に対する関心の低さ，適切な口腔ケアを行う知識や技術の欠如，口腔衛生の優先順位の低さなどの問題がある。したがって，専門的な知識，技術に基づいた特別な口腔衛生プログラムの導入が必要である。現在まで，口腔衛生プロトコールの実施や看護師や介護士の教育などにより，口腔衛生が短期的には改善したという報告がある[7,8]。一方，歯面に付着しているプラークには影響がなかったという報告もある[9]。これらのことから，安定した結果を得るためには，歯科医師，歯科衛生士などの専門家による介入を含んだ定期的なプラークコントロールが有効と思われる。また，専門家によるプラークコントロールがプロービング・ポケット・デプス，臨床的アタッチメント・レベル，プロービング時の出血などの歯周病学的パラメータにどのように影響するかは不明である。

本研究は，歯科衛生士による歯肉縁上プラークコントロールを2年間継続した場合の，歯面清掃状態および歯周組織に及ぼす影響を明らかにすることを目的とした。

対象および方法

1．対象者

東京都台東区の特別養護老人ホーム5施設の入居者で歯を有する88名（平均年齢81.8±9.1歳）を対象とした。

2．介入方法

研究開始時（BL）から2年間，2施設における27名の入居者では，日常のブラッシング（入居者自身，あるいは介護士による）に加え，歯科衛生士による週に一度の歯肉縁上プラークコントロールが行われた（介入群）。歯科衛生士によるプラークコントロールはシングルタフトブラシ，歯間ブラシおよび歯ブラシ，フッ化ナトリウム配合歯磨剤または0.05%クロルヘシジン配合洗口剤を使用し，一人につき3〜10分行われた。他の3施設の入居者61名では自身またはヘルパーによるブラッシングが行われた（対照群）。対象者または家族および各施設には歯周疾患の検査を行うこと，口腔衛生に関する介入を行うこと，および検査結果を個人が特定できない形で公表する承認を書面にて得た。本研究は日本歯科大学生命歯学部倫理委員会の承認を得て行われた（承認番号2110）。

3．検査項目

BLと2年後に現在歯数などを含む一般的な歯科検診の他に，以下の歯周病パラメータについて，2名の歯周病専門医が，TUCLプローブ，Williamsタイプ（株式会社シオダ）を用い，4点法により智歯および残根を除くすべての現在歯について計測を行った。

1）プラーク指数(PII, Silness と Löe, 1964)[10]

スコア0：歯面が清潔

スコア1：歯面は清潔にみえるが鋭利なプローブを用いて歯肉面3点からプラークが除去できる

スコア2：視認できるプラーク

スコア3：多量のプラークで歯面が覆われている。

2）プロービング・ポケット・デプス（PPD）

手用プローブにより，歯肉辺縁から歯周ポケット底部までの距離を1 mm単位で測定した。

3）臨床的アタッチメント・レベル（CAL）

手用プローブにより，セメント-エナメル境または修復物辺縁から歯周ポケット底部までの距離を1 mm単位で測定した。

4）プロービング時の出血（BOP）の有無

手用プローブを歯周ポケットに挿入した後，10秒以内に出血がみられた場合をBOP陽性として記録した。

研究開始前に，2名の測定者がプロービングの再現性を高めるための打ち合わせと確認を行った。無作為に選ばれた5名の入居者に対して，全顎のプロービングを2度ずつ行った結果，PPDとCALについて同一測定者および測定者間の標準偏差が0.5未満で，±1 mmの範囲で一致する確率は95%となった。

4．データの分析

各群の男女比，平均年齢，平均現在歯数の各パラメータのBLと2年後のデータの差の2群間の統計学的有意差をt検定により解析した。また2群間の要介護度，食形態の分布，口腔乾燥の有無および喪失歯数の差はカイ二乗検定により解析した。

表1　介入群，対照群の男女比，平均年齢，平均現在歯数

	N(男/女)	平均年齢 (S.D.)	平均現在歯数 (S.D.)
介入群	15 (10/5)	80.5(8.4)	11.3(6.5)
対照群	34(13/21)	79.6(9.0)	10.7(7.7)

表2　介入群，対照群における背景因子

		介入群	対照群
要介護度(%)	1	13.3	3.2
	2	6.7	3.2
	3	26.7	16.1
	4	46.7	58.1
	5	6.7	19.4
食形態(%)	普通食	53.8	44.1
	きざみ食	34.6	35.3
	流動食	7.7	5.9
	経管	3.8	14.7
口腔乾燥あり(%)		25.9	36.4

研究期間中，39名（介入群12名，対照群27名）が転居または死亡したため，解析から除外した。その結果，介入群15名，対照群34名が解析対象となった。

結　果

表1に各群の被験者の男女比，平均年齢，平均現在歯数，表2にその他の各群の背景因子を示す。介入群と対照群とで統計学的有意差はみられなかった。

平均PIIは，介入群においては2年間で0.3±0.4減少し，対照群では0.1±0.8増加し，両群間に統計学的有意差がみられた($p<0.05$，図1)。平均PPDは介入群では2.4±0.3mmから2.6±0.3 mmに，対照群では2.5±0.4 mmから2.8±0.4 mmに増加した（図2)。平均CALは介入群では4.1±1.3 mmから4.1±1.0 mmと大きな変化はなかったが，対照群では3.6±1.3 mmから3.8±1.0 mmに増加した（図3)。平均BOPは介入群では28.5±14.6%から36.9±18.0%に，対照群では31.2±21.1%から40.1±23.6%に増加した（図4)。しかしながら，平均PPD，平均CAL，平均BOPのBLから2年後の変化量に関して，2群間で統計学的有意差はみられなかった。

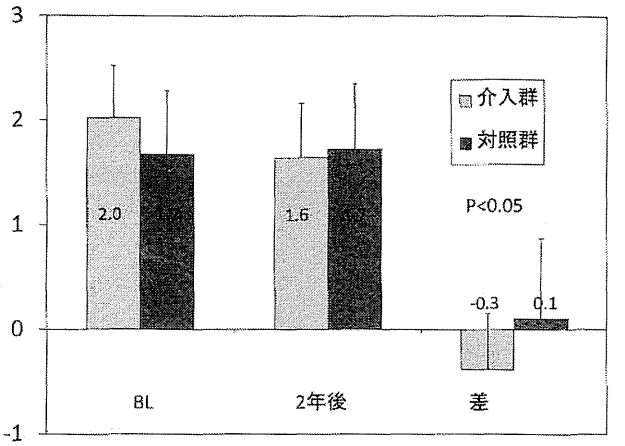

図1　介入群，対照群における平均PII(±S.D.)

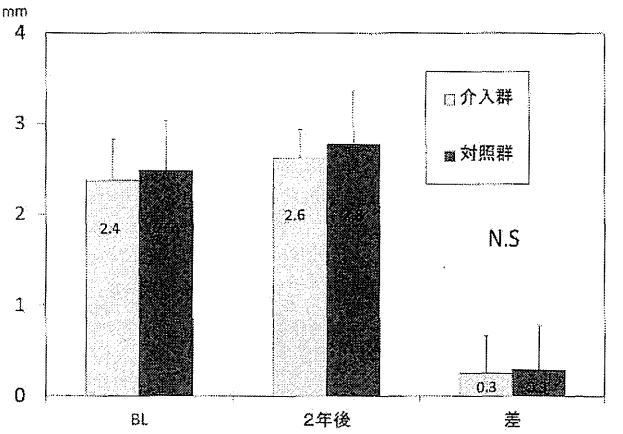

図2　介入群，対照群における平均PPD(mm,±S.D.)

BLから2年後の間に，介入群においては199歯中17歯(8.5%)喪失し，対照群において311歯中36歯（11.6%）が喪失したが，2群間で統計学的有意差はみられなかった（表3)。

考　察

本研究では，介護老人福祉施設入居者において，週に一度歯科衛生士が歯肉縁上プラークコントロールを行う口腔衛生プログラムを2年間継続した被験者において，従来の口腔衛生習慣が継続された対照群と比較して，プラークスコアが有意に改善された。MacEnteeら[11]の報告では，介護士が口腔の健康に関する講義を歯科衛生士から教育を受けた看護教育者から受講し，その後3カ月間，無制限に口腔の健康に関するアドバイスを受けたが，施設入居者の口腔衛生に影響しなかった。また，De Visschere

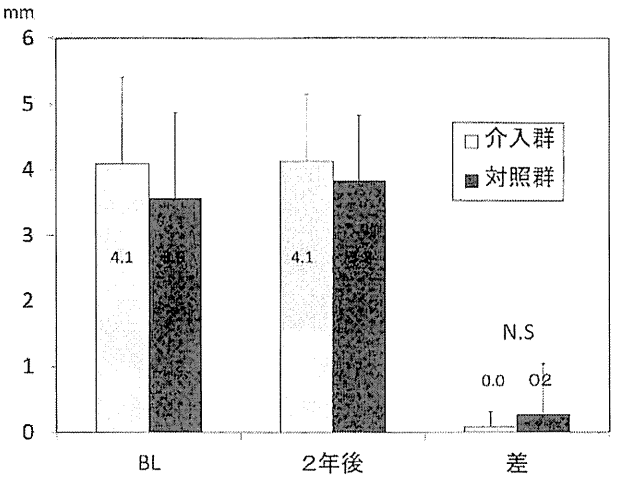

図3　介入群，対照群における平均 CAL（mm，±S.D.）

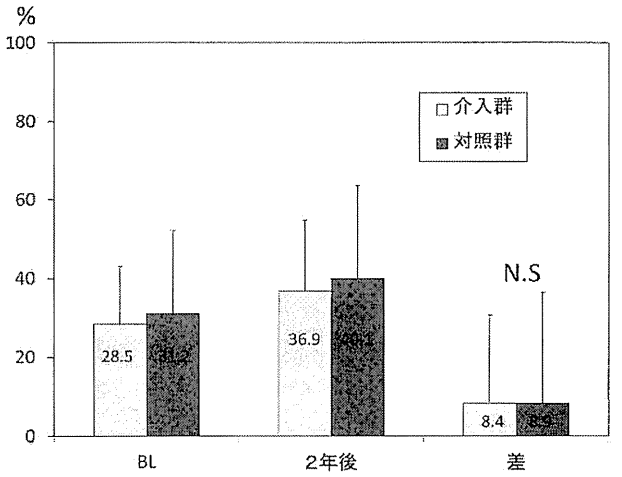

図4　介入群，対照群における平均 BOP（%，±S.D.）

ら[9]は，ガイドラインに基づいた口腔衛生プロトコールの実施にあたり，専門家による教育，監視が行われた場合，デンチャープラークに対しては効果があったが，舌や歯面に付着したプラークに対しては効果がなかったことを報告した。本研究においては，介護士への特別な教育は行われていないが，プラーク形成量が有意に減少したのは，専門家の介入頻度や技術の影響と考えられる。

PPD，CAL，BOP の変化に関しては介入群と対照群で差異がみられなかった。歯肉縁上プラークコントロールの歯周炎に対する効果についてはいくつかの報告がある。Dahlén ら[12]は，一般市民に対して口腔衛生指導を3カ月間行った結果，2年後に，歯肉縁下の細菌数の減少や歯周病関連細菌の比率の減少がみられたことを報告した。さらに Hellström ら[13]は，慢性歯周炎患者の5 mm 以上の歯周ポケットを対象とした研究で，ブラッシング指導および週に2～3回の専門家による口腔清掃を30週間継続した場合，骨縁上ポケット，骨縁下ポケット，根分岐部病変のいずれの場合でも，歯肉縁下の細菌数，*Porphyromonas gingivalis* の比率の減少がみられたことを報告した。Ximénez-Fyvie ら[14]の，週に一度専門家によるプラークコントロールを1年間継続した研究も同様の結果が得られている。他方，歯肉縁上プラークコントロールは歯肉縁下の細菌層に影響を与えなかったとの報告もあり[15,16]，さらに Westfelt ら[17]は，PPD 7 mm 以上の部位に3年間歯肉縁上プラークコントロールを継続したのみで，歯肉縁下のデブライドメントを行わなかった結果，約3分の1の部位にアタッチメントロスが起こったことを報告している。

表3　介入群，対照群における2年間での歯の喪失状況

	喪失歯率（%）	喪失歯数/BL 時の現在歯数
介入群	8.5	17/199
対照群	11.6	36/311

これらの結果の違いについての解釈は困難であるが，プラークコントロールの水準や頻度，歯周炎の程度の違い等が影響したと考えられる。本研究においても歯肉縁上プラークコントロールが定期的に行われた介入群でプラーク指数の平均値が改善はしたものの，プラークスコア2以上を示した歯面の割合は 61.8% で，前述の Hellström ら[13]の研究で 20% 以下であったことと比較すると歯面清掃状態は悪く，そのことが歯周病学的パラメータの改善に繋がらなかった可能性が考えられる。歯面清掃状態が対照群と比較して改善したことから，専門家による継続的な歯面清掃そのものの効果は期待できると考えられるが，歯周病学的パラメータを改善させ得るものにするためには，週に2～3度歯面清掃を行うなど，介入の回数を増やすことや，介護職員への口腔衛生についての教育の徹底などが必要と考えられる。

介入群において歯の喪失数が少なくなる傾向がみられたが，統計学的有意差はみられなかった。高齢者における歯の喪失原因の多くはう蝕とそれに関連

した要因があるという報告[18]や，義歯の鉤歯がリスクとなるという報告[19]もあり，歯周疾患以外の原因への対応が今後必要であろう。さらに，プラークコントロールの改善度をより高めるための，新たな口腔衛生プログラムを立案する必要があると考えられる。

結　論

専門家による週に一度のプラークコントロールを2年間継続した結果，対照群と比較して，

1．歯面清掃状態が有意に改善した。

2．平均CALは増加しなかったが有意な差はみられなかった。

3．平均PPD，平均BOPに有意差はみられなかった。

4．歯の喪失率が少ない傾向があったが統計学的有意差はみられなかった。

今後は，口腔衛生プログラム，介入の頻度や方法の改善，う蝕予防処置の導入などを取り入れた上で，長期的かつ大規模な研究を行う必要があると考えられた。

謝　辞

本研究は，平成24年度厚生労働科学研究費補助金（循環器疾患・糖尿病等生活習慣病対策総合研究事業）歯科介入型の新たな口腔管理法の開発及び介入効果の検証等に関する研究（課題番号）（H24-循環器等（歯）-一般-001）の援助および東京都台東区歯科医師会の協力を得て行われた。

文　献

1）関野　愉，久野彰子，菊谷　武，田村文誉，沼部幸博，島田昌子：介護老人福祉施設入居者の歯周疾患罹患状況，日歯周誌，**51**：229～237，2009.

2）Axelsson, P. and Lindhe, J.：Effect of controlled oral hygiene procedures on caries and periodontal disease in adults. Results after 6 years, J. Clin. Periodontol., **8**：239～248, 1981.

3）De Visschere, L. M., Grooten, L., Theuniers, G., Vanobbergen, J.N.：Oral hygiene of elderly people in long-term care institutions—a cross-sectional study, Gerodontology, **23**：195～204, 2006.

4）Tramini, P., Montal, S. and Valcarcel, J.：Tooth loss and associated factors in long-term institutionalised elderly patients, Gerodontology, **24**：196～203, 2007.

5）Padilha, D.M., Hugo, F.N., Hilgert, J.B. and Dal Moro, R. G.：Hand function and oral hygiene in older institutionalized Brazilians, J. Am. Geriatr. Soc., **55**：1333～1338, 2007.

6）Morishita, M., Takaesu, Y., Miyatake, K., Shinsho, F. and Fujioka, M.：Oral health care status of home-bound elderly in Japan, J. Oral Rehabil., **28**：717～720, 2001.

7）Frenkel, H., Harvey, I. and Needs, K.：Oral health care education and its effect on caregivers' knowledge and attitudes：a randomised controlled trial, Community Dent. Oral Epidemiol., **30**：91～100, 2002.

8）Budtz-Jørgensen, E., Mojon, P., Rentsch, A. and Deslauriers, N.：Effects of an oral health program on the occurrence of oral candidosis in a long-term care facility, Community Dent. Oral Epidemiol., **28**：141～149, 2000.

9）De Visschere, L., Schols, J., van der Putten, G.J., de Baat, C. and Vanobbergen, J.：Effect evaluation of a supervised versus non-supervised implementation of an oral health care guideline in nursing homes：a cluster randomised controlled clinical trial, Gerodontology, **29**：e96～e106, 2012.

10）Silness, J and Löe, H.：Periodontal disease in pregnancy. II. Correlation between oral hygiene and periodontal condition, Acta Odontologica Scanginavica., **24**：747～759, 1964.

11）MacEntee, M.I., Wyatt, C.C., Beattie, B.L., Paterson, B., Levy-Milne, R., McCandless, L. and Kazanjian, A.：Provision of mouth-care in long-term care facilities：an educational trial, Community Dent. Oral Epidemiol., **35**：25～34, 2007.

12）Dahlén, G., Lindhe, J., Sato, K., Hanamura, H. and Okamoto, H.：The effect of supragingival plaque control on the subgingival microbiota in subjects with periodontal disease, J. Clin. Periodontol., **19**：802～809, 1992.

13）Hellström, M.K., Ramberg, P., Krok, L. and Lindhe, J.：The effect of supragingival plaque control on the subgingival microflora in human periodontitis, J. Clin. Periodontol., **23**：934～940, 1996.

14）Ximénez-Fyvie, L. A., Haffajee, A. D., Som, S., Thompson, M., Torresyap, G. and Socransky, S.S.：The effect of repeated professional supragingival plaque removal on the composition of the supra- and subgingival microbiota, J. Clin. Periodontol., **27**：637～647, 2000.

15）Kho, P., Smales, F.C. and Hardie, J.M.：The effect of supragingival plaque control on the subgingival microflora, J. Clin. Periodontol., **12**：676～686, 1985.

16）Beltrami, M., Bickel, M. and Baehni, P. C.：The effect of supragingival plaque control on the composition of the subgingival microflora in human periodontitis, J. Clin. Periodontol., **14**：161～164, 1987.

17）Westfelt, E., Rylander, H., Blohmé, G., Jonasson, P. and Lindhe, J.：The effect of periodontal therapy in diabetics. Results after 5 years, J. Clin. Periodontol., **23**：92～100, 1996.

18）Chen, X. and Clark, J. J.：Tooth loss patterns in

older adults with special needs：a Minnesota cohort, Int. J. Oral Sci., 3：27～33, 2011.
19) Hirotomi, T., Yoshihara, A., Ogawa, H. and Miyazaki, H.：Tooth-related risk factors for tooth loss in community-dwelling elderly people, Community Dent. Oral Epidemiol., 40：154～163, 2012.

Effect of Regular Professional Supragingival Plaque Control in Elderly Nursing Home Residents：A Two-Year Study

Satoshi Sekino[1)], Takeshi Kikutani[2)], Fumiyo Tamura[2)], Akiko Hisano[3)], Yuzo Fujita[1)] and Yukihiro Numabe[1)]

[1)]Department of Periodontology, School of Life Dentistry at Tokyo, The Nippon Dental University
[2)]Tama Oral Rehabilitation Clinic , The Nippon Dental University, Dental Hospital
[3)]Division of General Dentistry, The Nippon Dental University Hospital

The purpose of this study was to clarify the effect of regular professional supra-gingival plaque control over 2 years on the dental hygiene status and periodontal conditions of elderly in need of care. The subjects were 88 nursing home elderly (mean age：81.8±9.1 years) in Taito-ku, Tokyo. Thirty nine subjects were excluded because they either moved away or died. Fifteen residents received weekly supra-gingival plaque control performed by dental hygienists in addition to habitual tooth brushing methods by themselves and/or helpers (intervention group) for a baseline. In another 34 subjects, self-performed tooth brushing and/or brushing by helpers were continued (control group). Probing pocket depth (PPD), clinical attachment level (CAL), bleeding on probing (BOP), plaque index (PlI) were recorded at baseline and 2 years. Reduction of mean PlI in the intervention group was 0.3±0.4 in 2 years, while in the control group, mean PlI increased by 0.1±0.8. The differences were statistically significant ($p<0.05$). There were no statistically significant differences with respect to mean PPD, mean CAL and mean BOP between the groups. In the intervention group, 17 out of 199 teeth were lost (8.5%), while 36 out of 311 teeth were lost (11.6%) in the control group. These results demonstrated that systemic professional oral care performed by dental hygienist improved the oral hygiene status in elderly residents in nursing homes. A further large-scale study on the introduction of a meticulous oral hygiene program is necessary.

Key words：elderly residents in nursing home, dental hygienist, plaque control, periodontitis, tooth loss

Archives of Gerontology and Geriatrics xxx (2012) xxx–xxx

Contents lists available at SciVerse ScienceDirect

Archives of Gerontology and Geriatrics

journal homepage: www.elsevier.com/locate/archger

Tooth loss as risk factor for foreign-body asphyxiation in nursing-home patients

Takeshi Kikutani [a,b,*], Fumiyo Tamura [b], Takashi Tohara [b], Noriaki Takahashi [b], Ken Yaegaki [c]

[a] Division of Clinical Oral Function, The Nippon Dental University Graduate School of Life Dentistry, 3-16 Fujimi 2-chome, Chiyoda-ku, Tokyo 102-8158, Japan
[b] 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
[c] Department of Community Dentistry, The Nippon Dental University School of Life Dentistry at Tokyo, 9-20 Fujimi 1-chome, Chiyoda-ku, Tokyo 102-8159, Japan

ARTICLE INFO

Article history:
Received 21 June 2011
Received in revised form 24 January 2012
Accepted 26 January 2012
Available online xxx

Keywords:
Tooth loss
Foreign-body asphyxiation
Nursing-home
Self-feeding ability

ABSTRACT

Foreign body asphyxiation causes severe medical conditions including pneumonia in the elderly requiring nursing care. The objective of this study was to elucidate the relationships between insufficient occlusal support due to tooth loss and the onset of asphyxiation accidents, and determine preventive measures for such accidents in nursing homes in Japan. The subjects were 437 elderly (110 men and 327 women) requiring nursing care. The frequency and risk factors for asphyxiation accidents and the food causing asphyxiation were examined in these subjects for 2.5 years, from June 2006 to December 2008. During the study period, 51 of the 437 subjects suffered asphyxiation. Self-feeding ability and loss of occlusal support were associated with a covariate-adjusted relative ratio for asphyxiation of 3.1 (95% confidence interval (CI) = 1.50–6.44) and 1.7 (95% CI = 1.12–2.74), respectively. To prevent asphyxiation in elderly people, it was found that maintaining or restoring occlusal support may be required. It was concluded that self-feeding ability and loss of occlusal support are significant risk factors for foreign-body asphyxiation among elderly people requiring nursing care.

1. Introduction

Asphyxiation occurs when any object is aspirated into the larynx or tracheobronchial tree, and causes airway obstruction: this obstruction can result in inability to breathe, with the need for rapid intervention to prevent asphyxial death (Ekberg and Feinberg, 1992). Therefore, asphyxiation cases are identified by signs and symptoms of dyspnea, abnormal respiratory rate, rhythm/depth of breathing, restlessness and cyanosis. Asphyxia is reported to be a common cause of death not only in the general population (Feinberg et al., 1992), but also in infants (<1 year of age) and the elderly. To date, a high frequency (incidence: 0.66 fatalities/100,000) of asphyxia has been reported in the general population each year (Fioritti et al., 1997). In Japan, deaths from asphyxiation have increased since the 1980s. Moreover, the mortality from asphyxiation incidents in infants has decreased by more than 60% in the past 30 years. However, mortality from asphyxiation in the elderly has increased rapidly (Ichikawa and Marui, 2000). This represents an important warning regarding asphyxiation to both elderly receiving care and their caregivers.

Samuels and Chadwick (2006) reported rapid eating, cramming of food into the mouth, and premature transfer of food into the pharynx as possible causes of asphyxiation in the elderly. Several reports have also suggested that oral stage dysfunction and cognitive impairment contribute to asphyxiation (Carter and Jancar, 1984; Feinberg et al., 1992; Finestone et al., 1998). A huge number of elderly people, including those requiring nursing care, lose teeth and/or occlusal support, resulting in decreased oral function (Hatch et al., 2001). Since wearing dentures is related to oral function, speech function and independent activities of daily living (Minakuchi et al., 2006), elderly people who lose occlusal support must wear dentures. However, it is sometimes difficult for elderly people requiring nursing care to wear dentures, for many reasons including mismanagement of dentures, losing dentures, and shortage of oral-care services. There have been few reports on the relationship between asphyxiation accidents and insufficient occlusal support due to tooth loss or failure to restore occlusal support by means of dentures. Haddon suggested that it is possible to eliminate these risk factors related to accidental death. Even when accidents do occur, the worst outcome can be avoided by thorough application of appropriate measures during and after an accident (Haddon, 1980).

In the present study, we examined the risk factors for asphyxiation accidents among the elderly in nursing homes, and determined the relationships among insufficient occlusal support caused by tooth loss, restoration of occlusal support by means of dentures, and asphyxiation accidents.

* Corresponding author at: 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.
Tel.: +81 3 3261 5511; fax: +81 3 3261 3924.
E-mail address: kikutani@tokyo.ndu.ac.jp (T. Kikutani).

0167-4943/$ – see front matter © 2012 Published by Elsevier Ireland Ltd.
doi:10.1016/j.archger.2012.01.010

2. Materials and methods

2.1. Participants

The survey was conducted in 486 individuals (mean age: 85.0 ± 8.5 years), whose guardians gave consent to their participation in the present study, among elderly people requiring care in 13 nursing homes in Japan. Of them, those who were discharged from nursing homes ($n = 49$) because of other reasons than asphyxiation were excluded from this study, since we could no longer peruse them. The study was performed on 437 subjects (110 men and 327 women; mean age, 80.8 ± 8.3 years for men and 86.4 ± 8.1 years for women; Barthel index, 25.1 ± 25.0).

2.2. Survey of asphyxiation

Asphyxiation occurring while eating food over a period of 2 years and 6 months from June 2006 to December 2008 was examined, and the outcomes were also determined. In this study, asphyxiation accidents were limited to those caused by food.

Asphyxiation cases were identified by signs and symptoms such as dyspnea, abnormal respiratory rate, rhythm/depth of breathing, restlessness and cyanosis as reported by the North American Nursing Diagnosis Association (2003).

2.3. Examination of risk factors for asphyxiation

The following six items were assessed to examine the risk factors for asphyxiation. In terms of the oral environment and oral function, the procedures used by dentists and physicians in each nursing home were studied.

2.3.1. Self-feeding ability

Subjects who could feed themselves at least partly without any help were assigned to the "independent group" and those who were able to eat only with assistance were assigned to the "dependent group".

2.3.2. Activity of daily living (ADL)

ADL in these subjects was evaluated using the Barthel Index (Mahoney and Barthel, 1965). When the index was 45 points or higher, ADL was considered to be maintained, and when the index was less than 40 points, ADL was considered to be decreased.

2.3.3. Cognitive function

The severity of senile dementia was evaluated according to "ADL independence of demented elderly", designed by the Ministry of Health, Labour and Welfare of Japan (http://www.mhlw.go.jp:80/topics/kaigo/kentou/15kourei/sankou4.html; Hirakawa et al., 2008). Cognitive impairment was identified at rank 2 and higher of this scale (Table 1).

2.3.4. Tongue coating

Tongue coating was visually evaluated according to the report by Miyazaki et al. (1995). We divided the scores into two groups (no, score 0 and 1; yes, score 2 and 3).

2.3.5. Food residue

We assessed food residue in the oral region after a meal (Ono et al., 2007).

2.3.6. Xerostomia

The presence or absence of xerostomia was examined. The categories reported by Kakinoki et al. (2004) were dry, mildly dry, wet (normal) and wet (high). The categories of dry and mildly dry were considered to indicate xerostomia.

Table 1
ADL independence of demented elderly (Ministry of Health, Labour and Welfare of Japan).

Rating criteria	Description
Rank 0	Clear mentality
Rank 1	Although demented, the subject is almost independent in ADL at home or elsewhere
Rank 2	The subject shows slight impairment of cognition, but is independent under a carer's observation
Rank 3	The subject sometimes shows impairment of cognition, thus a carer is required
Rank 4	The subject often shows impairment of cognition, thus a carer is required all time
Rank 5	The subject shows serious mental symptoms or problematic behavior, thus specific medical care is required

2.4. Assessment of oral function

Assessment of oral function was performed based on the current number of teeth, occlusal condition and presence or absence of swallowing disorder.

2.4.1. Assessment of occlusal condition

With regard to the occlusal condition, the Eichner classification of occlusal support regions (Eichner, 1955) was used for reference. Subjects with an Eichner occlusal support classification of A1–B1, who had occlusal support in at least three sites in the molars, were assigned to the "natural occlusal support group". Those in whom occlusal support was restored with removable dentures were assigned to the "denture occlusal support group". Those with occlusal support in two or fewer sites with an Eichner classification of B2–C3, with no occlusal support in the molars, and unrestorable occlusal support using removable dentures were assigned to the "occlusal support disruption group".

2.4.2. Swallowing disorder

Swallowing disorder was defined as cases in which choking or accidental aspiration occurred, and cases that showed a gurgling sound on auscultation of the neck region (Takahashi et al., 1994) after swallowing 3 ml of water.

2.5. Survey of diagnosis

The presence or absence of general conditions that might have affected swallowing function was determined.

2.6. Survey of concomitant medication

Medication that might have affected oropharyngeal function (e.g., psychotropic agents, antidepressants) (Carl and Johnson, 2006) was investigated.

2.7. Statistical analysis

Chi-squared test was used to determine the independence of each group in two-group comparisons. Risk factors were screened by logistic analysis of variance using the presence or absence of a history of asphyxiation as a dependent variable and the presence of significant factors as an independent variable. The stepwise method (backward elimination method) was used for variable selection. Windows Japanese version SPSS (Ver. 16) was used for statistical analysis, and the level of significance was a p value of <0.05.

Please cite this article in press as: Kikutani, T., et al., Tooth loss as risk factor for foreign-body asphyxiation in nursing-home patients. Arch. Gerontol. Geriatr. (2012), doi:10.1016/j.archger.2012.01.010

Table 2
Univariate analysis of subjects' demographics.

		Asphyxiation ($n=51$)	No asphyxiation ($n=386$)	Relative risk (95% CI)	p value
Sex	Male	10	100	1.43 (0.69–2.97)	0.21
	Female	41	286		
Self feeding	Independent	41	209	3.47 (1.69–7.13)	<0.001
	Dependent	10	177		
ADL	Maintained	34	312	2.11 (1.12–3.98)	0.02
	Decreased	17	74		
Cognitive function	Maintained	28	117	2.80 (1.55–5.06)	<0.001
	Decreased	23	269		
Tongue coating	Yes	20	135	1.20 (0.66–2.19)	0.55
	No	31	251		
Food residue	Yes	20	157	0.93 (0.51–1.69)	0.32
	No	31	222		
Xerostomia	Yes	15	132	0.80 (0.42–1.52)	0.44
	No	36	254		
Occlusal support	Natural occlusal support	5	83		
	Denture occlusal support	16	153		0.02
	Occlusal support disruption	30	150		
Swallowing disorder	Yes	27	124	2.38 (1.32–4.29)	0.03
	No	24	262		
Previous stroke	Yes	19	212	0.72 (0.40–1.32)	0.18
	No	32	174		
Drug administration	Yes	16	110	1.15 (0.61–2.16)	0.39
	No	35	276		

3. Results

3.1. Incidence of asphyxiation

Fifty-one subjects suffered asphyxiation due to food (10 men and 41 women; mean age, 85.6 ± 7.1 years). The annual incidence of asphyxiation accidents was 4.7%. Four subjects had two or more episodes of asphyxiation during the period (four times: one subject, three times: two subjects, two times: one subject). Death caused by asphyxiation occurred in two subjects.

The food causing asphyxiation was fruit in seven subjects, vegetables in four, meat in four, fish in four, rice in three, bread in one, and others in six. There were 29 unclear cases where several foods were involved. There could be multiple causes in those subjects. After the onset of asphyxiation, 13 subjects (25.5%) were transferred to an emergency clinic or hospitalized, but two of them died in hospital within 24 h.

3.2. Risk factors

Factors showing a significant relationship with the onset of asphyxiation were self-feeding [$p < 0.001$, relative risk = 3.47 (1.691–7.131)], ADL [$p = 0.02$, relative risk = 2.11 (1.12–3.98)], and cognitive function [$p < 0.001$, relative risk = 2.80 (1.55–5.06)]. Among 180 subjects who had lost occlusal support with their natural teeth and did not regain occlusion, 30 subjects (16.7%) suffered asphyxiation. However, among 169 subjects whose occlusal support was restored with dentures, 16 subjects (9.5%) suffered asphyxiation, and among 88 subjects with occlusal support with their natural teeth, 5 subjects (5.7%) suffered asphyxiation. The incidence of asphyxiation showed a significant difference ($p = 0.016$) among the three groups (Table 2) (Fig. 1).

3.3. Survey of diagnosis

The presence or absence of general conditions that might have affected swallowing function was determined, and found out that none of them had affected swallowing function (Table 3).

3.4. Results of logistic analysis

Risk factors were screened by logistic analysis of variance using the presence or absence of a history of asphyxiation as a dependent variable and the presence of significant factors in univariate analysis as an independent variable. The stepwise method (backward elimination method) was used for variable selection. As a result, "self-feeding" ($p < 0.001$, relative risk = 3.11, 95% CI:

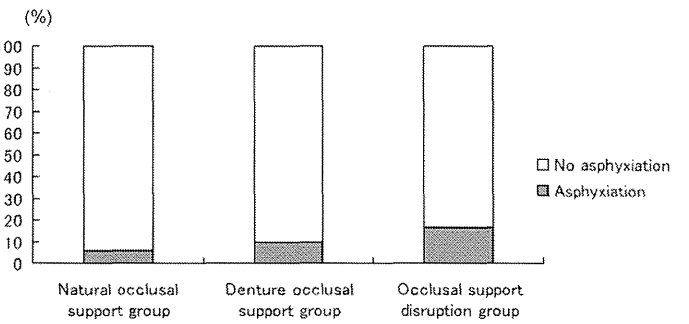

Fig. 1. Relationship between dental status and incidence of asphyxiation. Among 171 subjects who had lost occlusal support with their natural teeth and did not regain occlusion with dentures, 30 subjects (17.5%) suffered asphyxiation. Among 215 subjects whose occlusal support was restored by means of dentures, 21 subjects (9.8%) suffered asphyxiation. Among 113 subjects with occlusal support with their natural teeth, 5 subjects (4.4%) suffered asphyxiation ($p = 0.016$, chi-squared test).

Please cite this article in press as: Kikutani, T., et al., Tooth loss as risk factor for foreign-body asphyxiation in nursing-home patients. Arch. Gerontol. Geriatr. (2012), doi:10.1016/j.archger.2012.01.010

Table 3
Univariate analysis of subjects' general conditions.

		Asphyxiation ($n=51$)	No asphyxiation ($n=386$)	Relative risk (95% CI)	p value
Cerebrovascular disease	Yes	19	212	0.72 (0.40–1.32)	0.180
	No	32	174		
Neuromuscular disease	Yes	5	25	1.57 (0.57–4.30)	0.264
	No	46	361		
Cardiac disease	Yes	4	48	0.60 (0.21–1.74)	0.242
	No	47	338		
Respiratory disease	Yes	4	18	1.74 (0.57–5.36)	0.247
	No	47	368		
Diabetes	Yes	1	5	1.52 (0.17–13.31)	0.527
	No	50	381		
Bone and joint disease	Yes	16	97	1.36 (0.72–2.57)	0.395
	No	35	289		

1.50–6.44) and "occlusal support" ($p = 0.01$, relative risk = 1.75, 95% CI: 1.12–2.73) were selected as significant explanatory variables (Table 4).

4. Discussion

The annual incidence per capita of asphyxiation accidents in the present study was 4.7 per 1000 population in Japan; this is lower than the results from previous research carried out at day-care facilities for elderly people (Takahashi et al., 1994). The incidence of asphyxiation among elderly people in care facilities for the aged was clearly higher than that of elderly people living at home. The elderly people in care facilities appeared to be frailer than those who received care at home. Although the frequency was generally low, accidents were often fatal. Our results show that many individuals were hospitalized after asphyxiation accidents and some of them died. Among the subjects with asphyxiation, approximately 8% had several asphyxiation episodes during the study period, which is four times higher than that reported previously (Suda et al., 2008). Those who suffered several asphyxiation accidents were considered to be at higher risk of death.

We demonstrated that factors related to asphyxiation accidents include self-feeding, ADL, cognitive function, occlusal support of molars, and swallowing disorders. Of these, there was a strong correlation between occlusal support of molars and the incidence of asphyxiation. Many elderly people lose their teeth because of dental caries or periodontal disease, and many of those in the present study had lost occlusal support with their natural teeth. This may lead to reduced chewing ability in elderly people (Hatch et al., 2001). However, the rate of use of dentures, especially among frail individuals, is known to be low. The ability to use dentures is reduced by impaired cognitive function, apraxia, and spatial cognition disorders and is known to be affected by a decrease in ADL (Carter and Jancar, 1984).

We demonstrated that cognitive function is one of the risk factors for asphyxiation. In elderly people with reduced cognitive function requiring nursing care, it has been reported that swallowing without chewing as well as cramming food into the mouth often occurs (Samuels and Chadwick, 2006). These people have also been reported to show symptoms of fast-eating syndrome (Bazemore et al., 1991). In fact, many elderly people with dementia die because of accidental swallowing or asphyxiation (Brunnström and Englund, 2009). In comparison with patients with cerebrovascular dementia, patients with frontotemporal dementia are known to have abnormal eating habits, including cramming food and eating fast (Bathgate et al., 2001), which makes it necessary to take measures to prevent asphyxiation in accordance with the type of dementia.

Table 4
Independent predictors of asphyxiation.

	Coefficient (±S.E.)	p value	Relative risk	95% CI	
				Lower	Upper
Self feeding	1.13 (±0.37)	<0.001	3.11	1.50	6.44
Occlusal support	0.56 (±0.23)	0.01	1.75	1.12	2.73

S.E.: standard error.

It is interesting that the incidence of asphyxiation showed a strong association with the ability to self-feed. The ability to understand the use of eating utensils, a sufficient range of arm motion, and coordination of both arms and oral function are necessary for self-feeding. Good management of self-feeding ability is an important factor in maintaining quality of life of the elderly. According to Volicer et al. (1987), (50)% of patients with Alzheimer disease lose the ability to self-feed within 8 years after diagnosis. Apraxia and spatial-cognitive disorders cause problems in self-feeding ability. Many diseases associated with dementia are considered to impair self-feeding ability. To improve or maintain self-feeding ability, it is necessary to undertake very complex measures based on an understanding of one's own chewing function and swallowing function, and on selection of food in accordance with those functions. If selection of food is necessary, reprocessing of food could be undertaken such as by subdividing, cutting or mixing, to make the food match the functions mentioned above. Every individual must consider the pace of eating by coordinating the amount of food in each bite to prevent accidents.

The results of this study suggest that absence of occlusal support is a risk factor for asphyxiation. Individuals who had lost occlusal support with their natural teeth showed a higher risk of asphyxiation than those with occlusal support. These results suggest that restoration of occlusal support with dentures might be an effective procedure to prevent asphyxiation. If dentists undertook measures based on continuous dental management for frail elderly people, more people might become able to wear dentures (Kawana et al., 2010). Prevention of dental caries and periodontal diseases that cause tooth loss is, of course, essential to prevent loss of occlusal support, and should be included in the management plan. Maintenance of occlusal support for frail elderly people by means of continuous management by dentists is also effective to prevent asphyxiation.

To further prevent asphyxiation and eat safely in elderly people with little ability to control the speed and amount of food, it is important to assist such people while taking food, rather than encourage them to improve their self-feeding ability.

Please cite this article in press as: Kikutani, T., et al., Tooth loss as risk factor for foreign-body asphyxiation in nursing-home patients. Arch. Gerontol. Geriatr. (2012), doi:10.1016/j.archger.2012.01.010

Conflict of interest statement

None.

Acknowledgments

This study was supported by a Grant-in-Aid (20-17) and a Research Grant for Longevity Science (21-2) from of the Ministry of Health, Labour and Welfare, Japan (2009).

The authors thank all the patients and caregivers, and the nurses who participated in the study.

References

Bathgate, D., Snowden, J.S., Varma, A., Blackshaw, A., Neary, D., 2001. Behaviour in frontotemporal dementia, Alzheimer's disease and vascular dementia. Acta Neurol. Scand. 103, 367–378.

Bazemore, P.H., Tonkonogy, J., Ananth, R., 1991. Dysphagia in psychiatric patients: clinical and videofluoroscopic study. Dysphagia 6, 2–5.

Brunnström, H.R., Englund, E.M., 2009. Cause of death in patients with dementia disorders. Eur. J. Neurol. 16, 488–492.

Carl, L.L., Johnson, P.R., 2006. Drugs and Dysphagia: How Medications Can Affect Eating and Swallowing. Pro-Ed, Austin, TX.

Carter, G., Jancar, J., 1984. Sudden deaths in the mentally handicapped. Psychol. Med. 14, 691–695.

Eichner, K., 1955. Über eine Gruppeneinteilung der Lunckengebisse für die Prothetic. Dtsch. Zahnarztl. Z. 10, 1831–1834 (in German).

Ekberg, O., Feinberg, M., 1992. Clinical and demographic data in 75 patients with near-fatal choking episodes. Dysphagia 7, 205–208.

Feinberg, M.J., Ekberg, O., Segall, L., Tully, J., 1992. Deglutition in elderly patients with dementia: findings of videofluorographic evaluation and impact on staging and management. Radiology 183, 811–814.

Finestone, H.M., Fisher, J., Greene-Finestone, L.S., Teasell, R.W., Craig, I.D., 1998. Sudden death in the dysphagic stroke patient—a case of airway obstruction caused by a food bolus: a brief report. Am. J. Phys. Med. Rehabil. 77, 550–552.

Fioritti, A., Giaccotto, L., Melega, V., 1997. Choking incidents among psychiatric patients: retrospective analysis of thirty-one cases from the west Bologna psychiatric wards. Can. J. Psychiatry 42, 515–520.

Haddon Jr., W., 1980. Advances in the epidemiology of injuries as a basis for public policy. Public Health Rep. 95, 411–421.

Hatch, J.P., Shinkai, R.S., Sakai, S., Rugh, J.D., Paunovich, E.D., 2001. Determinants of masticatory performance in dentate adults. Arch. Oral Biol. 46, 641–648.

Hirakawa, Y., Kuzuya, M., Enoki, H., Hasegawa, J., Iguch, A., 2008. Caregiver burden among Japanese informal caregivers of cognitively impaired elderly in community settings. Arch. Gerontol. Geriatr. 46, 367–374.

Ichikawa, M., Marui, E., 2000. Mortality of unintentional injuries in childhood and later adulthood in Japan: 1968–1997. Jpn. J. Health Hum. Ecol. 66, 126–136.11.

Kakinoki, Y., Nishihara, T., Arita, M., Shibuya, K., Ishikawa, M., 2004. Usefulness of new wetness tester for diagnosis of dry mouth in disabled patients. Gerodontology 21, 229–231.

Kawana, H., Kikutani, T., Takahashi, N., Hirabayashi, M., Tashiro, H., Fukui, T., Tamura, F., 2010. Effect of continuous management of oral function in the nursing home for denture-wearing elderly under long-term care. J. Gerodont. 25, 3–10 (in Japanese).

Mahoney, F.I., Barthel, D.W., 1965. Functional evaluation: the Barthel index. Md. State Med. J. 14, 61–65.

Minakuchi, S., Takaoka, S., Ito, J., Shimoyama, K., Uematsu, H., 2006. Factors affecting denture use in some institutionalized elderly people. Spec. Care Dentist 26, 101–105.

Ministry of Health, Labour and Welfare of Japan, 2011. Activity of Daily Living Independence of Demented Elderly. Available at: http://www.mhlw.go.jp:80/topics/kaigo/kentou/15kourei/sankou4.html (accessed on May 29, 2011, in Japanese).

Miyazaki, H., Sakao, S., Katoh, Y., Takehara, T., 1995. Correlation between volatile sulphur compounds and certain oral health measurements in the general population. J. Periodontol. 66, 679–684.

NANDA International, 2003. NANDA Nursing Diagnosis: Definitions and Classification 2003–2004. North American Nursing Diagnosis Association, Philadelphia, p. 256.

Ono, T., Kumakura, I., Arimoto, M., Hori, K., Dong, J., Iwata, H., Nokubi, T., Tsuga, K., Akagawa, Y., 2007. Influence of bite force and tongue pressure on oro-pharyngeal residue in the elderly. Gerodontology 24, 143–150.

Samuels, R., Chadwick, D.D., 2006. Predictors of asphyxiation risk in adults with intellectual disabilities and dysphagia. J. Intellect. Disabil. Res. 50, 362–370.21.

Suda, M., Kikutani, T., Tamura, F., Yoneyama, T., 2008. Associated factors for suffocation accidents in the disabled elderly at home. J. Gerodont. 23, 3–11 (in Japanese).

Takahashi, K., Groher, M.E., Michi, K., 1994. Methodology for detecting swallowing sounds. Dysphagia 9, 54–62.

Volicer, L., Seltzer, B., Rheaume, Y., Fabiszewski, K., Herz, L., Shapiro, R., Innis, P., 1987. Progression of Alzheimer-type dementia in institutionalized patients: a cross-sectional study. J. Appl. Gerontol. 6, 83–94.

Please cite this article in press as: Kikutani, T., et al., Tooth loss as risk factor for foreign-body asphyxiation in nursing-home patients. Arch. Gerontol. Geriatr. (2012), doi:10.1016/j.archger.2012.01.010

Geriatrics Gerontology Medline Indexed

Geriatr Gerontol Int 2013; **13:** *50–54*

ORIGINAL ARTICLE: EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

Relationship between nutrition status and dental occlusion in community-dwelling frail elderly people

Takeshi Kikutani,[1] Mitsuyoshi Yoshida,[4] Hiromi Enoki,[5] Yoshihisa Yamashita,[6] Sumio Akifusa,[7] Yoshihiro Shimazaki,[6] Hirohiko Hirano[2] and Fumio Tamura[3]

[1]Division of Oral Rehabilitation, the Nippon Dental University Graduate School of Life Dentistry, [2]Research Team for Promoting Independence of the Elderly, Tokyo Metropolitan Institute of Gerontology, [3]Rehabilitation Clinic for Speech and Swallowing Disorders, The Nippon Dental University School of Life Dentistry at Tokyo, Dental Hospital, Tokyo, [4]Dental Department, Hiroshima City General Rehabilitation Center, Hiroshima, [5]Department of Health and Medical science, Aichi Shukutoku University, Aichi, [6]Section of Preventive and Public Health Dentistry, Division of Oral Health, Growth and Development, Kyushu University Faculty of Dental Science, and [7]Department of Health Management, School of Oral Health Sciences, Kyushu Dental College, Fukuoka, Japan

Aim: This study aimed to determine the risk of malnutrition in some communities where the frail elderly receive public long-term care insurance. We also clarified the dental problems in those at risk of malnutrition.

Methods: A total of 716 frail elderly who lived in eight cities in Japan (240 males and 476 females with a mean age of 83.2 ± 8.6 years) were divided into three groups according to Mini Nutritional Assessment short form results: well nourished, at risk of malnutrition and malnourished. They were also divided into three groups in terms of remaining teeth occlusion and denture occlusion: group A, natural dentition with adequate function; group B, partially or fully edentulous, but maintaining functional occlusion with dentures in either or both jaws; and group C, functionally inadequate occlusion with no dentures. The relationship between nutrition status and dental occlusion was evaluated using logistic regression analysis with sex, age, activities of daily living and cognitive function as covariates.

Results: The number of participants in each of the groups was as follows: 251 well nourished, 370 at risk of malnutrition and 95 malnourished. When they were divided into just two groups, (i) well nourished and (ii) at risk of malnutrition plus malnourished, in order to study malnutrition risk factors, there were significant relationships between their nutritious status and sex, Barthel index, and occlusion.

Conclusion: This large-scale cross-sectional survey showed that loss of natural teeth occlusion was a risk factor for malnutrition among community-dwelling frail elderly. **Geriatr Gerontol Int 2013; 13: 50–54.**

Keywords: frail elderly people, Mini Nutritional Assessment short form, nutrition, occlusion.

Introduction

The intake of nutrients from daily meals is the foundation of life. Low nutrition decreases the immunological defenses, reduces physical functions, and can be a direct or indirect cause of morbidity and mortality among the elderly.[1,2] It has been reported that 1–15% of outpatients and 15–60% of the institutionalized elderly suffer from protein-energy malnutrition (PEM),[3] suggesting that the condition of elderly at risk of malnutrition should be investigated and improved without delay.

Accepted for publication 16 February 2012.

Correspondence: Dr Mitsuyoshi Yoshida DDS PhD, Dental Department, Hiroshima City General Rehabilitation Center, Tomo-minami 1-39-1, Asaminami-ku, Hiroshima 731-3168, Japan. Email: mitsu@hiroshima-u.ac.jp

Several screening methods are available for determining malnutrition, but the use of a questionnaire is a simpler and more convenient method for a large-scale survey.[4] Especially, The Mini Nutritional Assessment short form (MNA-SF) has been highly utilized worldwide, and its sensitivity and specificity have already been shown.[5,6]

The present study evaluated the malnutrition risk for community-dwelling frail elderly receiving public long-term homecare insurance in Japan using the MNA-SF to determine whether dental occlusion might influence the risk of malnutrition.

Methods

The participants were 716 elderly individuals living at home and receiving public long-term care insurance services (240 males and 476 females with a mean age of

83.2 ± 8.6 years) in eight prefectures in Japan (Tokyo, Fukushima, Kanagawa, Yamanashi, Shizuoka, Niigata, Fukuoka and Okinawa). Their malnutrition risk was evaluated using the MNA-SF, and also age, sex and underlying medical problems using the Charlson index[7] were determined. In addition, activities of daily living (ADL) and cognitive function were evaluated using the Barthel index[8] and the Clinical Dementia Rating,[9] respectively, based on information from caregivers or care managers. This evaluation also determined one of the living environment factors, whether or not living alone.

The participants received oral examinations by a dentist or dental hygienist at home or at the day care facility they usually used, and molar occlusion was classified into the following three groups according to edentulous condition and denture-wearing status:

- Group A, natural dentition with adequate function
- Group B, partially or fully edentulous, but maintaining functional occlusion with dentures in either or both jaws
- Group C, functionally inadequate occlusion with no dentures

Swallowing function was evaluated using a stethoscope to determine whether cervical auscultation of swallowing sounds was normal or abnormal.[10] Before the examination, the dentist and dental hygienist in charge were instructed about the cervical auscultation method.

The participants were divided into three groups according to the result of the MNA-SF: (i) well-nourished; (ii) at risk of malnutrition; and (iii) malnourished. The relationship between participants' general condition and oral status was analyzed using the χ^2-test and one-way ANOVA. In addition, participants were also divided into two groups: (i) well-nourished; and (ii) at risk of malnutrition or malnourished. Logistic regression analysis was carried out to study the significant risk factors influencing malnutrition. Participants were also divided into two groups according to whether they were: (i) well-nourished *plus* those at risk of malnutrition; and (ii) malnourished. Logistic regression analysis was carried out to clarify the characteristics of malnourished subjects. PASW Statistics 18 (IBM, Tokyo, Japan) was used for statistical analysis with the significance level set at 95%.

Results

The MNA-SF showed the following: 251 individuals (94 males and 157 females) were well nourished, 370 (120 males and 250 females) were at risk of malnutrition and 95 (26 males and 69 females) were malnourished. Table 1 shows the general condition of participants, number of missing teeth and number of remaining teeth roots among those without occlusion according to nutrition group. The number of participants who lived alone by nutrition group was 30 in the well-nourished group (17.9%), 29 in the at risk of malnutrition group (14.0%) and 16 in the malnourished group (28.6%; $P < 0.05$).

The number of participants by occlusal relationship was 174 in group A (80 males and 94 females with a mean age of 78.7 ± 9.0 years), 421 in group B (120 males and 301 females with a mean age of 84.6 ± 8.0 years) and 121 in group C (40 males and 81 females with a mean age of 84.9 ± 7.7 years), which indicated that there was a significant correlation between occlusal relationship and nutrition status ($P < 0.05$; Fig. 1).

Cervical auscultation showed that the 516 participants exhibited normal swallowing sounds (151 males and 365 females with a mean age of 82.8 ± 8.4 years) and 200 had abnormal swallowing sounds (89 males and 111 females with a mean age of 84.0 ± 9.0 years). There was a significant relationship between normal swallowing sounds and nutrition status ($P < 0.05$, Fig. 2).

The results of the logistic regression analysis showed a significant relationship between malnutrition risk and sex, Barthel index, and occlusal relationship (Table 2).

Table 1 General condition and the number of missing teeth by nutrition group

	Well nourished	At risk of malnutrition	Malnourished
Age	81.9 ± 8.6	83.9 ± 8.3*	83.8 ± 9.3
Charlson index	1.4 ± 1.5	1.6 ± 1.4	1.8 ± 1.4**
Barthel index	77.1 ± 20.8	57.2 ± 27.8*	34.3 ± 28.6**,***
Clinical dementia rating	0.8 ± 0.9	1.2 ± 1.0*	1.4 ± 1.1**
No. missing teeth	20.2 ± 10.6	22.4 ± 9.8*	21.2 ± 9.6
No. remaining teeth root	0.9 ± 2.2	1.7 ± 3.3*	2.3 ± 4.0**
No. occlusal group (group A/B/C)	80/145/26	66/232/72	28/44/23†
No. swallowing sounds (normal/abnormal)	208/43	262/108	46/49†

One-way ANOVA and Games-Howell pairwise comparison test were used for parametric variables. *$P < 0.05$, well-nourished versus at risk of malnutrition; **$P < 0.05$, well nourished versus malnourished; ***$P < 0.05$, at risk of malnutrition versus malnourished. †The χ^2-test was used for non-parametric variables (<0.05).

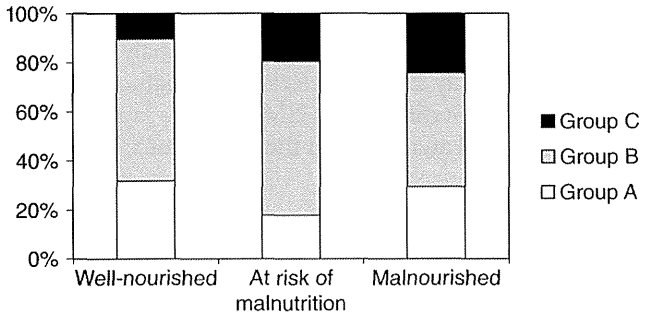

Figure 1 Relationship between nutrition and occlusion (χ^2-test, $P < 0.05$). Group A: natural dentition with adequate function. Group B: partially or fully edentulous, but maintaining functional occlusion with dentures in either or both jaws. Group C: functionally inadequate occlusion with no dentures.

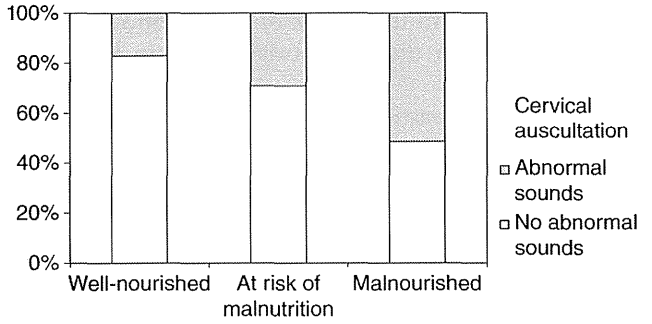

Figure 2 Relationship between nutrition and abnormal swallowing sounds detected by cervical auscultation (χ^2-test, $P < 0.05$).

A significant relationship was also observed between malnutrition and Barthel index, abnormal swallowing sounds by cervical auscultation, and living alone (Table 3).

Discussion

The results of the present study showed that the number of frail elderly with malnutrition was 13.3% (95), which is nearly in agreement with the results of a previous study carried out in Japan.[11] Furthermore, the number of the participants at risk of malnutrition, including those in the at risk of malnutrition and malnourished groups was 64.9% (465), which surprisingly exceeded 50% of the participants. This result shows that improvement in the nutrition status of frail elderly living in home care needs to be urgently addressed.

The Barthel index was the significant factor documenting both malnutrition risk and malnourishment in the present study. Many researchers agree that there is a relationship between physical function and nutrition status.[12] It might be concluded that individuals whose daily activity is limited tend to avoid shopping for food items, resulting in nutritional disturbance.

In addition to the Barthel index, sex was found to be a significant factor influencing malnutrition risk. The present study showed that older females had a 1.845-fold greater malnutrition risk than older males (95% CI 1.121–3.036), which agreed with the results of a previous study that showed that older females were more likely to develop nutritional disturbance, both obesity and malnutrition.[13]

Furthermore, occlusal status was significantly related to malnutrition risk. The group C individuals (functionally inadequate occlusion with no dentures) had a 3.189-fold greater malnutrition risk than group A (natural dentition with adequate function; 95% CI 1.437–7.080). 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.[14] The most pronounced difference in intake involves hard-to-chew foods, such as vegetables and some fruits, therefore tooth loss affects elements of nutritional intake, such as dietary fiber and vitamins.[15] These micronutrients are the key element in maintaining good nutrition, which suggests that lack of such food might result in greater malnutrition risk.

In addition, group B (partially or fully edentulous, but maintaining functional occlusion with dentures in either or both jaws) had a 1.704-fold greater malnutrition risk than group A (95% CI 1.013–2.864). Previous studies have shown that individuals who have lost natural molar contacts consume lesser amounts of hard-to-chew foods, such as vegetables and fruits, even though they use their dentures during food intake.[16] Our findings in the present study support the view that denture use is not sufficient to compensate for natural teeth. Recently, Bradbury *et al.* showed that food instruction encourages an increase in the consumption of vitamins and minerals among new denture wearers.[17] In general, denture treatment has not usually included in such dietary intervention. Future studies will be required to identify the effect of dietary intervention on the prevention of malnutrition in denture users.

In contrast, there was no significant relationship between malnourishment and occlusion in frail elderly participants. There were significant relationships between malnutrition and Barthel index, abnormal swallowing sounds detected by cervical auscultation, and living alone. These results suggest that malnourished elderly have already developed dysphagia resulting in dietary modification;[18] therefore, their malnutrition might be less influenced by a proper occlusal relationship. A vicious cycle, in which decreased ability to

Table 2 Items significantly involved in malnutrition risk

	B	Standard deviation	Wald	*P*-value	Exp (B)	95% Confidence interval	
Sex	0.612	0.254	5.803	0.016	1.845	1.121	3.036
Age	−0.001	0.015	0.006	0.939	0.999	0.971	1.028
Charlson index	0.089	0.082	1.168	0.280	1.093	0.930	1.284
Barthel index	−0.036	0.005	43.381	0.000	0.965	0.955	0.975
Clinical Dementia Rating	0.156	0.140	1.251	0.263	1.169	0.889	1.537
Swallowing sounds	0.482	0.297	2.627	0.105	1.619	0.904	2.900
Occlusal relationship (a) group A *vs* group B	0.533	0.265	4.039	0.044	1.704	1.013	2.864
Occlusal relationship (b) group A *vs* group C	1.160	0.407	8.125	0.004	3.189	1.437	7.080
Living alone	0.353	0.301	1.380	0.240	1.424	0.790	2.567
Constant	1.701	1.265	1.807	0.179	5.479		

The participants were divided into two groups according to their nutrition status: (i) a well-nourished group; and (ii) a group that included those at risk of malnutrition and malnourished. Group A, natural dentition with adequate function; group B, partially or fully edentulous, but maintaining functional occlusion with dentures in either or both jaws; group C, functionally inadequate occlusion with no dentures.

Table 3 Items significantly involved in malnutrition

	B	Standard deviation	Wald	*P*-value	Exp (B)	95% Confidence interval	
Sex	0.613	0.388	2.501	0.114	1.846	0.864	3.947
Age	−0.002	0.021	0.007	0.933	0.998	0.958	1.040
Charlson Index	0.014	0.104	0.019	0.891	1.014	0.827	1.244
Barthel Index	−0.035	0.007	27.940	0.000	0.966	0.953	0.978
Clinical Dementia Rating	−0.072	0.178	0.165	0.685	0.930	0.657	1.318
Swallowing sounds	1.060	0.340	9.684	0.002	2.885	1.480	5.623
Occlusal relationship (a) group A *vs* group B	−0.453	0.391	1.343	0.246	0.636	0.295	1.368
Occlusal relationship (b) group A *vs* group C	−0.485	0.520	0.871	0.351	0.616	0.222	1.705
Living alone	1.461	0.403	13.143	0.000	4.312	1.957	9.502
Constant	−0.746	1.777	0.176	0.674	0.474		

Participants were divided into two groups according to their nutritious status: (i) a group of well-nourished individuals and those at risk of malnutrition; and (ii) a group of malnourished individuals. Group A, natural dentition with adequate function; group B, partially or fully edentulous, but maintaining functional occlusion with dentures in either or both jaws; group C, functionally inadequate occlusion with no dentures.

swallow food could accelerate malnutrition, was also considered. Elderly people who live alone are less likely to follow through with dietary modification,[19] and it might lead to malnutrition regardless of occlusal status.

In conclusion, the present study, as well as previous studies, has shown that retaining the natural teeth plays an important role in the prevention of nutritional disturbance, and that early dental treatment in the elderly is important to protect their teeth and occlusion. Dieticians, as well as other care staff, should monitor oral conditions, such as remaining teeth and occlusion, in the elderly in order to prevent malnutrition. We also suggest that all dentists enhance their skills and knowledge in the fields of swallowing function and nutritional guidance.

Acknowledgments

This study was supported by the Ministry of Health, Labour and Welfare.

References

1 Lesourd B. Nutrition: a major factor influencing immunity in the elderly. *J Nutr Health Aging* 2004; **8**: 28–37.
2 Landi F, Zuccala G, Gambassi G *et al.* Body mass index and mortality among older people living in the community. *J Am Geriatr Soc* 1999; **47**: 1072–1076.
3 Guigoz Y, Lauque S, Vellas BJ. Identifying the elderly at risk for malnutrition. The mini nutritional assessment. *Clin Geriatr Med* 2002; **18**: 737–757.
4 Phillips MB, Foley AL, Barnard R, Isenring EA, Miller MD. Nutritional screening in community-dwelling older adults: a systematic literature review. *Asia Pac J Clin Nutr* 2010; **19**: 440–449.
5 Vellas B, Villars H, Abellan G *et al.* Overview of the MNA–Its history and challenges. *J Nutr Health Aging* 2006; **10**: 456–463.
6 Kaiser MJ, Bauer JM, Ramsch C *et al.* MNA-International Group. Validation of the Mini Nutritional Assessment short-form (MNA-SF): a practical tool for identification of nutritional status. *J Nutr Health Aging* 2009; **13**: 782–788.
7 Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis* 1987; **40**: 373–383.
8 Mahoney FI, Barthel DW. Functional evaluation; the Barthel index. *Md State Med J* 1965; **14**: 61–65.
9 Morris JC. The Clinical Dementia Rating (CDR): current version and scoring rules. *Neurology* 1993; **43**: 2412–2414.
10 Takahashi K, Groher ME, Michi K. Methodology for detecting swallowing sounds. *Dysphagia* 1994; **9**: 54–62.
11 Izawa S, Kuzuya M, Okada K *et al.* The nutritional status of frail elderly with care needs according to the mini-nutritional assessment. *Clin Nutr* 2006; **25**: 962–967.
12 Mirarefin M, Sharifi F, Fakhrzadeh H *et al.* Predicting the value of the Mini Nutritional Assessment (MNA) as an indicator of functional ability in older Iranian adults (Kahrizak elderly study). *J Nutr Health Aging* 2011; **15**: 175–180.
13 Morley JE. Nutrition and the older female: a review. *J Am Coll Nutr* 1993; **12**: 337–343.
14 Carlsson GE. Masticatory efficiency: the effect of age, theloss of teeth and prosthetic rehabilitation. *Int Dent J* 1984; **34**: 93–97.
15 Yoshida M, Kikutani T, Yoshikawa M, Tsuga K, Kimura M, Akagawa Y. Correlation between dental and nutritional status in community-dwelling elderly Japanese. *Geriatr Gerontol Int* 2011; **11**: 315–319.
16 Marshall TA, Warren JJ, Hand JD, Xie XJ, Stumbo PJ. Oralhealth, nutrient intake and dietary quality in the very old. *J Am Dent Assoc* 2002; **133**: 1369–1378.
17 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.
18 Garcia JM, Chambers E 4th. Managing dysphagia through diet modifications. *Am J Nurs* 2010; **110**: 26–33.
19 Ramic E, Pranjic N, Batic-Mujanovic O, Karic E, Alibasic E, Alic A. The effect of loneliness on malnutrition in elderly population. *Med Arh* 2011; **65**: 92–95.

Dysphagia
DOI 10.1007/s00455-012-9407-z

ORIGINAL ARTICLE

Tongue Thickness Relates to Nutritional Status in the Elderly

Fumiyo Tamura · Takeshi Kikutani · Takashi Tohara · Mitsuyoshi Yoshida · Ken Yaegaki

Received: 21 July 2011 / Accepted: 5 April 2012

Abstract Many elderly people under long-term care suffer from malnutrition caused by dysphagia, frequently leading to sarcopenia. Our hypothesis is that sarcopenia may compromise oral function, resulting in dysphagia. The objectives of this study were to evaluate sarcopenia of the lingual muscles by measuring the tongue thickness, and elucidate its relationship with nutritional status. We examined 104 elderly subjects (mean age = 80.3 ± 7.9 years). Anthropometric data, such as triceps skinfold thickness and midarm muscle area (AMA), were obtained. The tongue thickness of the central part was determined using ultrasonography. Measurement was performed twice and the mean value was obtained. The relationship between tongue thickness and nutritional status was analyzed by Pearson's correlation coefficient and Spearman's rank correlation coefficient. AMA and age were identified by multiple-regression analysis as factors influencing tongue thickness. The results of this study suggest that malnutrition may induce sarcopenia not only in the skeletal muscles but also in the tongue.

Keywords Tongue thickness · Nutritional status · Dysphagia · Sarcopenia · Ultrasonography · Deglutition · Deglutition disorders

F. Tamura (✉) · T. Kikutani · T. Tohara
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
e-mail: fumita@tokyo.ndu.ac.jp

T. Tohara
e-mail: takashitohara@qa2.so-net.ne.jp

T. Kikutani
Division of Clinical Oral Rehabilitation, The Nippon Dental University Graduate School of Life Dentistry at Tokyo, 9–16, Fujimi 1-chome, Chiyoda-ku, Tokyo 102-0071, Japan
e-mail: kikutani@tokyo.ndu.ac.jp

M. Yoshida
Dental Department, Hiroshima City General Rehabilitation Center, Hiroshima, Japan

K. Yaegaki
Department of Hygiene, The Nippon Dental University School of Life Dentistry at Tokyo, Tokyo, Japan
e-mail: yaegaki-k@tky.ndu.ac.jp

The tongue plays an important role in feeding and swallowing function. Feinberg et al. [1] reported that bolus misdirection due to dysfunction and abnormality was more frequent at the oral stage alone or at both the oral and pharyngeal stages than at the pharyngeal stage alone. Dysfunction and abnormality of the tongue might also be a reason for dysphagia, since problems at the oral stage are one of the reasons for dysphagia. Many elderly people under long-term care suffer from malnutrition caused by dysphagia and frequently develop sarcopenia because of malnutrition [2]. Sarcopenia is defined as loss of muscular mass, strength, and physical performance. Sarcopenia caused by aging is also affected by the levels of anabolic hormones, which may suppress appetite or lead to a reduction of protein synthesis, resulting in worsening of the condition [3, 4] and subsequent restriction of physical activities in the elderly.

Elderly people frequently suffer from eating malfunction and malnutrition [5, 6]. Fewer occluding pairs of teeth decrease chewing function and increase chewing difficulty [7]. Therefore, chewing ability may contribute to the regulation of nutritional status in the elderly, as reported

Published online: 27 April 2012

previously [8]. Subsequently, chewing ability is associated with not only oral health status but also with the physical constitution of the elderly [8]. Low tongue pressure reflects dysphagic tongue movement and cough [9]. Moreover, a decline of oral muscle strength as well as fewer occluding teeth may cause malfunction of feeding; therefore, we presume that malnutrition may worsen in dysphagic patients. Our hypothesis is that sarcopenia may occur in the tongue as well as in other tissues. In other words, we speculated that muscle volume may relate to tongue sarcopenia rather than to body size. If so, sarcopenia of the lingual muscles would compromise oral function in the elderly. Once atrophy of the tongue occurs, people may start to develop malnutrition because of dysphagia. In most cases, the meal texture of these people becomes softer, requiring less power of tongue movement. Consequently, tongue atrophy may be promoted. The objectives of this study were to evaluate sarcopenia of the lingual muscles by measuring the tongue thickness and to elucidate its relationship with nutritional status.

Subjects and Methods

We studied 104 elderly subjects (32 men and 72 women, mean age = 80.3 ± 7.9 years). All maintained occlusal support with either natural dentition or dentures. Neither paralysis nor atrophy of the tongue was observed. The anthropometric data of triceps skinfold thickness (TSF), midarm muscle area (AMA), body weight (BW), and height (HT) were measured to evaluate nutritional status [8, 10].

Anthropometric measurements were conducted as follows: Mid-upper-arm circumference (MAC) was measured on the left arm with a tape measure. TSF was measured with Harpenden Skinfold Calipers over the triceps muscle at the midway point between the acromion and the olecranon process. AMA was calculated from MAC and TSF values based on a previously reported formula [11]. The mean of the twice-repeated measurements was taken as the true value. Tongue thickness was measured using ultrasonography (Nemio 17, SSA-550A, Toshiba Medical Systems, Tokyo, Japan). A fixation device to retain a 3.75-MHz convex probe (contact face size = 12 × 70 mm) in an appropriate position was employed to obtain accurate images, as shown in Fig. 1. To assure stable image acquisition, the probe was firmly fixed to the subject's lower jaw by wrapping a belt around the head. The subjects were asked to remain seated in an upright position. They were also instructed to swallow their saliva often and to set the tongue at the resting position. Then, ultrasonic measurements were carried out.

The measurement points were determined on the upper and lower surfaces of the lingual muscles in the center of

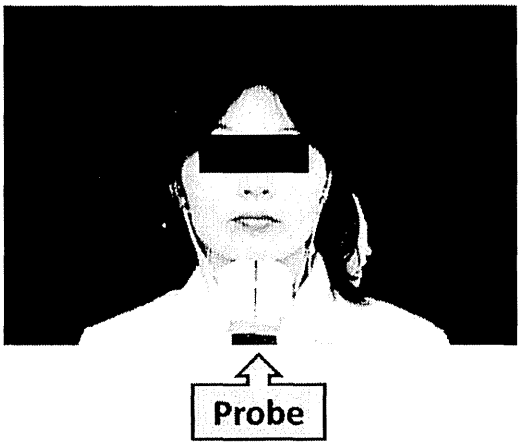

Fig. 1 Position of ultrasonic probe in frontal view

the plane perpendicular to the Frankfurt horizontal plane in a frontal section, as shown in Fig. 2 [12]. This perpendicular plane went through the distal surfaces of the mandibular second premolars on both sides. The measurement point on the coronal plane is shown in Fig. 3. The vertical distance was measured from the surface of the mylohyoid muscle to the tongue dorsum. Figure 4 shows an image of a frontal section of the tongue on ultrasonography. Measurements were performed twice in freeze-frame when the tongue was restored to the resting position after swallowing saliva, and the mean values were obtained. To determine the reliability of the tongue thickness measurement, the two-way mixed-effects model of the intraclass correlation coefficient (ICC) (1,2) was used. The ICC values were above 0.75, indicating good reliability; values of 0.9 and

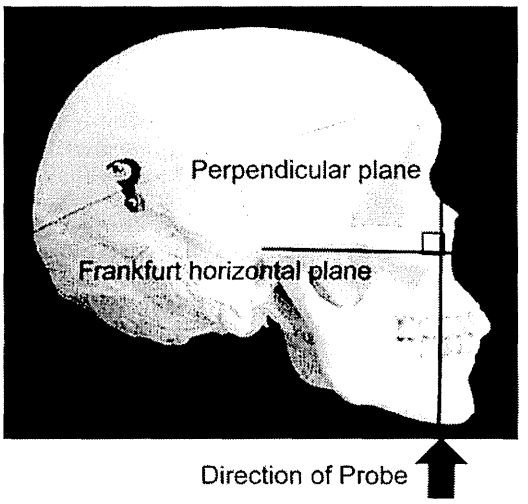

Fig. 2 Position of ultrasonic probe in lateral view. The measurement points were determined at the center of the plane perpendicular to the Frankfurt horizontal plane in a frontal section. The perpendicular plane passes through the distal surfaces of the mandibular second premolars on both sides

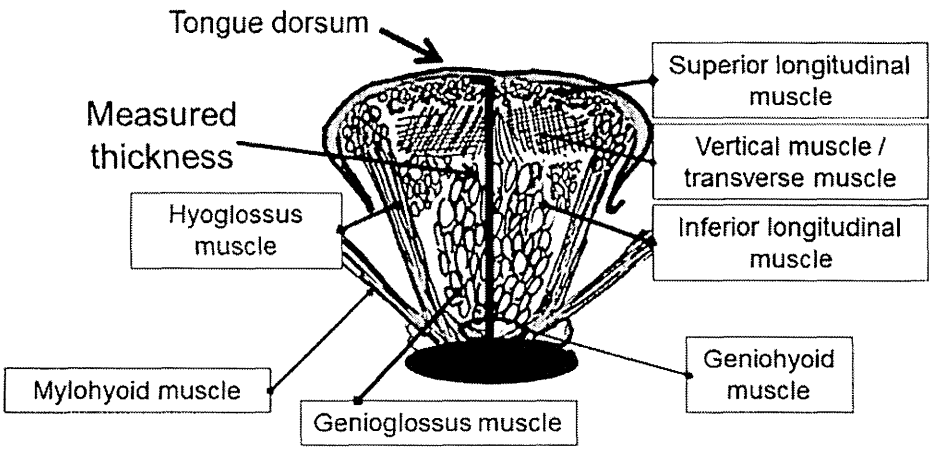

Fig. 3 Diagram of tongue. Measured thickness is the vertical distance from the surface of mylohyoid muscle to the tongue dorsum

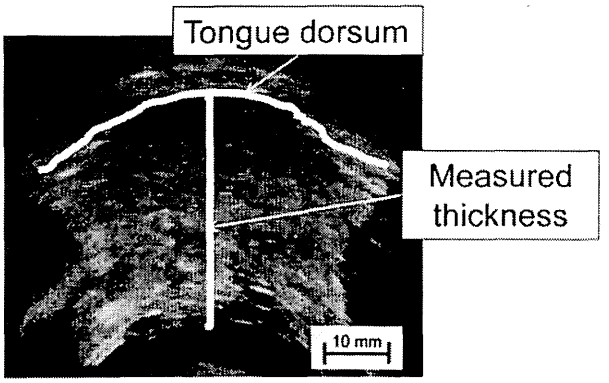

Fig. 4 Ultrasonographic image

above are reportedly even more reliable for ensuring the validity and reproducibility of clinical measurements [13]. The ICC (1,2) value for the intrarater reliability of tongue thickness measurement was 0.856 (95 % CI: 0.741–0.924).

The relationship between tongue thickness and nutritional status was analyzed using Pearson's correlation coefficient and Spearman's rank correlation coefficients using the software SPSS v16 (SPSS, Inc., Chicago, IL).

This study was approved by the Ethics Committee of The Nippon Dental University, School of Life Dentistry at Tokyo, Dental Hospital. Before starting measurements, the purpose and the protocol were explained to the subjects and/or their guardians in order to obtain their consent.

Results

Baseline Characteristics of Subjects

Table 1 gives the baseline characteristics of our subjects. TSF = 11.4 ± 4.6 mm, AMA = 34.9 ± 7.6 cm^2, HT = 151.2 ± 8.8 cm, BW = 48.9 ± 8.8 kg, and tongue thickness = 46.9 ± 5.5 mm.

Table 1 Baseline characteristics of subjects (n = 104)

	Mean	SD
Age (years)	80.3	7.9
TSF	11.4	4.6
AMA	34.9	7.6
Height (cm)	151.2	8.8
Body weight (kg)	48.9	8.8
Tongue thickness (mm)	46.9	5.5

TSF triceps skinfold thickness, *AMA* arm muscle area

Correlation Coefficients Between Tongue Thickness and Other Variables

Table 2 gives the correlation coefficients between tongue thickness and the other variables examined. Tongue thickness correlated with age ($r = -0.393$, $P < 0.001$), TSF ($r = 0.225$, $P < 0.05$), AMA ($r = 0.424$, $P < 0.001$), HT ($r = 0.312$, $P < 0.01$), and BW ($r = 0.434$, $P < 0.001$).

Table 2 Pearson's rank correlation coefficient between tongue thickness and other variables

Variables	Coefficient	P value
Age	−0.393	0.000
TSF	0.225	0.022
AMA	0.424	0.000
Height	0.312	0.001
Body weight	0.434	0.000

TSF triceps skinfold thickness, *AMA* arm muscle area

Table 3 Factors related to tongue thickness by stepwise multiple regression analysis

Variables	Beta	*t*	*P* value
AMA	0.231	3.412	0.001
Age	−0.188	−2.868	0.005

AMA arm muscle area

Model 1: Multiple correlation coefficient (R) = 0.424; adjusted coefficient of determination (R^2) = 0.180

Model 2: Multiple correlation coefficient (R) = 0.492; adjusted coefficient of determination (R^2) = 0.227

Stepwise Multiple Regression Analysis

Table 3 shows the results of a stepwise multiple regression analysis conducted to identify the factor most strongly influencing tongue thickness. The multiple correlation coefficient (R) was 0.492 and the adjusted coefficient of determination (R^2) was 0.227.

Discussion

Masticatory movement is governed by the coordinated functions of oral organs: teeth, jaw, cheek, lips, and tongue. Among them, the tongue plays an important role in mastication and swallowing since it transports food to the molars, initiates mastication, mixes foods with saliva, and propels a food bolus into the pharynx. Furthermore, the swallowing reflex occurs because the tongue and the soft palate close at the region of the fauces. Many elderly people under long-term care develop malnutrition because of a decline in masticatory and swallowing functions as described above. Improvement in swallowing is considered the most effective way to treat dysphagia because oral dysfunction is also strongly associated with dysphagia [1]. Therefore, evaluating tongue dysfunction or abnormality may be an essential diagnostic procedure for dysphagia. There are many methods for evaluating tongue function, i.e., measuring the strength [14–17] and speed and location of movement [18]. The strength of the tongue has been evaluated by measuring the maximum tongue pressure against the palate [14, 15]. There are some reports that tongue function in the elderly declines with age [14, 15, 19, 20]. However, the effects of malnutrition on tongue volume in the elderly are still unknown. In our study we used ultrasonography to measure tongue thickness. Ultrasonography is widely used for functional analysis of dysphagia and is also reported to be very practical for anatomical analysis [21]. Furthermore, ultrasonography has enormous potential for visualizing the tongue in clinical research because it is noninvasive and it is easy to perform repeated examinations.

The age-associated loss of both muscle mass and strength, termed sarcopenia, is highly relevant to nursing home residents [22]. It was reported that tongue sarcopenia was observed more frequently in aged rats than in control rats [23, 24]. However, the relationship between tongue sarcopenia and aging in humans is obscure. The absence of occlusal support affects tongue movement and oral function [14, 25, 26]. In this study we employed subjects with posterior occlusal dentition of their natural teeth or dentures to eliminate confounding variables.

It has been suggested that TSF and AMA correlate with nutritional status [8, 10]. TSF represents fat volume and AMA the muscle volume of the upper arm. Since there was a significant association between tongue thickness and nutritional status, tongue muscle volume may also be related to nutritional status.

Furthermore, it was suggested that sarcopenia may develop not only in skeletal muscles but also in the tongue. Hence, dysphagia, tongue disuse syndrome, or malnutrition may affect tongue thickness, with subsequent worsening of malnutrition. Moreover, Saito et al. [27] reported that in rats, the structures of tongue muscles (genioglossus and geniohyoid) may be affected by fat deposition in myofibers. Determination of the fat fraction may be required in our future studies on tongue sarcopenia [28].

It was suspected that tongue thickness correlates with mandibular length. In this regard, an animal study [29] showed the relationship between tongue thickness and mandibular length from infancy through childhood, whereas no such relationship was identified in a human study [30]. However, in the present study we demonstrated a significant relationship between tongue thickness and AMA (an index indicating muscle mass) and age by applying multiple regression analysis. Neither HT, a marker of bone in humans, nor BW (a similar marker) was found to correlate with tongue thickness, suggesting that general muscle volume and/or age alone may affect this feature of the tongue.

Atrophy of the tongue may not be the only reason for reduced tongue function and inability to maintain nutritional status. However, Kikutani et al. [31] reported that oral functional training to maintain and/or improve feeding function is very efficient for improving the nutritional condition. It was reported that muscle is replaced by fat or fibrous tissues with aging [32], implying that tongue exercise might restore muscle tissue. Robbins et al. [32] and Yeates et al. [33] also reported that exercising the tongue prevented general sarcopenia. Therefore, effective measures or protocols to prevent malnutrition, which involve tongue exercise or rehabilitation, may be necessary to improve tongue disuse syndrome. For this purpose, our method of monitoring tongue thickness by ultrasonography may provide information for a tongue exercise protocol or

treatment plan. We will study further the relationship between tongue pressure and tongue thickness in a future investigation.

Conclusion

The findings of this study suggest that tongue thickness is related to nutritional status in the elderly.

Acknowledgments The authors thank Drs. Tetsuo Hanagata and Akira Ozawa at Yamanashi Dental Association, Drs. Yasumasa Akagawa and Kazuhiro Tsuga at Hiroshima University, and Dr. Misaka Kimura at Kyoto Prefectural University of Medicine for helpful discussions. This study was supported in part by a Research Grant for Longevity Science (H19-2) from of the Ministry of Health, Labour and Welfare, Japan.

Conflict of interest The authors have no conflicts of interest to declare.

References

1. Feinberg MJ, Ekberg O. Videofluoroscopy in elderly patients with aspiration: importance of evaluating both oral and pharyngeal stages of deglutition. AJR Am J Roentgenol. 1991;156:293–6.
2. Rosenberg IH, Roubenoff R. Stalking sarcopenia. Ann Intern Med. 1995;123:727–8.
3. Greenlund LJ, Nair KS. Sarcopenia—consequences, mechanisms, and potential therapies. Mech Ageing Dev. 2003;124:287–99.
4. Roubenoff R. Sarcopenia: effects on body composition and function. J Gerontol A Biol Sci Med Sci. 2003;58:1012–7.
5. Ney DM, Weiss JM, Kind AJ, Robbins J. Senescent swallowing: impact, strategies, and interventions. Nutr Clin Pract. 2009;24:395–413.
6. White GN, O'Rourke F, Ong BS, Cordato DJ, Chan DK. Dysphagia: causes, assessment, treatment, and management. Geriatrics. 2008;63:15–20.
7. Leake JL. An index of chewing ability. J Public Health Dent. 1990;50:262–7.
8. 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.
9. Yoshida M, Kikutani T, Tsuga K, Utanohara Y, Hayashi R, Akagawa Y. Decreased tongue pressure reflects symptom of dysphagia. Dysphagia. 2006;21:61–5.
10. Chazot C, Laurent G, Charra B, Blanc C, VoVan C, Jean G, et al. Malnutrition in long-term haemodialysis survivors. Nephrol Dial Transpl. 2001;16:61–9.
11. Heymsfield SB, McManus C, Smith J, Stevens V, Nixon DW. Anthropometric measurement of muscle mass: revised equations for calculating bone-free arm muscle area. Am J Clin Nutr. 1982;36:680–90.
12. Okayama H, Tamura F, Kikutani T, Kayanaka H, Katagiri H, Nishiwaki K. Effects of a palatal augmentation prosthesis on lingual function in postoperative patients with oral cancer: coronal section analysis by ultrasonography. Odontology. 2008;96:26–31.
13. Portney LG, Watkins MP. Foundations of clinical research: applications to practice. Englewood Cliffs: Prentice-Hall; 2000.
14. Kikutani T, Tamura F, Nishiwaki K, Kodama M, Suda M, Fukui T, et al. Oral motor function and masticatory performance in the community-dwelling elderly. Odontology. 2009;97:38–42.
15. Hayashi R, Tsuga K, Hosokawa R, Yoshida M, Sato Y, Akagawa Y. A novel handy probe for tongue pressure measurement. Int J Prosthodont. 2002;15:385–8.
16. Ziegler W. Task-related factors in oral motor control: speech and oral diadochokinesis in dysarthria and apraxia of speech. Brain Lang. 2002;80:556–75.
17. Utanohara Y, Hayashi R, Yoshikawa M, Yoshida M, Tsuga K, Akagawa Y. Standard values of maximum tongue pressure taken using newly developed disposable tongue pressure measurement device. Dysphagia. 2008;23:286–90.
18. Klawe JJ, Tafil-Klawe M. Age-related response of the genioglossus muscle EMG-activity to hypoxia in humans. J Physiol Pharmacol. 2003;54(Suppl 1):14–9.
19. Peng CL, Miethke RR, Pong SJ, Lin CT. Investigation of tongue movements during swallowing with M-mode ultrasonography. J Orofac Orthop. 2007;68:17–25.
20. Ardakani FE. Evaluation of swallowing patterns of the tongue using real-time B-mode sonography. J Contemp Dent Pract. 2006;7:67–74.
21. Ajaj W, Goyen M, Herrmann B, Massing S, Goehde S, Lauenstein T, et al. Measuring tongue volumes and visualizing the chewing and swallowing process using real-time TrueFISP imaging—initial clinical experience in healthy volunteers and patients with acromegaly. Eur Radiol. 2005;15:913–8.
22. Bauer J, Kaiser M, Sieber CC. Sarcopenia in nursing home residents. J Am Med Dir Assoc. 2008;9:545–51.
23. Ota F, Connor NP, Konopacki R. Alterations in contractile properties of tongue muscles in old rats. Ann Otol Rhinol Laryngol. 2005;114:799–803.
24. Schwarz EC, Thompson JM, Connor NP, Behan M. The effects of aging on hypoglossal motoneurons in rats. Dysphagia. 2009;24:40–8.
25. Tamura F, Suzuki S. Effects of edentulism on lingual functions during swallowing. J Disabil Oral Health. 2004;5:83–7.
26. Tamura F, Mizukami M, Ayano R, Mukai Y. Analysis of feeding function and jaw stability in bedridden elderly. Dysphagia. 2002;17:235–41.
27. Saito T, Yamane A, Kaneko S, Ogawa T, Ikawa T, Saito K, et al. Changes in the lingual muscles of obese rats induced by high-fat diet feeding. Arch Oral Biol. 2010;55:803–8.
28. Humbert IA, Reeder SB, Porcaro EJ, Kays SA, Brittain JH, Robbins J. Simultaneous estimation of tongue volume and fat fraction using IDEAL-FSE. J Magn Reson Imaging. 2008;28:504–8.
29. Liu ZJ, Shcherbatyy V, Gu G, Perkins JA. Effects of tongue volume reduction on craniofacial growth: a longitudinal study on orofacial skeletons and dental arches. Arch Oral Biol. 2008;53:991–1001.
30. Siebert JR. A morphometric study of normal and abnormal fetal to childhood tongue size. Arch Oral Biol. 1985;30:433–40.
31. Kikutani T, Enomoto R, Tamura F, Oyaizu K, Suzuki A, Inaba S. Effects of oral functional training for nutritional improvement in