significant relationship between "spilling food" and labial pressure during ingestion or the coefficient of variation of labial pressure during ingestion was noted.

A

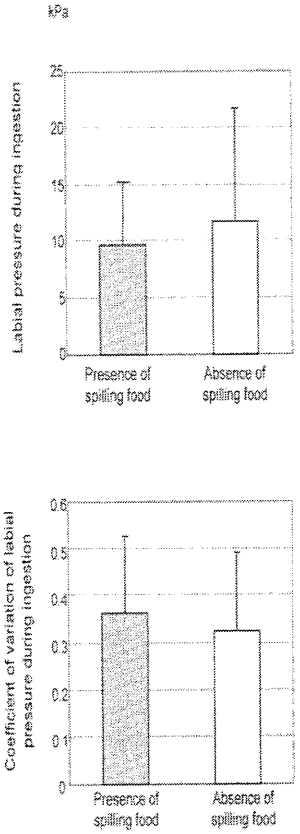
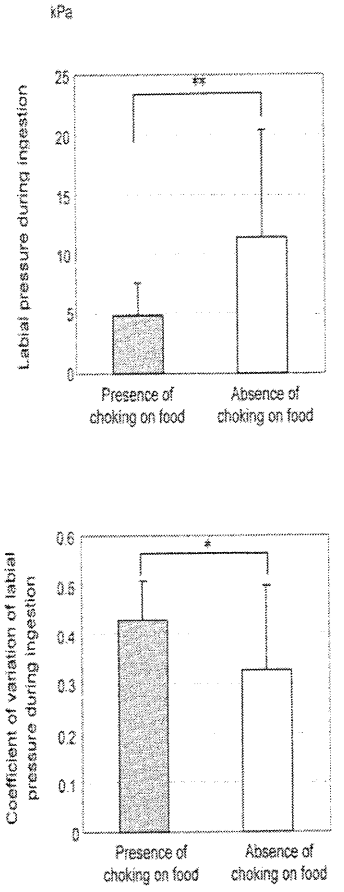


Figure 6-B Relationship between "choking on food" and lip-closing function during ingestion in elderly group. Labial pressure during ingestion and the coefficient of variation of labial pressure during ingestion were significantly lower ($p<0.01$) and significantly higher ($p<0.05$), respectively.

B



This promoted the current investigation of the relationship between lip-closing function during ingestion and these events in the elderly group. It was expected that "spilling food" is closely related to lip-closing function, however, there was no significant difference between the groups.

The results suggested that "spilling food" might not be caused by lower labial pressure and poorer skilled movement of the elderly. The elderly who presented with "choking on food", having an impairment at the pharyngeal stage, showed significantly lower labial pressure and poorer skilled movement. This suggests that lip-closing function may also play an important role at the pharyngeal stage of the feeding or swallowing process. Considering that "spilling food" and "choking on food" are indicators of life prognosis (Kikutani et al, 2006), the maintenance and promotion of lip-closing function may be crucial factors for the prevention or recovery of feeding/swallowing dysfunction in patients with lip-closing dysfunction - which is one cause of feeding/swallowing impairment.Another limitation of the current study is the lack of middle aged individuals and/or children. It is important to carry out further studies including more individuals who are in their 40's and 50's or children, by means of a cross-sectional study to elucidate changes in labial pressure in each generation from children to the elderly. Furthermore, the effect of the presence or absence of dentures on labial pressure during ingestion was determined in edentulous patients by Kawamura (1979). The existence of excess pressure on lip closing was found in persons who had lost posterior occlusal support. The subjects in this study were limited to people with Eichner classification A1 - B1, and therefore, further studies will be needed to examine the relationship between the status of remaining teeth and lip function. Although the eligibility criteria employed in this study eliminated the effects of morphological changes, such as jaw position and/or missing teeth on the data obtained in this paper, the horizontal labial pressure is also influenced by lip morphology (Kawamura, 1979). Lip morphology was not examined in this study. We plan to classify lip morphology and further investigate its relationship in the future.

CONCLUSION

This study indicated that the vertical labial pressure was compensated for by greater power in place of weakened skilled movement with age. However, both skilled movement and labial pressure may decrease in the elderly needing care.

Contact Author:

Fumiyo Tamura, DDS, PhD
Rehabilitation Clinic for Speech and Swallowing Disorders
The Nippon Dental University Hospital
The Nippon Dental University,
School of Life Dentistry at Tokyo
3-16, Fujimi 2-chome, Chiyoda-ku,
Tokyo 102-8158, Japan
TEL: +81-3-3261-5511
FAX: +81-3-3261-3924
E-mail: fumita@tokyo.ndu.ac.jp

Additional Authors

Tomoko Fukui, DDS, PhD

Takeshi Kikutani, DDS, PhD

Reiko Machida, DDS, PhD
Rehabilitation Clinic for Speech and Swallowing Disorders
The Nippon Dental University School of Life Dentistry at Tokyo
Dental Hospital, 3-16, Fujimi 2-chome
Chiyoda-ku, Tokyo 102-8158, Japan

Mitsuyoshi Yoshida, DDS, PhD
Hiroshima City General Rehabilitation Center,
1-39-1, Tomominami
Asaminami-ku, Hiroshima 731-3168, Japan

Takeyoshi Yoneyama, DDS, PhD
Yoneyama Dental Clinic
1375-1, Shimotogari, Nagaizumi-cho
Sunto-gun, Shizuoka 411-0943, Japan

Akira Hamura, DDS, PhD
Division of General Dentistry
The Nippon Dental University School of Life Dentistry
Tokyo Dental Hospital, 3-16, Fujimi 2-chome
Chiyoda-ku, Tokyo 102-8158, Japan

ACKNOWLEDGMENTS

The authors thank for Professor Ken Yaegaki at Department of Hygiene, The Nippon Dental University School of Life Dentistry at Tokyo for his fruitful discussions.

Sources of funding: This study was funded by 2004 Health and Labour Sciences Research Grants, for a Comprehensive Research Project on Medical Technology Assessment "Comprehensive research on oral care methods and preventive effects of sinopulmonary infection in the elderly" from the Ministry of Health, Labour and Welfare, and 2004 Health and Labour Sciences Research Grants, for a Comprehensive Research Project on Longevity Science "Research on effects of occlusion recovery on improvement of swallowing function in the elderly" from the Ministry of Health, Labour and Welfare.

RERERENCES

Baum, B.J., & Bodner, L. (1983). Aging and oral motor function: evidence for altered performance among older persons. Journal of Dental Research. 62, 2-6.

Chigira, A., Omoto, K., Mukai, Y., & Kaneko, Y. (1994). Lip closing pressure in disabled children: a comparison with normal children. Dysphagia. 9, 193-198.

Eichner, K. (1955). Über eine Gruppeneinteilung der Lunckengebisse für die Prothetic. Deutsche Zahnarztliche Zeitschrift. 10, 1831-1834.

Floystrand, F. (1986). Vestibular and lingual muscular pressure on complete maxillary dentures. Acta Odontologia Scandinavica. 44, 71-75.

Fucile, S., Wright, P.M., Chan, I., Yee, S., Langlais, M.E., & Gisel, E.G. (1998). Functional oral-motor skills: Do they change with age? Dysphagia 13, 195-201.

Inagaki, A. (1993). Development of an estimation method of body fat percentage using body mass index, physical strength diagnosis/test for ability to exercise: for junior high school students. The Japanese Journal of Behaviormetrics. 20, 8l-91 [in Japanese]

Kaneko, Y., Mukai, Y., & Omoto, K. (1987). Impairment of eating function. Tokyo: Ishiyaku Publishers. [in Japanese]

Kawamura, Y. (1979). Oral Physiology for Dental University Students. Tokyo: Nagasue Syoten. [in Japanese]

Kikutani, T., Enomoto, R., Tamura, F., Oyaizu, K., Suzuki, A., & Inaba, S. (2006). Effects of oral functional training for nutritional improvement in Japanese older people requiring long-term care. Gerodontology. 23, 93-98.

Leopold, N.A., & Kagel, M.C. (1983). Swallowing, ingestion and dysphagia: a reappraisal. Archives of Physical Medicine and Rehabilitation. 64, 371-373.

McHenry, M.A., Minton, J.T., Hartley, L.L., Calhoun, K., & Barlow, S.S. (1999). Age-related changes in orofacial force generation in women. Laryngoscope. 109, 827-830.

Newman, D.G., Barnes, A., & Newman, J. (1983). A study of bilabial lip pressure in a normal population. Australian Orthodontic Journal. 8, 51-55.

Ono, T., Hori, K., & Nokubi, T. (2004). Pattern of tongue pressure on hard palate during swallowing. Dysphagia. 19, 259-264.

Sheth, N., & Diner, W.C. (1988). Swallowing problems in the elderly. Dysphagia. 2, 209-215.

Takahashi, M., & Mukai, Y. (2002). Relationship between labial pressure/buccal pressure and lip movement in pointing movement. Pediatric Dental Journal. 40, 64-76. [in Japanese]

Tamura, F. & Suzuki, S. (2004). Effects of edentulisum on lingual functions during swallowing. Journal of International Association for Disability and Oral Health. 5, 83-87.

Tamura, F., Tomita, K., Okano, T., Mizukami, M., Kikutani, T., & Mukai, Y. (2004). Effect of the presence or absence of full dentures on labial pressure of edentulous patients at the time of swallowing. Japanese Journal of Gerodontology. 19, 169-173. [in Japanese]

Tomita, K., Okano, T., Tamura, F., & Mukai, Y. (2002). Relationship between labial pressure and maximum labial pressure at the time of swallowing - Comparison between the elderly and adults - Japanese Journal of Dysphagia Rehabilitation. 6, 19-26. [in Japanese]

Odontology (2009) 97:38–42
DOI 10.1007/s10266-008-0094-z

ORIGINAL ARTICLE

Takeshi Kikutani · Fumiyo Tamura · Keiko Nishiwaki
Miho Kodama · Makio Suda · Tomoko Fukui
Noriaki Takahashi · Mitsuyoshi Yoshida
Yasumasa Akagawa · Misaka Kimura

Oral motor function and masticatory performance in the community-dwelling elderly

Received: July 8, 2008 /Accepted: September 30, 2008

Abstract This study was performed to ascertain the relationships between oral motor functions, such as those of the tongue and lips, and age in the community-dwelling elderly, as well as to investigate the effects of these factors on masticatory performance. The subjects were 268 healthy elderly Japanese living in Kyoto. They were divided into four age groups and further classified into the following two groups by the presence or absence of posterior occlusal support: Eichner A or B1–B3 (group A), and Eichner B4 or C (group B). They were wearing removable or fixed dentures if they had missing teeth. Oral function evaluation items included (1) masticatory performance and (2) oral motor skills. Significant differences were noted among the age groups in tongue pressure within group A ($P < 0.01$) and group B ($P < 0.05$), and in the number of repetitions of the syllables /ta/ and /ka/ in group B (/ta/: $P < 0.05$, /ka/: $P < 0.01$). The number of natural teeth ($\beta = 0.463$, $P < 0.001$) in group A and tongue pressure ($\beta = 0.436$, $P < 0.001$) in group B were the only predictors of masticatory performance when the data were analyzed by multiple regression analysis. The tongue may compensate for the missing teeth in masticatory performance of those elderly who have lost their natural teeth. The results of this study highlight the importance of tongue function in masticatory performance.

Key words Mastication · Occlusal support · Oral motor function · Community-dwelling elderly · Aging

T. Kikutani (✉) · F. Tamura · K. Nishiwaki · M. Kodama · M. Suda · T. Fukui · N. Takahashi
Rehabilitation Clinic for Speech and Swallowing Disorders, The Nippon Dental University Hospital, 3-16 Fujimi 2-chome, Chiyoda-ku, Tokyo 102-8158, Japan
Tel. +81-3-3261-5511; Fax +81-3-3261-3924
e-mail: kikutani@tokyo.ndu.ac.jp

M. Yoshida · Y. Akagawa
Department of Advanced Prosthodontics, Hiroshima University Graduate School of Biomedical Sciences, Hiroshima, Japan

M. Kimura
School of Nursing, Kyoto Prefectural University of Medicine, Kyoto, Japan

Introduction

It is well known that a decrease of masticatory performance affects nutrient intake.[1,2] Furthermore, masticatory performance, which is closely related to quality of life,[3] is essential to the maintenance of the activities of daily living in the elderly. In some reports, the number of teeth, the state of occlusal support, and denture stability have been shown to be factors associated with masticatory performance.[4–6] Mastication is controlled by suprabulbar structures, and consists of coordinated movements of masticatory organs such as the tongue, lips, cheeks, and mandible. Motor functions of these organs are known to deteriorate with age[7] and to influence masticatory performance. However, there are only a few reports on the relationships between changes in tongue and lip function and masticatory performance with age.[8] This study was performed to ascertain the relationships between motor functions of the tongue and lips and age in the community-dwelling elderly, as well as to investigate the effects of these factors on masticatory performance.

Subjects and methods

The subjects were 268 healthy elderly Japanese (86 men, 182 women) 65 to 88 years of age living in Kyoto who participated in a health seminar sponsored by Kyoto Prefectural University of Medicine.

The age groups consisted of 77 subjects 65–69 years old (22 men and 55 women), 86 subjects 70–74 years old (30 men and 56 women), 66 who were 75–79 years old (21 men and 45 women), and 39 who were 80 years or older (13 men and 26 women). All were able to walk without assistance from a caregiver or family member and had no physical or mental dysfunction, nor any speech impairment that interfered with daily activities. Moreover, the subjects had no clinical symptoms such as caries, periodontal disease, periodontitis, or temporomandibular disorders that could influence masticatory performance, and they were wearing

Table 1. Groups of subjects based on occlusal status

	Total no. of subjects (male/female)	Mean age (range) (years)	Average number of natural teeth
Group A	190 (60/130)	72.0 (67.4–76.6)	25.1 ± 4.8
Group B	78 (26/52)	76.3 (70.5–82.1)	7.6 ± 6.7

Group A, naturally adequate dentition; Group B: denture wearers

removable or fixed dentures if they had missing teeth. Subjects with pain from dentures or who were wearing poorly fitting dentures at the time of the survey were excluded from the study.

The subjects were further classified into two groups by the presence or absence of posterior occlusal support by natural teeth (Table 1): group A, subjects who still had occlusal support in the premolar and molar regions, corresponding to Eichner A or B1–B3; and group B, subjects who had no occlusal support in the premolar or molar regions, corresponding to Eichner B4 or C.

The number of natural teeth was counted, and the averages are shown in Table 1. Oral function evaluation items included (1) masticatory performance and (2) oral motor skills.

Determination of masticatory performance

Masticatory performance was measured by using a color-changeable chewing gum (Lotte, Tokyo Japan) designed for judging masticatory ability.[9] The subjects were instructed to chew the gum very hard for 3 min. The gum was collected immediately after the 3 min of chewing and pressed to a thickness of 1.5 mm by covering it with a polyethylene film and then placing it between two glass plates. Then, the glass plates were removed and color measurements of the gum with the polyethylene film were performed with a colorimeter (CR-13, Konika Minolta, Tokyo, Japan). The measurements were performed at three random points on the gum, and the average a* value was analyzed. The chewing rate was also measured.

Oral motor skills

Tongue movement was evaluated as the maximum pressure generated by the tongue pressed to the palate, by using the method of Hayashi et al.[10] The subjects were instructed to push a balloon-like sensor as hard as possible against the anterior palate using their tongues. After this maneuver had been repeated several times, until their manner of chewing had stabilized, the measurement was performed five times and the average value was calculated. The subjects were instructed to pronounce a monosyllable repeatedly for 10 s as fast as possible to test oral diadochokinesis.[11] The evaluator recorded the number of repeated syllables and calculated the number of syllables produced per second. The monosyllables used for the evaluation were /pa/, /ta/, and /ka/.

Prior to this study, we explained the objectives, method, and expected outcomes to the subjects orally and in writing and obtained their consent. This study was approved by the Ethics Committee of the Nippon Dental University, School of Life Dentistry at Tokyo.

Statistical analysis

Relationships among the age groups and the results of each oral function evaluation were analyzed by analysis of variance and Tukey's method. An unpaired t test was used to analyze the statistically significant differences in subjects between groups A and B. Furthermore, Pearson's correlation coefficient was calculated to study the relationships between the oral function evaluation items and a*. Multiple regression analysis using the stepwise method was performed, setting the items for which significant relationships were observed as independent variables. $P < 0.05$ was considered statistically significant.

Results

Relationships among oral motor function, occlusal support, and age

Relationship between masticatory performance and age. The average a* value, an indicator of masticatory performance, was greater in group A than in group B (16.0 and 12.6, respectively, $P < 0.001$). No significant differences were noted among the age groups in either group A or group B (Table 2).

Relationship between chewing rate and age. The average chewing rate in 3 min was higher (203.7) in group A than in group B (170.3) ($P < 0.001$). No significant differences were noted among the age groups within either group A or group B (Table 2).

Relationship between tongue pressure and age. The average tongue pressure value was similar in groups A and B (34. 9 and 34.2 kPa, respectively). Significant differences among the age groups were noted within both group A ($P < 0.01$) and group B ($P < 0.05$) (Table 2).

Relationship between oral diadochokinesis and age. The average number of repetitions of the syllables /pa/, /ta/ and /ka/ per second was higher in group A than in group B ($P < 0.001$). No significant differences among the age