Functional Outcomes for Clinical Evaluation of Implant Restorations

Francesco Bassi, MD, DDS[a]/Alan B. Carr, DMD[b]/Ting-Ling Chang, DDS[c]/Emad W. Estafanous, BSD, MSD[d]/
Neal R. Garrett, PhD[e]/Risto-Pekka Happonen, DDS, PhD[f]/Sreenivas Koka, DDS, MS, PhD, MBA[g]/
Juhani Laine, DDS, PhD[h]/Martin Osswald, MBDS, MDent[i]/Harry Reintsema, DDS, PhD[j]/
Jana Rieger, MSc, PhD[k]/Eleni Roumanas, DDS[e]/Thomas J. Salinas, DDS, MS[b]/
Clark M. Stanford, BSc, DDS, PhD[l]/Johan Wolfaardt, BDS, MDent, PhD[m]

The functional outcomes related to treating patients afflicted with tooth loss are an important hallmark in substantiating prosthodontic intervention. The Oral Rehabilitation Outcomes Network (ORONet) conducted two international workshops to develop a core set of outcome measures, including a functional domain. The process followed the general format used in the Outcome Measures in Rheumatology (OMERACT) workshops to develop consensus for clinical outcome measures in arthritis research, which included: developing a comprehensive list of potential outcomes in the literature; submitting them to a filter for validity, clinical discrimination, and feasibility; and ranking those measures meeting all the filter criteria for relative value. The search was conducted to include functional assessments of speech, swallowing, mastication, nutrition, sensation, and motor function as they relate to dental implant therapies. This literature review surveyed 173 papers that produced some result of these descriptors in the functional domain. Of these, 67 papers reported on functional assessments and further defined objective and subjective outcomes. Many of these results were patient-perceived improvements in function, while others were objective assessments based on established methodologies and instruments. Objective evaluations of masticatory function and speech may meet criteria for validity and discriminability for selected interventions, but are generally not feasible for routine use in clinical care settings. The current recommendation is to employ a well-validated survey instrument that covers mastication and speech, such as the Oral Health Impact Profile (OHIP-14, short form), recognizing that patient perceptions of function may differ from objective ability. *Int J Prosthodont 2013;26:411–418. doi: 10.11607/ijp.3404*

A primary goal of prosthodontic rehabilitation is the restoration of function. Tooth loss can produce varying degrees of impairment in mastication, swallowing, and speech, potentially impacting nutrition and physical health, social interactions, and psychologic health. Functional outcomes related to

[a] *Professor, Department of Biomedical Science and Human Oncology, Prosthodontic Section, University of Turin, Torino, Italy.*
[b] *Professor, Mayo Clinic College of Medicine/Consultant, Department of Dental Specialties, Division of Prosthodontics, Mayo Clinic, Rochester, Minnesota, USA.*
[c] *Clinical Professor, Division of Advanced Prosthodontics, UCLA School of Dentistry, UCLA, Los Angeles, California, USA.*
[d] *Assistant Professor, Department of Prosthodontics, College of Dentistry, University of Iowa, Iowa City, Iowa, USA.*
[e] *Professor, Division of Advanced Prosthodontics, UCLA School of Dentistry, UCLA, Los Angeles, California, USA.*
[f] *Professor, Department of Oral and Maxillofacial Surgery, Institute of Dentistry, Faculty of Medicine, University of Turku, Turku, Finland.*
[g] *Executive Director, Foundation for Oral Rehabilitation, Lucerne, Switzerland.*
[h] *Senior Prosthodontist, Department of Oral and Maxillofacial Diseases, Turku University Hospital, Turku, Finland.*
[i] *Assistant Professor, Institute for Reconstructive Sciences in Medicine, Misericordia Community Hospital; Division of Otolaryngology-Head and Neck Surgery, Department of Surgery, Faculty of Medicine and Dentistry, University of Alberta, Edmonton, Alberta, Canada.*
[j] *Associate Professor, Center for Special Dental Care and Maxillofacial Prosthetics, Department of Oral and Maxillofacial Surgery, University Medical Centre Groningen and University of Groningen, Groningen, The Netherlands.*
[k] *Professor, Faculty of Rehabilitation Medicine, University of Alberta, Edmonton, Alberta, Canada.*
[l] *Centennial Fund Professor, Dows Institute for Dental Research and Department of Prosthodontics, College of Dentistry, University of Iowa, Iowa City, Iowa, USA.*
[m] *Professor, Institute for Reconstructive Sciences in Medicine, Misericordia Community Hospital; Division of Otolaryngology-Head and Neck Surgery, Department of Surgery, Faculty of Medicine and Dentistry, University of Alberta, Edmonton, Alberta, Canada.*

Correspondence to: *Dr Neal Garrett, Division of Advanced Prosthodontics, School of Dentistry, University of California, Los Angeles, Box 951668, Los Angeles, CA 90095-1668, USA. Email: ngarrett@ucla.edu*

This paper was presented, in part, at the 14th Biennial Meeting of the International College of Prosthodontists, Hawaii, September 2011.

Table 1 Overview of Search Results

No. of abstracts retrieved	173
No. of articles excluded (reviews and others)	26
No. of articles excluded (no functional outcomes)	80
No. of articles included	67

tooth loss and prosthodontic rehabilitation have been proposed as a critical component or domain in determining patient perceptions of oral health–related quality of life.[1] There continues to be a need for functional evaluation in prosthodontic research to direct the most effective treatment decisions to meet patient expectations, provide health benefit, and maximize health care resource utilization.

While the incidence of edentulism in developed countries seems to be declining,[2–6] there is still a need for management of tooth loss as a chronic disease state that demands clinical resources and therefore begs for validation of related outcomes. The partially dentate patient, encompassing a larger proportion of patients, also requires an effort in validating functionally based outcomes.[7,8] Loss of multiple adjacent teeth and edentulism have been related to patient perceptions of problems with mastication and speech function.[9]

Physiologic parameters such as tissue health and bone loss have been associated with evaluation of prosthodontic treatment success and the need for new/additional/revised treatment, particularly in evaluation of dental implant-based therapies. This class of outcomes was included in the Oral Rehabilitation Outcomes Network (ORONet) working group evaluation of longevity outcomes. For the purpose of this review, the focus was on both subjective and objective outcomes related to oral function following tooth loss and restoration, including mastication, speech, and swallowing. Secondary outcomes related to the ability to perform these primary functions, such as oral sensation and perception, occlusal force, and motor function, are also included in this review.

Materials and Methods

ORONet conducted two international workshops in 2008 and 2009 to develop a core set of outcome measures that could be used across network sites to document clinical and patient-centered outcomes of implant-based restorations. The process followed the general format used in the Outcome Measures in Rheumatology (OMERACT) workshops[10] to develop consensus for clinical outcome measures in arthritis research, including: developing a comprehensive list of potential outcomes in the literature; submitting them to a filter for validity, clinical discrimination, and feasibility; and ranking those meeting by all the filter criteria for relative value.

Potential search terms to permit identification of functional outcome measure in the literature were circulated among the ORONET working group members for review and refinement. The final search string was intended to include functional assessments of speech, mastication, nutrition, sensation, and motor function as they relate to dental implant therapies. The search string was submitted to the PubMed/Medline search and database engine ("dental implants"[Mesh] AND ("speech" OR "swallowing" OR "mastication" OR " nutrition" OR "sensory function" OR "motor function") AND (("1995/01/01"[PDat]:"2007/12/31"[PDat]) AND (Humans[Mesh]) AND (English[lang]))) to generate a listing of publications of potential interest for this standardized review for the first workshop in 2008, and the search was repeated for the second workshop with the dates modified to include all articles in years 2008 and 2009. Only those articles that contained an abstract were included. The abstracts were retrieved and initially reviewed for content by the ORONet Functional Outcomes Working Group (JR, FB, TS, NG). Included were clinical research studies with a clear functional outcome measure. Review articles, case reports, technique illustrations, and studies without a clear description of a functional outcome measure were excluded.

Results

The search string returned 173 abstracted papers from January 1, 1995, to December 31, 2009 (Table 1). Upon review, 26 were found to be review articles, technique articles, or case reports and were excluded. In addition, 80 articles were excluded due to not containing clearly described functional outcome measures. Thus, of the 173 abstracts retrieved, 67[11–77] were found to be suitable for review of the complete article and abstraction of the functional outcome measures reported.

The functional outcomes from those 67 papers were distributed in five broad categories (Table 2): mastication, speech, nutrition, swallowing, and sensation. Some of the papers had two or more outcome measurement categories, and each was counted in the appropriate category.

Outcomes Related to Mastication

Many of the 58 studies[11–16,18–25,27–29,31–33,35–48,50–53,55,57–63,65–70,72–77] on mastication used qualitative outcomes (arbitrary questionnaires, validated questionnaires, visual analog scales, 40/58, 69%) and to a lesser extent quantitative outcomes related to masticatory performance (8/58, 14%), or motor responses (11/58, 19%) such as electromyography (EMG), occlusal force, or other kinematic methods of measuring this parameter. Some of the studies used successive treatment stage evaluation by swallowing threshold performance, chewing strokes, and sieve measurement to demonstrate an objective improvement with the patient serving as a control. It should be noted that 6 of the 58 articles (10%) reported unspecified outcomes related to mastication.

Three articles addressed patients who underwent tumor resection of the jaws and subsequently underwent surgical and/or prosthodontic rehabilitation.[23,37,57] Although patient numbers were diminutive and a cross-sectional approach was used, an improvement in mastication was noted. The mastication and speech outcomes were rated by using indices that were referenced from studies of those patients (without jaw resection) treated with dental implants. It may be beneficial to further compare qualitative findings as a patient-specific perceived improvement to those that are interpolated quantitative outcomes related to assumed masticatory improvement. Some of the perceived outcomes were qualitative in nature and were not standardized.

Evaluating these outcomes in light of the OMERACT filter for truth, discrimination, and feasibility, several measures were found by the ORONet group to be valid (truth) and discriminatory (reliable and sensitive), including objective measures of particle size analysis following mastication, EMG, and kinematic measures. These measures have been validated based on their application with varied patient characteristics and prosthetic treatments. However, these measures were designed for use in clinical trials, and the ORONet working group found the methods were not feasible for routine clinical application, failing the filter requirement.

Of the survey instruments, the Oral Health Impact Profile (OHIP) was found to meet the criteria of truth when viewed as a patient perspective of function, discriminability (evidence of reliability and sensitivity), and feasibility (particularly the short form).

Outcomes Related to Nutrition

Of the 10 articles[19,21,27,28,38,43,45,61–62,75] that evaluated nutrition, 9 (90%) were primarily qualitative questionnaires and may be summarized with respect to patient-perceived improvements in dietary choices. One study[45] used serologic and other physiologic vital statistics, such as the Body Mass Index (BMI), to ascertain nutrition quality. Compared to those treated with complete dentures, implant overdenture subjects had significant increases in serum albumin, hemoglobin, and serum B12 when evaluated at 6 months post-treatment. Subjective assessments of the patient's ability to chew foods with less restriction were also noted. While being an often-cited objective measure for nutrition studies, BMI may not be a valid or sensitive measure for prosthodontics interventions, as it does not directly measure change in the nutritional content of a diet or a number of other variables that may affect it significantly. This study had a relatively small number of subjects, further citing the need for additional randomized controlled trials with larger populations.

Examiner-created questionnaires and food reports/diaries may give a more patient-centered indication for the food types chosen. However, this may not be a valid method for determining outcomes related to nutrition as this value may be confounded by patient perceptions, ethnic influences, socioeconomic factors, and other circumstances poorly correlated with nutritional status improvement.

Table 2 Categories of Functional Outcome Measures with Frequency of Utilization

	Frequency
Mastication	
Surveys	40
Objective measures	8
Motor	11
Unspecified	6
Nutrition	
Surveys	9
Objective measures	1
Unspecified	0
Oral sensation	
Surveys	4
Objective measures	2
Unspecified	1
Speech	
Surveys	29
Objective measures	6
Unspecified	4
Swallowing	
Surveys	7
Objective measures	2
Unspecified	2

Due to the small number of studies and subjects, the Functional Working Group found it difficult to validate a feasible nutritional outcome measure to guide therapy.

Outcomes Related to Sensation

Of the seven articles[15,19,26,31,47,49,64] surveying sensation as the outcome, four included some questionnaires or visual analog scale (VAS) as an instrument in defining outcome. Other references favorably surveyed patient-perceived improvements in comfort/taste of consuming hot and cold foods with mandibular implant-retained prostheses.[47] One study surveyed the donor site morbidity associated with retromolar bone grafts, which did not show compromised sensation.[49] Further outcomes of two-point discrimination, pain, and thermal tests were limited. Intervention in these cases was entirely surgical and not inclusive of prosthodontic intervention. Assessment of perception of thickness threshold was used in one study to provide objective measurement of sensation differences between conventional and implant-retained prostheses.[64]

Outcomes Related to Speech

In the 38 studies with speech outcomes,[11,12,14,15,17,19–21,23,26–31,33,34,37–40,42,43,45,47,51–57,59,62,63,66,67,75] there were 39 different outcomes reported. The great majority (29/39, 74%) of these outcomes were patient perceptions (VAS, OHIP, or other questionnaires) of speech improvement following prosthodontic therapy. sSeveral studies used both trained and untrained listeners to assess speech intelligibility, all of which trended toward significant speech improvement with dental implant treatment.[23,30,34,57,63] This domain was found to be sensitive to patients afflicted with defects of the head and neck post-tumor ablative surgery or those jaws surgically and prosthetically reconstructed. Further, one reference disclosed that a specific prosthetic design may be preferred over the alternative for improved consonant production.[30] The balance of the literature included a clinically based or quantitative assessment, which may not be sensitive to tooth replacement therapy in the partially dentate or edentulous patient without extensive oral-facial impairment from tissue loss due to a variety of medical conditions and rehabilitation (for example, surgical ablation and reconstruction due to oropharyngeal cancer).

Clinical assessments of articulation, intelligibility, auditory analysis, examiner-created questionnaires, and validated questionnaires such as the OHIP may be easily applied but not necessarily sensitive to traditional prosthodontic interventions. In addition, the manner in which consonant production varies from culture to culture and between subjects may complicate interpretation of more objective tests across populations. This is especially true for patients treated for cancer of the head and neck.

The Functional Working Group found that none of the measures for speech assessment could satisfy all three filter requirements for truth, discriminability, and feasibility for routine implant-based and conventional prosthodontic restorations. Again, the OHIP is the one instrument that appears to best meet the demands for feasibility and validity (from the patient-centered perspective), but discriminability remains a question for this domain.

Outcomes Related to Swallowing

Nine of 10 studies[15,28,37,42,45,51,52,57,63,71] evaluating swallowing used questionnaires in what appeared to be an attempt to determine the ability to swallow without invasive assessment methods. Although small effects were noted for those treated with implant-retained overdentures, the major impacts were seen for patients afflicted with head and neck cancer who underwent prosthodontic rehabilitation.

Oral transit times and other quantitative assessments of swallowing efficiency are objective methods, but may also yield very individualized results since most defects are unique and present with specific challenges and disabilities. Two studies[63,70] used these quantitative methods to illustrate modest differences in muscle function and preparatory phases of swallowing after treatment. Based on the number of subjects within the study groups, outcomes cannot be reliably inferred. The limited discriminability of survey instruments, and even objective methodologies, to most prosthodontic treatments indicates there is no currently suitable core outcome measure for swallowing that meets all three filter criteria.

Discussion

The articles reviewed in the study appeared to be primarily based on outcomes related to patient-perceived improvement and objective measurements with benchmark parameters. Some of the subjective outcome measurements may have value in interpretation of treatment efficacy, as they present the perspective of those who have perceived self-improvement in function. However, many of the instruments used were not subjected to extensive evaluation of replicability, validity, or sensitivity of the instruments, particularly for typical implant-based prosthodontic

therapies. The objective outcome measurements also have value in providing perspective to collective and future studies in assessing these outcomes.

As many of the studies surveyed improvement of function after surgical and prosthodontic intervention, the results of some outcomes are found with relatively small numbers of patients and interpretation should be cautioned. The functional domains of mastication seem to be well represented and favorable in outcome from objective and subjective methods in the articles surveyed. It is noteworthy to interpret that improvement in mastication was more likely to be seen if the initial impairment or anatomical defect was large (ie, edentulism and jaw resection). This generalization is taken with caution based on the limited sampling size and specific patient heterogeneity.

The improvement of speech was variable in outcome from both patient-perceived improvements and that of third-person trained and untrained listeners. Although subjective and objective improvement was noted to be significant for patients with head and neck cancer treated with implants,[23,57] these sample sizes were also small and could be better substantiated in the future with multicenter sampling approaches. For those patients without significant orofacial defects, the discriminability of both survey instruments and objective speech measures are limited for the majority of prosthodontic applications.

Nutrition was assessed primarily through patient-perceived improvements in dietary choices. Only one study looked objectively at serologic and anthropomorphic characteristics to assess outcomes related to implant prosthodontic intervention with modest improvement. Although some preferences exist from patient-specific examples, the variability of these questionnaire results is widespread, making interpretation difficult.

Swallowing was assessed primarily by patient-centered outcomes. Only a few of the studies looked at specific quantifiable parameters giving rise to assessing the preparatory phases of swallowing, which relates to mastication outcomes. Pharyngeal and esophageal phases of swallowing were not inclusive in any of the studies, and it may be doubtful to make any specific inference that swallowing was improved by prosthodontic intervention. This is further supported by the fact that the physiology of swallowing is more comprehensive than simply oral preparation.[78] Much of the improvement associated with swallowing was found to be significant for patients with combination tongue/mandible defects, and this level of impairment may be critical for researchers to be able to observe improvement in transit times, normal reflexive swallowing, and age/disease-associated differences.[79,80]

Motor outcomes were only represented by one study that was narrow in focus and based on physical improvement of daily activities with implant-retained mandibular overdentures. The majority of these findings, however, were targeted at eating and speaking, making this more of an outcome related to mastication and speech. Perhaps this was a loosely defined parameter, which may be bundled into speech and mastication subdomains.

The sensory domain was represented by only seven references, which surveyed residual neurosensory deficit and discriminatory capacity. This outcome was interpreted almost entirely through that of the patient's perspective, which may be variable based upon loss of tissues and some levels of neurologic adaptation. Again, the interpretation of this outcome was limited, with more studies needed to yield acceptable objective and patient-centered outcomes.

Of some concern was the observation that of the 67 papers that purported to have outcomes related to the functional domains of interest, 13 (19%) did not give a clear definition of the bases of the outcome statements made in the article. Provision of at least a simple core measure would greatly assist these investigators in providing scientifically and clinically useful information.

While no single survey instrument or objective methodology strongly met all three requirements of the OMERACT filter (truth, discrimination, and feasibility), the OHIP-14 (short form) appears to be the best current alternative as a core measure. The reduction of questions from 49 in the original version to 14 in the short form greatly improves the feasibility for routine clinical use, while it maintains good validity, sensitivity to oral conditions, and reliability.[81] Since the domains cover questions related to eating, diet, speech, and function, the instrument provides a broad patient perspective of oral function

Conclusion

Restoration of function remains a primary goal in the management of tooth loss. Issues of improvement in mastication and speech are critical from the patient perspective. A variety of subjective and objective methodologies have been used to capture patient benefits in function with prosthodontic treatment, both conventional and implant-based. While several of these measures have been validated and can discriminate between oral conditions and prosthodontic treatments, feasibility for routine clinical use remains a problem. The OHIP-14 was found to be the best candidate for obtaining patient perspectives of oral function within a clinical setting.

Acknowledgment

The authors reported no conflicts of interest related to this study.

References

1. Guckes AD, Scurria MS, Shugars DA. A conceptual framework for understanding outcomes of oral implant therapy. J Prosthet Dent 1996;75:633–639.
2. Armour BS, Swanson M, Waldman HB, Perlman SP. A profile of state-level differences in the oral health of people with and without disabilities, in the US, in 2004. Public Health Rep 2008; 123:67–75.
3. Zitzmann NU, Hagmann E, Weiger R. What is the prevalence of various types of prosthetic dental restorations in Europe? Clin Oral Implants Res 2007;18(suppl 3):20–33.
4. Osterberg T, Carlsson GE, Sundh V, Mellstrom D. Number of teeth: A predictor of mortality in 70-year-old subjects. Community Dent Oral Epidemiol 2008;36:258–268.
5. Dye BA, Tan S, Smith V, et al. Trends in oral health status: United States, 1988–1994 and 1999–2004. Vital Health Stat 11 2007; (248):1–92.
6. Douglass CW, Shih A, Ostry L. Will there be a need for complete dentures in the United States in 2020? J Prosthet Dent 2002;87:5–8.
7. Ikebe K, Nokubi T, Ettinger RL, et al. Dental status and satisfaction with oral function in a sample of community-dwelling elderly people in Japan. Spec Care Dentist 2002;22:33–40.
8. Zarb GA, Schmitt A. The longitudinal clinical effectiveness of osseointegrated dental implants in anterior partially edentulous patients. Int J Prosthodont 1993;6:180–188.
9. Hugo FN, Hilgert JB, de Sousa Mda L, da Silva DD, Pucca GA Jr. Correlates of partial tooth loss and edentulism in the Brazilian elderly. Community Dent Oral Epidemiol 2007;35:224–232.
10. Tugwell P, Boers M. OMERACT conference on outcome measures in RA clinical trials: Introduction. J Rheumatol 1993;20: 528–530.
11. Awad MA, Lund JP, Dufresne E, Feine JS. Comparing the efficacy of mandibular implant-retained overdentures and conventional dentures among middle-aged edentulous patients: Satisfaction and functional assessment. Int J Prosthodont 2003; 16:117–122.
12. Awad MA, Lund JP, Shapiro SH, et al. Oral health status and treatment satisfaction with mandibular implant overdentures and conventional dentures: A randomized clinical trial in a senior population. Int J Prosthodont 2003;16:390–396.
13. Bakke M, Holm B, Gotfredsen K. Masticatory function and patient satisfaction with implant-supported mandibular overdentures: A prospective 5-year study. Int J Prosthodont 2002; 15:575–581.
14. Bedrossian E, Rangert B, Stumpel L, Indresano T. Immediate function with the zygomatic implant: A graftless solution for the patient with mild to advanced atrophy of the maxilla. Int J Oral Maxillofac Implants 2006;21:937–942.
15. Berretin-Felix G, Machado WM, Genaro KF, Nary Filho H. Effects of mandibular fixed implant-supported prostheses on masticatory and swallowing functions in completely edentulous elderly individuals. Int J Oral Maxillofac Implants 2009;24:110–117.
16. Berretin-Felix G, Nary Filho H, Padovani CR, Trindade Junior AS, Machado WM. Electromyographic evaluation of mastication and swallowing in elderly individuals with mandibular fixed implant-supported prostheses. J Appl Oral Sci 2008;16:116–121.
17. Bevilacqua RG, Ritoli EL, Kang C, Mabry K, Castiglione CL. Midmaxillary internal distraction osteogenesis: Ideal surgery for the mature cleft patient. Plast Reconstr Surg 2008;121:1768–1778.
18. de Albuquerque Junior RF, Lund JP, Tang L, et al. Within-subject comparison of maxillary long-bar implant-retained prostheses with and without palatal coverage: Patient-based outcomes. Clin Oral Implants Res 2000;11:555–565.
19. de Bruyn H, Collaert B, Linden U, Bjorn AL. Patient's opinion and treatment outcome of fixed rehabilitation on Branemark implants. A 3-year follow-up study in private dental practices. Clin Oral Implants Res 1997;8:265–271.
20. Del Fabbro M, Boggian C, Taschieri S. Immediate implant placement into fresh extraction sites with chronic periapical pathologic features combined with plasma rich in growth factors: Preliminary results of single-cohort study. J Oral Maxillofac Surg 2009;67:2476–2484.
21. Esfandiari S, Lund JP, Penrod JR, Savard A, Thomason JM, Feine JS. Implant overdentures for edentulous elders: Study of patient preference. Gerodontology 2009;26:3–10.
22. Fontijn-Tekamp FA, Slagter AP, Van der Bilt A, van't Hof MA, Kalk W, Jansen JA. Swallowing thresholds of mandibular implant-retained overdentures with variable portion sizes. Clin Oral Implants Res 2004;15:375–380.
23. Fukuda M, Takahashi T, Nagai H, Iino M. Implant-supported edentulous maxillary obturators with milled bar attachments after maxillectomy. J Oral Maxillofac Surg 2004;62:799–805.
24. Geertman ME, Slagter AP, van't Hof MA, van Waas MA, Kalk W. Masticatory performance and chewing experience with implant-retained mandibular overdentures. J Oral Rehabil 1999; 26:7–13.
25. Geertman ME, van Waas MA, van't Hof MA, Kalk W. Denture satisfaction in a comparative study of implant-retained mandibular overdentures: A randomized clinical trial. Int J Oral Maxillofac Implants 1996;11:194–200.
26. Gluckman H, Otto M. Success, survival and failure. SADJ 2008; 63:514–517.
27. Gurlek A, Miller MJ, Jacob RF, Lively JA, Schusterman MA. Functional results of dental restoration with osseointegrated implants after mandible reconstruction. Plast Reconstr Surg 1998; 101:650–655.
28. Harding SA, Hodder SC, Courtney DJ, Bryson PJ. Impact of perioperative hyperbaric oxygen therapy on the quality of life of maxillofacial patients who undergo surgery in irradiated fields. Int J Oral Maxillofac Surg 2008;37:617–624.
29. Heydecke G, Boudrias P, Awad MA, De Albuquerque RF, Lund JP, Feine JS. Within-subject comparisons of maxillary fixed and removable implant prostheses: Patient satisfaction and choice of prosthesis. Clin Oral Implants Res 2003;14:125–130.
30. Heydecke G, McFarland DH, Feine JS, Lund JP. Speech with maxillary implant prostheses: Ratings of articulation. J Dent Res 2004;83:236–240.
31. Heydecke G, Thomason JM, Lund JP, Feine JS. The impact of conventional and implant supported prostheses on social and sexual activities in edentulous adults: Results from a randomized trial 2 months after treatment. J Dent 2005;33:649–657.
32. Hobkirk JA, Brouziotou-Davas E. The influence of occlusal scheme on masticatory forces using implant stabilized bridges. J Oral Rehabil 1996;23:386–391.
33. Hug S, Mantokoudis D, Mericske-Stern R. Clinical evaluation of 3 overdenture concepts with tooth roots and implants: 2-year results. Int J Prosthodont 2006;19:236–243.
34. Kaptein ML, De Putter C, De Lange GL, Blijdorp PA. A clinical evaluation of 76 implant-supported superstructures in the composite grafted maxilla. J Oral Rehabil 1999;26:619–623.

35. Karkazis HC. EMG activity of the masseter muscle in implant supported overdenture wearers during chewing of hard and soft food. J Oral Rehabil 2002;29:986–991.
36. Kimoto K, Garrett NR. Effect of mandibular ridge height on masticatory performance with mandibular conventional and implant-assisted overdentures. Int J Oral Maxillofac Implants 2003; 18:523–530.
37. Kwakman JM, Voorsmit RA, Freihofer HP. Improvement in oral function following tumour surgery by a combination of tongue plasty by the Steinhauser technique and osseointegrated implants. J Craniomaxillofac Surg 1997;25:15–18.
38. Landes CA, Paffrath C, Koehler C, et al. Zygoma implants for midfacial prosthetic rehabilitation using telescopes: 9-year follow-up. Int J Prosthodont 2009;22:20–32.
39. Leung AC, Cheung LK. Dental implants in reconstructed jaws: Patients' evaluation of functional and quality-of-life outcomes. Int J Oral Maxillofac Implants 2003;18:127–134.
40. Levi A, Psoter WJ, Agar JR, Reisine ST, Taylor TD. Patient self-reported satisfaction with maxillary anterior dental implant treatment. Int J Oral Maxillofac Implants 2003;18:113–120.
41. Liddelow GJ, Henry PJ. A prospective study of immediately loaded single implant-retained mandibular overdentures: Preliminary one-year results. J Prosthet Dent 2007;97(6, suppl):S126–S137.
42. Mazor Z, Steigmann M, Leshem R, Peleg M. Mini-implants to reconstruct missing teeth in severe ridge deficiency and small interdental space: A 5-year case series. Implant Dent 2004;13: 336–341.
43. Melas F, Marcenes W, Wright PS. Oral health impact on daily performance in patients with implant-stabilized overdentures and patients with conventional complete dentures. Int J Oral Maxillofac Implants 2001;16:700–712.
44. Mijiritsky E, Ormianer Z, Klinger A, Mardinger O. Use of dental implants to improve unfavorable removable partial denture design. Compend Contin Educ Dent 2005;26:744–746.
45. Morais JA, Heydecke G, Pawliuk J, Lund JP, Feine JS. The effects of mandibular two-implant overdentures on nutrition in elderly edentulous individuals. J Dent Res 2003;82:53–58.
46. Morneburg TR, Proschel PA. In vivo forces on implants influenced by occlusal scheme and food consistency. Int J Prosthodont 2003;16:481–486.
47. Morris HF, Ochi S, Rodriguez A, Lambert PM. AICRG, Part IV: Patient satisfaction reported for Ankylos implant prostheses. J Oral Implantol 2004;30:152–161.
48. Murata T, Yamashita Y, Kurokawa H, Takahashi T. Dental rehabilitation using an implant-supported overdenture after repair of a fracture in a severely resorbed edentulous mandible: A case report. Int J Oral Maxillofac Implants 2004;19:749–752.
49. Nkenke E, Radespiel-Troger M, Wiltfang J, Schultze-Mosgau S, Winkler G, Neukam FW. Morbidity of harvesting of retromolar bone grafts: A prospective study. Clin Oral Implants Res 2002; 13:514–521.
50. Ohkubo C, Kobayashi M, Suzuki Y, Hosoi T. Effect of implant support on distal-extension removable partial dentures: In vivo assessment. Int J Oral Maxillofac Implants 2008;23:1095–1101.
51. Ohkubo C, Kobayashi M, Suzuki Y, Sato J, Hosoi T, Kurtz KS. Evaluation of transitional implant stabilized overdentures: A case series report. J Oral Rehabil 2006;33:416–422.
52. Pace-Balzan A, Cawood JI, Howell R, Butterworth CJ, Lowe D, Rogers SN. The further development and validation of the Liverpool Oral Rehabilitation Questionnaire: A cross-sectional survey of patients attending for oral rehabilitation and general dental practice. Int J Oral Maxillofac Surg 2006;35:72–78.
53. Penarrocha M, Carrillo C, Boronat A. Retrospective study of 68 implants placed in the pterygomaxillary region using drills and osteotomes. Int J Oral Maxillofac Implants 2009;24:720–726.
54. Penarrocha M, Carrillo C, Boronat A, Marti E. Level of satisfaction in patients with maxillary full-arch fixed prostheses: Zygomatic versus conventional implants. Int J Oral Maxillofac Implants 2007;22:769–773.
55. Penarrocha M, Carrillo C, Uribe R, Garcia B. The nasopalatine canal as an anatomic buttress for implant placement in the severely atrophic maxilla: A pilot study. Int J Oral Maxillofac Implants 2009;24:936–942.
56. Penarrocha M, Larrazabal C, Balaguer J, Serrano C, Silvestre J, Bagan JV. Restoration with implants in patients with recessive dystrophic epidermolysis bullosa and patient satisfaction with the implant-supported superstructure. Int J Oral Maxillofac Implants 2007;22:651–655.
57. Peng X, Mao C, Yu GY, Guo CB, Huang MX, Zhang Y. Maxillary reconstruction with the free fibula flap. Plast Reconstr Surg 2005; 115:1562–1569.
58. Pera P, Bassi F, Schierano G, Appendino P, Preti G. Implant anchored complete mandibular denture: Evaluation of masticatory efficiency, oral function and degree of satisfaction. J Oral Rehabil 1998;25:462–467.
59. Powers MP, Bosker H. Functional and cosmetic reconstruction of the facial lower third associated with placement of the transmandibular implant system. J Oral Maxillofac Surg 1996; 54:934–942.
60. Rismanchian M, Bajoghli F, Mostajeran Z, Fazel A, Eshkevari P. Effect of implants on maximum bite force in edentulous patients. J Oral Implantol 2009;35:196–200.
61. Roumanas ED, Garrett NR, Hamada MO, Diener RM, Kapur KK. A randomized clinical trial comparing the efficacy of mandibular implant-supported overdentures and conventional dentures in diabetic patients. Part V: Food preference comparisons. J Prosthet Dent 2002;87:62–73.
62. Sandberg G, Stenberg T, Wikblad K. Ten years of patients' experiences with fixed implant-supported prostheses. J Dent Hyg 2000;74:308–316.
63. Sansone KM, Filho HN, Berretin-Felix G, Brasolotto AG. Oral myofunctional and vocal characteristics in subjects subjected to oral rehabilitation with osseointegrated implants. Clin Oral Implants Res 2006;17:328–330.
64. Schierano G, Arduino E, Bosio E, Preti G. The influence of selective grinding on the thickness discrimination threshold of patients wearing complete dentures. J Oral Rehabil 2002;29: 184–187.
65. Schmitt A, Zarb GA. The notion of implant-supported overdentures. J Prosthet Dent 1998;79:60–65.
66. Siadat H, Alikhasi M, Mirfazaelian A, Geramipanah F, Zaery F. Patient satisfaction with implant-retained mandibular overdentures: A retrospective study. Clin Implant Dent Relat Res 2008; 10:93–98.
67. Takahashi T, Fukuda M, Funaki K, Tanaka K. Magnet-retained facial prosthesis combined with an implant-supported edentulous maxillary obturator: A case report. Int J Oral Maxillofac Implants 2006;21:805–807.
68. Tang L, Lund JP, Tache R, Clokie CM, Feine JS. A within-subject comparison of mandibular long-bar and hybrid implant-supported prostheses: Evaluation of masticatory function. J Dent Res 1999;78:1544–1553.
69. van der Bilt A, van Kampen FM, Cune MS. Masticatory function with mandibular implant-supported overdentures fitted with different attachment types. Eur J Oral Sci 2006;114:191–196.
70. van Kampen FM, van der Bilt A, Cune MS, Fontijn-Tekamp FA, Bosman F. Masticatory function with implant-supported overdentures. J Dent Res 2004;83:708–711.
71. Walton JN, MacEntee MI. Choosing or refusing oral implants: A prospective study of edentulous volunteers for a clinical trial. Int J Prosthodont 2005;18:483–488.

72. Walton JN, MacEntee MI, Glick N. One-year prosthetic outcomes with implant overdentures: A randomized clinical trial. Int J Oral Maxillofac Implants 2002;17:391–398.
73. Wennerberg A, Carlsson GE, Jemt T. Influence of occlusal factors on treatment outcome: A study of 109 consecutive patients with mandibular implant-supported fixed prostheses opposing maxillary complete dentures. Int J Prosthodont 2001;14:550–555.
74. Widmark G, Andersson B, Andrup B, Carlsson GE, Ivanoff CJ, Lindvall AM. Rehabilitation of patients with severely resorbed maxillae by means of implants with or without bone grafts. A 1-year follow-up study. Int J Oral Maxillofac Implants 1998; 13:474–482.
75. Willis MS, Schacht RN, Toothaker R. Anterior dental extractions among Dinka and Nuer refugees in the United States: A case series. Spec Care Dentist 2005;25:193–198.
76. Woodmansey KF, Ayik M, Buschang PH, White CA, He J. Differences in masticatory function in patients with endodontically treated teeth and single-implant-supported prostheses: A pilot study. J Endod 2009;35:10–14.
77. Zitzmann NU, Sendi P, Marinello CP. An economic evaluation of implant treatment in edentulous patients-preliminary results. Int J Prosthodont 2005;18:20–27.
78. Logemann JA. Swallowing physiology and pathophysiology. Otolaryngol Clin North Am 1988;21:613–623.
79. Logemann JA. Effects of aging on the swallowing mechanism. Otolaryngol Clin North Am 1990;23:1045–1056.
80. Wheeler RL, Logemann JA, Rosen MS. Maxillary reshaping prostheses: Effectiveness in improving speech and swallowing of postsurgical oral cancer patients. J Prosthet Dent 1980; 43:313–319.
81. Slade GD. Derivation and validation of a short-form oral health impact profile. Community Dent Oral Epidemiol 1997;25:284–290.

Literature Abstract

Are frequent dental x-ray examinations associated with increased risk of vestibular schwannoma?

This matched case-control study aimed to evaluate environmental risk factors that might result in vestibular schwannoma. It specifically investigated if having increased exposure to certain forms of radiation, such as diagnostic or therapeutic, and non-ionizing radiation from wireless phones, contribute to vestibular schwannoma (VS). Three hundred forty-three patients diagnosed with VS, who underwent gamma knife surgery between the years 1997 and 2007 were matched to 343 control patients with spinal degenerative disorders according to age (± 5 years) and sex. Information regarding factors associated with the development of a schwannoma, such as previous exposure to medical radiation or wireless phone technologies, were collected via a questionnaire or by phone interview by a trained recruiter. Potential confounders were estimated by use of the McNemar test. Conditional multivariate logistic regression was used to estimate adjusted odds ratios (ORs) and 95% confidence intervals (CIs). Race, education, cigarette smoking, alcohol consumption, occupational exposure to noise, use of cell phones, and family history of cancer were adjusted for. A single factor: exposure to dental radiographs once yearly (OR = 2.27, 95% CI = 1.01–5.09) or once every 2–5 years (OR = 2.65, 95% CI = 1.20–5.85) was associated with a higher risk. No relationship was found between the use of cell phones or cordless phones and VS. The authors conclude that patients diagnosed with VS were found to have a higher frequency of exposure to dental radiographs compared with the control group. However, as this retrospective study has numerous fundamental limitations, the authors suggested that the advice to reduce exposure to dental x-ray imaging to lessen the risk of developing VS should be objectively considered against the potential value of frequent dental imaging in the facilitation of dental diseases.

Han YY, Berkowitz O, Talbott E, Kondiziolka D, Donovann M, Lunsford LD. *J Neurosurg* 2012;117(suppl):78–83. **References:** 19.
Reprints: L. Dade Lunsford, MD, Department of Neurological Surgery, Suite B-400, UPMC Presbyterian Hospital, 200 Lothrop Street, Pittsburgh, PA 15213. **Email:** lunsfordld@upmc.edu—*Sheralyn Quek, Singapore*