Speech Intelligibility Enhancement After Maxillary Denture Treatment and Its Impact on Quality of Life

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Purpose: Tooth loss and its prosthetic rehabilitation significantly affect speech intelligibility. However, little is known about the influence of speech deficiencies on oral health–related quality of life (OHRQoL). The aim of this study was to investigate whether speech intelligibility enhancement through prosthetic rehabilitation significantly influences OHRQoL in patients wearing complete maxillary dentures. Speech intelligibility by means of an automatic speech recognition system (ASR) was prospectively evaluated and compared with subjectively assessed Oral Health Impact Profile (OHIP) scores. ***Materials and Methods:*** Speech was recorded in 28 edentulous patients 1 week prior to the fabrication of new complete maxillary dentures and 6 months thereafter. Speech intelligibility was computed based on the word accuracy (WA) by means of an ASR and compared with a matched control group. One week before and 6 months after rehabilitation, patients assessed themselves for OHRQoL. ***Results:*** Speech intelligibility improved significantly after 6 months. Subjects reported a significantly higher OHRQoL after maxillary rehabilitation with complete dentures. No significant correlation was found between the OHIP sum score or its subscales to the WA. ***Conclusion:*** Speech intelligibility enhancement achieved through the fabrication of new complete maxillary dentures might not be in the forefront of the patients' perception of their quality of life. For the improvement of OHRQoL in patients wearing complete maxillary dentures, food intake and mastication as well as freedom from pain play a more prominent role. *Int J Prosthodont 2014;27:61–69. doi: 10.11607/ijp.3597*

Tooth loss affects multiple parameters. Facial appearance, masticatory ability, nutrition, and speech are impaired, as well as psychosociologic parameters such as quality of life.[1–3] In particular, prosthetic dentistry has put special emphasis on patient-centered assessments such as quality of life and satisfaction with dentures.[4,5] Thus, dental rehabilitation depends not only on physical or anatomical parameters but is strongly influenced by personal criteria, such as the demand for social integrity.[6–8] In fact, studies indicate that the focus of dental treatment lies more in improving social interaction and self-image than in physical function.[6,9] Furthermore, studies have determined that an assessment through a clinician by means of predefined dental parameters does not yield high correlations when it comes to patient satisfaction with dentures, since adaptation capabilities and individual psychologic parameters are not taken into account.[10–12] Therefore, the outcome of dental rehabilitation is strongly influenced by the patient's satisfaction with the dental situation in everyday life and with oral function–related tasks such as the ability to properly articulate.[13] Thus, when focusing on the general health status, clinical indicators alone are not fully capable of representing the global treatment outcome and health status.[14]

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Specific instruments have been developed for the purpose of measuring patient satisfaction with oral therapy.[15] Oral health–related quality of life (OHRQoL) describes the impact of oral health–related problems on quality of life.[16] It can be evaluated through the Oral Health Impact Profile (OHIP), which is a widely used tool for reliably rating the perceptual impact of oral disorders on the quality of life.[17] Patient-based outcome measurements concerning the quality of life in patients undergoing prosthetic rehabilitation are available in recent literature and state a certain dissatisfaction with edentulism[14] and its conventional treatment.[5] However, the fabrication of new complete dentures does not necessarily have a significant impact on the OHRQoL.[18] This remains controversial in the literature, since other studies report an improvement of the OHRQoL through the fabrication of new dentures for specific domains of the OHIP.[18] Since the ability to speak is a factor considered in the OHIP and a crucial part of oral functions, the patient's speech outcome represents an eminent factor for the patient's evaluation of the prosthetic rehabilitation.

Tooth loss will ultimately lead to disturbed articulation and therefore an impaired speech outcome.[19] Edentulism but also prosthetic treatment will lead to disturbed articulation.[20–22] Numerous works concerning phonetics and dentures have determined the prominent role of dentures with regard speech production.[23] Maxillary complete dentures in particular influence articulation abilities and therefore speech outcome due to the replaced anterior teeth[24,25] and the presence of palatal coverage.[26] To date, studies examining speech intelligibility with regard to prosthetic rehabilitation were mainly performed and evaluated using subjective methods such as speech and language therapists or randomly chosen listeners.[27–29] Yet, with regard to evidence-based medicine, these methods lack validation and reproducibility because of variable listeners' experiences as well as their personal perception.[30] To overcome this subjective, costly, and time-consuming method and make speech measurements more applicable to research, computer-based semiautomatic spectral analysis has been introduced to the field of prosthetic dentistry. However, these measurements were only applied to single speech patterns such as consonants /s/,[31,32] single words,[33] or specific sounds[34] and are not applicable in clinical practice.

For the superior parameter of speech intelligibility, which is a global factor for patients in everyday social life, these methods still cannot serve as a reliable benchmark for how much the patient is affected in his/her social integration through complete maxillary dentures with regard to comprehensibility and quality of life. Recently, the authors' workgroup introduced and validated an automatic speech recognition system named PEAKS (Program for the Evaluation and Analysis of all Kinds of Speech Disorders) in the field of prosthetic dentistry[35] and prospectively evaluated the speech intelligibility within the process of dental rehabilitation for different kinds of prostheses.[36] In prior studies, the program has been established in multiple medical fields such as maxillofacial surgery and otolaryngology[35,37,38] and is already applied in regular clinical follow-up examinations.

To date, there is no study that can provide data about how and to what extent speech intelligibility enhancement influences the quality of life in patients wearing complete maxillary dentures. Therefore, the aim of this study was to evaluate how elderly patients perceived the enhancement in speech intelligibility through prosthetic rehabilitation with regard to their OHRQoL.

Materials and Methods

Participants

All patients requested prosthetic treatment due to subjective discomfort with their current dental situation. They underwent maxillary prosthetic rehabilitation in the Department of Prosthodontics, Erlangen University Hospital, Erlangen, Germany. Before being included in the study, each subject was screened for the following exclusion parameters: mental impairment or related factors that can affect the patient's ability to self-asses, inflammation of the hard or soft tissue in the oral cavity not due to dentures in situ, speaking disorders or other mannerisms not caused by dental or prosthetic status, and patients with auditory defects.

Based on these parameters and the assessment of the dental situation, 28 patients were assigned to participate in the study (Table 1). The mean age was 64.3 years (SD: 9.10, range: 44 to 85 years) and 64% were men. Patients had worn complete maxillary dentures for a mean of 4.96 years prior to rehabilitation, with a minimum in situ time of 3 years (range: 3 to 8 years).

In accordance with their dental status, 28 participants received complete dentures in the maxilla. The mandibular denture status was not altered throughout the treatment since the mandibular denture status was rated as sufficient in each subject. Subjects were native German speakers using a local dialect.

All patients provided written informed consent to take part in this study. The study respected the principles of the 1975/1983 Helsinki declaration and was approved by the ethics committee of the University of Erlangen-Nuremberg (approval no. 3816).

Table 1 Patient Characteristics

	Test group			Control group		
	F	M	Total	F	M	Total
	n = 10	n = 18	n = 28	n = 10	n = 30	n = 40
Mean age ± SD (range) (y)	63 ± 11 (44–85)	65 ± 8 (48–78)	64 ± 9 (44–85)	62 ± 11 (34–82)	53 ± 11 (44–79)	59 ± 12 (34–82)
Mean age ± SD of maxillary edentulism (range) (y)	58.30 ± 10.70 (39–80)	59.94 ± 7.78 (43–72)	59.36 ± 8.78 (39–80)	–	–	–
Mean ± SD prosthesis in situ prior to rehabilitation (range) (y)	4.70 ± 1.33 (3–8)	5.11 ± 1.45 (3–7)	4.96 ± 1.40 (3–8)	–	–	–

Control Group

Forty subjects with a mean age of 59 ± 12 years without any speech disorders or oral diseases and with a complete maxilla and mandible without prosthetic treatment served as the control group (Table 1). The control and patient groups were matched according to age and sex. All subjects in the control group were native German speakers using a local dialect similar to that of the patient group.

Assessment of Dental Status

The adequacy of the maxillary dentures was assessed by one staff supervisor of the Department of Prosthodontics, University Hospital of Erlangen, regarding the following parameters: presence of pain concerning the chewing muscles, the soft and hard tissue in functional and nonfunctional situations, the presence of variances in the soft tissue such as redness or ulcers due to inadequate dentures, unbalanced occlusal relationship under function, an interocclusal distance greater or less than 2 mm in a physiologic resting position, and unacceptable fit proven by a soft pattern.

If one of the above parameters existed, the prosthesis was found to be inadequate and subsequently included in the study for further treatment.

Denture Design

Patients received new complete maxillary dentures in the follow-up treatment. Planning and construction of the prostheses was carried out by undergraduate students under the supervision of two faculty members of the Department of Prosthodontics. The dentures were fabricated in a commercial dental laboratory. Polymethyl-methacrylate resin (PMMA) was used for the denture base. The morphology of the palatal coverage, concerning the extension as well as the thickness of the palate (ranging from 1.5 to 2.5 mm), was chosen in consideration of technical (stability) and functional (retention, speaking, cleaning) requirements and kept to a minimum.

Prior to insertion of the newly fabricated denture, the responsible assistant medical director of the Department of Prosthodontics supervised the adequacy of the rehabilitation. No specific instructions regarding phonetics and speech were given to the patients upon denture delivery.

Speech Recordings

Speech recordings were processed during regular outpatient examinations. The two recording sessions were taken under standardized laboratory conditions in a low noise setting. The subjects were asked to read the German version of the text *The North Wind and the Sun*, consisting of 108 words and including all phonemes of the German language. Due to its phonetic balance, it acts as a referee text for the International Phonetic Alphabet by the International Phonetic Association. The text was presented on a computer screen divided into 10 paragraphs according to syntactic boundaries. To ensure that optical/visual problems were not affecting the patients' reading performance, the text was displayed in large letters. The recordings were performed using a close talk microphone (Sennheiser PC 131) at a sampling frequency of 16 kHz and quantized with 16 bits. To standardize the recording method, a distance of 2 cm between the mouth and microphone was chosen.

The patients were asked to read the text on two dates: *(1)* with inadequate prosthesis in situ (pretreatment) and *(2)* with a new prosthesis in situ after an adaptation time of 6 months (posttreatment).

PEAKS

The automatic speech recognition system PEAKS is a state-of-the-art method for standardized measurements of speech intelligibility in the area of prosthetic dentistry, established and validated by the authors' workgroup.[39] The internal dictionary can resort to all phonemes of the German language and has been trained using recorded data from the VERBMOBIL Project.[40] By first using mel-frequency cepstrum coefficients and consecutively hidden Markov models, the system can objectively compare the recorded data to the internal dictionary with its word models. Subsequently, a probability of the correctly spoken words is computed as further described in Stemmer.[41]

The word accuracy (WA) is calculated as follows: WA (%) = C – W / R × 100% (C = correctly spoken words; W = wrongly inserted words; R = all words in the referee text).

OHIP-G 14

The OHIP-G 14 (OHIP German short version) was used to assess OHRQoL. Fourteen OHRQoL items were rated on a scale of 0 to 4 (0 = never, 1 = hardly ever, 2 = occasionally, 3 = fairly often, and 4 = very often). It comprises the following domains: functional limitation (two questions), handicap (one question), physical disability (three questions), physical pain (two questions), psychologic disability (one question), psychologic discomfort (three questions), and social disability (two questions). Accordingly, the values are added and can range from 0 to 56 points. A higher score characterizes an impaired OHRQoL, whereas a lower score indicates a superior OHRQoL. The patients were required to fill out the OHIP-G 14 form 1 week before maxillary prosthetic rehabilitation, wearing an inadequate prosthesis, as well as 6 months after dental rehabilitation. According to prior studies from Szentpetery et al and Eitner et al,[42,43] categories that included the responses "fairly often" and "very often" were considered "frequently reported problems."

Statistics

For testing homogeneity of variance, the Levene and Shapiro-Wilk tests were used for proof of normal distribution. If not indicated otherwise, the statistical preconditions were given for all tests calculated. Descriptive statistics, means, frequencies, and SDs were calculated through explorative data analysis. A Student *t* test was used to compare parametric data before and after the rehabilitation. The Wilcoxon rank test was used to compare nonparametric data. The Pearson chi-square test was used for distribution independence. The association between changes in word accuracy and the OHIP scores was calculated using Spearman rank correlation coefficient. Statistical significance was stated with two-sided adjusted *P* values ≤ .05. All statistical tests were performed using SPSS version 19 for Windows (IBM).

Results

Automatic Standardized Scoring of WA

WA in patients with inadequate complete maxillary dentures in situ before new denture construction (57.57; SD: 14.97; range: 5.56 to 79.63) was significantly reduced compared with 6 months after rehabilitation with adequate maxillary dentures in situ (63.27; SD: 12.80; range: 25.75 to 78.58) and with the control group (69.79; SD: 10.59; range: 32.40 to 88.00). However, the WA level of the test group did not align with the control group after 6 months of adaptation time ($P = .025$).

Evaluation of OHIP-G 14 Scores

Self-assessment with OHIP-G 14 questionnaires prior to treatment yielded a range of 0 to 39 (possible maximum, 54). The posttreatment self-assessment yielded a range from 0 to 29. A significantly lower (superior) summary OHIP score was documented 6 months after maxillary dental rehabilitation compared with the pretreatment scores (pretreatment: 13.07; SD: 9.22; 6 months posttreatment: 5.14; SD: 6.77; $P < .01$).

Subjects during the pretreatment period most frequently answered questions with "fairly often" or "very often" in regard to the following items: feeling uncomfortable about eating any food (7 patients), having painful aching in their mouth (6 patients), and being irritable around other people (6 patients). Six-months posttreatment with adequate complete dentures, the items feeling impaired with regard to their sense of taste (3 patients) and feeling uncomfortable about eating any food (3 patients) were highlighted most often (Table 2). Concerning the item "difficulty pronouncing certain words," 10 of 28 subjects (35.7%) did not state any difficulty before treatment with the inadequate prosthesis in situ. After treatment, 18 of 28 subjects (64.3%) did not report any difficulties regarding the articulation of words. However, no significant difference could be stated with regard to the pre- and posttreatment assessment of this specific OHIP-G 14 item ($P = .19$). Two subjects reported frequent difficulties pronouncing words prior to treatment. Six months posttreatment, one individual

Table 2 Pre- and Posttreatment Data from the OHIP-G-14 and Objectively Assessed Word Accuracy

	Pretreatment	Posttreatment	*P*
OHIP-G 14 summary score	13.07 (SD, 9.22)	5.14 (SD, 6.77)	< .01
Most frequent problems:			
1. Being irritable around other people	7 (28%)	1 (3%)	< .01
2. Painful aching in their mouth	6 (25%)	0 (0%)	< .01
3. Uncomfortable about eating food	6 (25%)	3 (10%)	< .01
4. Impaired sense of taste	3 (10%)	3 (10%)	> .05
Word accuracy (%)	57.57 (SD, 14.97)	63.27 (SD, 12.80)	< .01

Table 3 Correlations Between WA and the OHIP Sum Score and Subscales

	Pretreatment		Posttreatment	
	Correlation to WA*	*P*	Correlation to WA*	*P*
Functional limitation	0.212	.319	0.322	.117
Physical pain	−0.16	.940	−0.139	.508
Psychologic discomfort	0.101	.639	−0.050	.811
Psychologic disability	0.163	.447	0.202	.332
Physical disability	0.054	.801	0.038	.855
Social disability	−0.282	.182	0.038	.858
Handicap	0.048	.825	0.097	.644
OHIP subitem no. 1	0.146	.459	0.174	.405
OHIP summary score	0.083	.700	0.095	.658

WA = word accuracy
*Spearman rank correlation coefficient.

assessed himself as still having frequent difficulties with pronunciation.

Correlation Between WA and OHIP Scores

Table 3 lists the OHIP sum score and scores of the seven subscales correlated with WA. The OHIP subitem number one (difficulty pronouncing certain words) was also investigated with regard to a possible correlation with WA. No correlation could be found between WA scores and OHIP scores. WA and OHIP-G 14 summary scores are shown in Fig 1.

Discussion

It was the aim of the study to assess the influence of speech intelligibility enhancement that can be achieved through prosthetic dental rehabilitation on the OHRQoL. Since the demand for treatment cannot completely be derived from clinical parameters, combinations of subjective and objective measurement methods are preferred.[14] This study is the first to have evaluated the OHIP-G 14 as self-reported quality of life in combination with the objective assessment of speech intelligibility in the dental prosthetic rehabilitation of elderly people.

Subjective, patient-centered instruments have been developed in recent years that take the individual psychosociologic factors into account when assessing the impact of diseases or their treatment on quality of life. The OHIP-G 14, as a valid and widely known method for assessing these parameters, was applied for obtaining the subjective data and impact on OHRQoL. This study yielded an improvement in OHRQoL after conventional prosthetic rehabilitation, showing significant differences to the pretreatment OHIP-G 14 self-assessment score. Similar results were found in the literature.[44,45] An improvement in

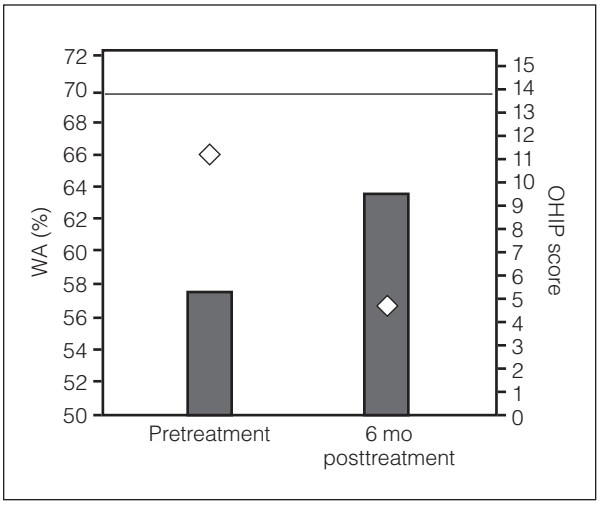

Fig 1 WA and OHIP-G 14 summary scores with regard to the pre- and posttreatment assessment.

OHRQoL is known to be a result of dental care in general[44] and of prosthetic rehabilitation in particular.[46] Furthermore, it has been proven that wearing adequate complete dentures has a positive impact on the OHIP-G and quality of life.[45,47] In accordance with a prior study regarding complete maxillary dentures made using the copying technique, the item "being irritated around other people," which was reported most frequently prior to rehabilitation, improved significantly in the 6-month posttreatment assessment.[18] In contrast, studies indicate that oral rehabilitation does not necessarily impact the general OHRQoL when an insufficient prosthesis is restored.[18,48]

There exists much research in prosthetic dentistry that reports on the prominent influence of a maxillary prosthetic rehabilitation with regard to speech.[24,31,32] Thus, subjects having their complete maxillary denture replaced were chosen because the mandible appeared to be more important for providing stability for mastication rather than speech production.[49–51] Similar to a prior study, after 6 months of adaptation time, speech intelligibility was significantly enhanced through new complete maxillary dentures compared with the previously worn inadequate maxillary prostheses.[36] Still, alignment with the control group in regard to speech intelligibility did not completely take place within the 6-month period. These results matched those of a prior study, having retrospectively assessed speech intelligibility in patients with adequate and inadequate complete maxillary dentures.[35] The influence of time on speech production after rehabilitation with dentures was assessed in the literature. Results of these studies suggest a habituation period of 2 to 4 weeks or longer.[27,28,52] While Marxkors suggested a habituation period of 6 months to assure that the specific neuromuscular adaptation processes are completed,[53] elderly subjects in particular tend to have more problems adjusting to new dentures.[54,55] However, a recent study was able to show a descriptive amelioration without a significant level of speech intelligibility between 1 week and 6 months after the insertion of new dentures.[36] Still, an observation period of 6 months was chosen in this study to ensure that the process of individual habituation was completed. It has to be taken into account that adaptation to a prosthesis prior to the new fabrication might also play an important role with regard to the results of speech intelligibility amelioration. Since all patients in this study had worn inadequate maxillary dentures in situ for at least 3 years, the habituation process to these dentures could have been accelerated due to the already existing neural and proprioceptive adaptation prior to the fabrication of new dentures.

Concerning speech intelligibility, the OHIP-G 14 data did not report significant changes for the item "difficulty pronouncing certain words," which is part of the OHIP definition of functional limitation.[56] Furthermore, only 8 of 28 subjects (28.8%) reported a subjective amelioration in "pronouncing words" after prosthetic rehabilitation. However, a significant improvement in speech outcome can be observed when objectively evaluating speech intelligibility with the automatic speech recognition system. But neither the OHIP sum score nor the scores of the seven subscales were highly correlated with objective speech intelligibility. The OHIP subitem number one (difficulty pronouncing certain words) in particular was found to have no correlation with speech outcome. In contrast to the most reported items (being irritable around other people, feeling uncomfortable about eating any food, and experiencing painful aching in their mouth), articulatory problems did not appear to have a major impact on the OHRQoL of elderly patients when considering the fabrication of new complete maxillary dentures. Subsequently, it can be stated that speech intelligibility enhancement achieved by replacing inadequate dentures with adequate ones might play a minor role compared with patients' mastication abilities and food intake, as well as freedom from pain. This conclusion must necessarily be tempered with regard to the design of the study. It has to be taken into account that even before prosthetic attendance, reduced speech quality was not a critical factor for the fabrication of new maxillary dentures, as reported in the pretreatment data.

A bilaterally balanced occlusion concept was chosen for the fabrication of new dentures. Even if there is no real evidence for the use of a bilaterally balanced complete denture over a canine-guided complete denture, improved stability and masticatory function as well as a reduction in alveolar bone resorption are reported.[57–59] Furthermore, since complete denture restoration by means of a bilaterally balanced occlusion is reported to have a shorter adaptation period, an early adaptation to new dentures might result in superior patient satisfaction and OHRQoL.[60] Since the treatment was conducted by undergraduate students, the reproducibility of the study could be questioned. However, the fabrication of the prostheses was processed under constant supervision by the same external dental laboratory, the accuracy and adequacy of the prostheses were constantly checked by the responsible assistant medical director, and only perfectly fitting prostheses were inserted to ensure the adequacy of the complete maxillary dentures. The computer-based automatic scoring of speech intelligibility by the PEAKS speech recognition system was previously introduced by the authors.[61,62] The automatic system is based on the accuracy of spoken words (WA), and its implementation in various medical fields is stated in prior studies.[37,38,63–65] In the area of prosthetic dentistry, there exists a high correlation of the automatically scored WA to speech intelligibility.[66] However, it has to be kept in mind that the WA is similar but not akin to speech intelligibility, with both being influenced by the same parameters (voice, phonematic and morphosyntactic structures, velocity, amplitude). Furthermore, for the implementation of an automatic speech recognition system in clinical practice, a personal computer with headphones is needed. However, speech recordings can be attained chairside within a short period of time, so a simple integration into a clinical setting can be realized. Still, speech intelligibility measurement through the automatic speech recognition system can only be provided for people with the ability to read and without other speech impairments.

It must be kept in mind that other questionnaires could be more suitable for conducting a subjective speech assessment, with a subsequently higher correlation with objective speech intelligibility. Furthermore, it still remains questionable to what extent the speech adaptation capabilities are diminished in elderly patients with hearing impairments, as they make up a large cohort in prosthetic dentistry. With these valuable questions still unanswered, further investigations have to be conducted.

Conclusion

OHRQoL can be significantly ameliorated through oral rehabilitation concerning complete maxillary dentures in elderly people as well as improvement in speech intelligibility. However, no significant influence of speech intelligibility enhancement on the OHRQoL could be found. The data suggests that speech intelligibility enhancement achieved through the fabrication of new complete maxillary dentures is not in the forefront of elderly patients' perception of their OHRQoL. For improving the quality of life in elderly patients, food intake and mastication as well as freedom from pain might play a more prominent subjective role than an enhancement in speech intelligibility.

Acknowledgment

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Literature Abstract

Association of smokeless tobacco use and smoking in adolescents in the United States: An analysis of data from the Youth Risk Behavior Surveillance System survey, 2011

The study investigated patterns of use of smokeless and smoking tobacco among a representative cross section of adolescents in the United States. Cigarette usage is in decline and smokeless tobacco has been marketed for use in smoke-free places and as part of a harm reduction strategy or alternative to smoking. Its use has been linked to oral diseases, including cancer, soft-tissue lesions, periodontal disease, and caries. It comes in many forms that can be placed under the lip, chewed, or dissolved. The aim of the study was to determine if adolescent smokers are also more likely to use smokeless tobacco than nonsmokers. The sample was taken from a previous study survey sent to school students in grades 9 to 12, from those respondents who answered questions on tobacco use, and numbered 9,655. Direct questions on use of tobacco products were asked. Sex, race, ethnicity, and education were determined. Lifestyle variables such as playing on a sports team, body mass index, and soda use were queried. Risk-taking behaviors such as binge drinking, marijuana use, having sexual intercourse, and riding in a vehicle with a driver who had been drinking were assessed. Multivariable analysis showed that smokeless tobacco users were more likely to be nonHispanic white, overweight, and male, to ride with a driver who has been drinking and to have engaged in binge drinking and sexual intercourse. There was a prevalence of 16.8% of smokers and 3.92% for dual tobacco use. The author concluded that there is a strong association between using smokeless tobacco products and smoking and users were also more likely to engage in certain risk-taking behaviors. As health care providers, this data can help target adolescents who match a pattern of behavior and who may also use tobacco in its different forms.

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