Incidence of and Risk Factors for Tooth Loss in a Population of Older Canadians

D. Locker, J. Ford and J.L. Leake

J DENT RES 1996 75: 783
DOI: 10.1177/00220345960750020801

J Dent Res 75(2): 783-789, February, 1996

Incidence of and Risk Factors for Tooth Loss in a Population of Older Canadians

D. Locker, J. Ford, and J.L. Leake

Community Dental Health Services Research Unit, Faculty of Dentistry, University of Toronto, 124 Edward Street, Toronto, Ontario M5G 1G6, Canada

Abstract. Data on the incidence of tooth loss in community-dwelling older Canadians have not previously been reported. Since recent US studies of older adults were conducted in predominantly rural communities, their results may not be generalizable to Canada, where the majority of older adults live in major metropolitan or urban settings. This paper describes a study designed to estimate the incidence of tooth loss in older Canadians and to identify factors predictive of that loss. Using personal interviews and clinical examinations, we obtained baseline and three-year follow-up data from 491 dentate subjects. Overall, 23.2% lost one or more teeth between baseline and follow-up. Only six, or 1.2%, became edentulous. Twelve baseline factors were significantly associated with the probability of loss. However, in a logistic regression analysis, only five had significant independent effects. These were gender, marital status, self-rating of oral health status, the number of decayed root surfaces, and a mean periodontal attachment loss of 4 mm or more. The predictive ability of the model was poor, largely because tooth loss is a complex outcome which depends on decisions taken by dentists and patients. Since this decision-making process cannot be captured in epidemiological studies, observational studies are needed to cast further light on tooth loss in this population.

Key words: tooth loss, edentulism, incidence, older adults.

Received February 8, 1995; Accepted December 21, 1995

Introduction

Numerous cross-sectional surveys have described patterns of tooth loss in adult populations and documented the decline in rates of edentulism (Halse *et al.*, 1985; Weintraub and Burt, 1985; Battistuzzi *et al.*, 1987; Brown and Meskin, 1988; Hoover *et al.*, 1989; Heft and Gilbert, 1991). However, relatively few studies have examined the incidence of tooth loss or edentulism (Ahlqwist *et al.*, 1986, 1991; Hand *et al.*, 1988; Burt *et al.*, 1990; Eklund and Burt, 1994; Takala *et al.*, 1994).

Longitudinal studies of tooth loss in community-dwelling older Americans (Hunt *et al.*, 1988, 1995; Hand *et al.*, 1991; Drake *et al.*, 1995) have indicated that the incidence of tooth loss is relatively high. For example, among elderly Iowans, 21% lost one or more teeth over an 18-month period (Hunt *et al.*, 1988), and 39% experienced loss over a five-year period (Hand *et al.*, 1991). A study of North Carolina adults aged 65 years and over found that 18-month and three-year incidence rates were 36% and 53% for Blacks and 19% and 29% for Whites, respectively (Drake *et al.*, 1995; Hunt *et al.*, 1995). Nevertheless, the annualized incidence of edentulism, at less than one percent, was very low. The distribution of tooth loss in the populations studied was highly skewed, with a small number of subjects accounting for a high percentage of the teeth lost. In addition, social as well as clinical factors were predictive of tooth loss. The predictive ability of models based on these factors, however, was sometimes poor (Hunt *et al.*, 1995).

Estimates of the incidence of tooth loss among community-dwelling older Canadians have not been previously reported. The US studies may not be generalizable to Canada, since they were conducted in predominantly rural communities, when most older Canadians live in major metropolitan or urban centers. The fact that tooth loss is influenced by social and cultural factors may also limit the extent to which US data can be readily applied to Canadians.

Consequently, this paper describes the results of a three-year longitudinal study designed: (1) to estimate the incidence of tooth loss and edentulism in a population of older Canadians, and (2) to identify clinical, social, and behavioral factors which predicted tooth loss.

Materials and methods

Sample selection and recruitment

The data reported here were obtained as part of a longitudinal study of the oral health and treatment needs of adults aged 50 years and over living independently in two metropolitan and two non-metropolitan communities in Ontario, Canada. At baseline in 1989, subjects were identified by means of a telephone interview survey based on random-digit dialing. All those completing a short telephone-administered questionnaire were invited to take part in the next phase, which consisted of a detailed personal interview and comprehensive clinical examination.

The telephone interview was completed by 3033 subjects, constituting a response rate of 78%. A comparison of the characteristics of these subjects with census data indicated that they were representative of the target population. Subsequently, 907 subjects completed the baseline interview and examination. Differences between subjects who did and did not participate in this phase were minimal, and extensive non-response bias analysis suggested that non-participation had little effect on the estimates derived from the baseline study (Locker, 1993).

Interview and clinical examination

Baseline data were collected in community clinics or subjects' own homes by three teams of calibrated dental hygienists and recorders. The baseline interview was extensive and included questions on socio-demographic and socio-economic characteristics, self-perceived oral health status, general health status, use of dental services, preventive health behaviors, life stress, and attitudes toward dental treatment.

During the clinical examination, data were obtained on the presence and condition of all remaining teeth, excluding third molars. Measures of coronal and root caries, periodontal attachment loss, gingival pocketing and recession, bleeding, and calculus were obtained. Retained roots were recorded as such and were not considered as teeth for the purposes of the analysis. All dentures were assessed for fit, retention, stability, and occlusion. The examination was conducted by means of a mirror, explorer, and pressure-sensitive periodontal probe. Radiographs were not taken, and calculus was not removed prior to the examination. Further details of survey methods along with data on the prevalence of oral disease in this population are to be found in previous papers (Locker and Leake, 1993a,b).

In 1992, three years after the baseline survey, all subjects were followed up and asked to participate in another personal interview and clinical examination. Clinical examination procedures at follow-up were identical to those at baseline. All incoming data were checked to ensure that third molars excluded at baseline had not been erroneously included at follow-up.

Data collection procedures at baseline and follow-up were approved by the University of Toronto Human Subjects Certification Committee.

Data analysis

Baseline and follow-up data were compared so that we could estimate the proportions of subjects losing teeth and the number of teeth lost during the three-year observation period. Although tooth loss is not a disease, but the complex outcome of disease and socio-economic/attitudinal factors, the data were analyzed by an approach appropriate for an epidemiological study with a cohort design. The associations between tooth loss and a variety of socio-demographic, general health, and behavioral variables were examined with use of data from the personal interview. Associations between tooth loss and baseline clinical characteristics were also examined. Since all clinical measures were continuous or numerical discrete variables, they were reduced to categorical variables, some by means of median splits. Estimates of relative risk were calculated for all variables. For each, the category hypothesized to show the lowest incidence rate was used as a reference category and assigned a relative risk of 1.0. The mean number of teeth lost was also calculated for each category of each predictor variable, and t tests and one-way analysis of variance were used to determine the significance of the differences in means.

We undertook a logistic regression analysis by backward stepwise selection to identify which baseline variables showing significant associations with the probability of tooth loss had independent effects and to assess the predictive value of their combined effects. All predictor variables which had p-values of less than 0.05 or relative risks of 1.5 or greater were entered into the analysis. To generate odds ratios which could be compared across the independent variables, we entered all variables in a binary format coded 0 or 1. To simplify interpretation of the model, we included only main effects.

In backward stepwise selection, all variables are included in the initial model. Then, at each step, the variable with the largest significance level is removed, provided it is equal to or larger than 0.05. If the residual Chi-square statistic for variables not in the model is small, each variable is evaluated for re-entry based on its individual score statistic. The process continues until no further variables meet deletion or entry criteria.

Finally, non-response bias analysis was done to assess the direction and magnitude of the effects of loss to follow-up on the estimated incidence of tooth loss. The methods used in this analysis are simple mathematically and have been described previously (Locker *et al.*, 1990; Locker, 1993).

Results

Response and characteristics of respondents

At baseline, complete interview and clinical data were collected from 699 dentate subjects. At follow-up, complete data were collected from 491 or 70.2% of these subjects.

The subjects who were and were not successfully followed up were compared on 21 variables describing their baseline socio-demographic, general health, and behavioral characteristics. Significant differences emerged for only four. Those lost to follow-up were more likely to live in the two non-metropolitan communities (44.6% *vs.* 31.9%: $p < 0.05$), less likely to have dental insurance (38.1% *vs.* 54.9%: $p < 0.001$), less likely to visit a dentist regularly (62.2% *vs.* 70.2%: $p < 0.05$), and less likely to have visited the dentist in the previous year (62.6% *vs.* 76.5%: $p < 0.001$) than those who remained in the study.

Differences were also observed for three of ten clinical measures examined. Those lost to follow-up also had a higher mean number of decayed crown surfaces, a higher mean periodontal attachment loss, and a larger percentage of sites with loss of attachment of 5 mm or more at baseline (Table 1).

Incidence of tooth loss and edentulism

Almost one-quarter, 23.2% (95% confidence limits: 19.5% to 26.9%), of subjects lost one or more teeth over the three-year observation period. However, the distribution of tooth loss was highly skewed. Of the 114 subjects losing teeth, 69 lost one and 21 lost two. Only 24 subjects lost three or more teeth, and these accounted for just over half of the total loss observed. The mean number of teeth lost was 0.48 (SD = 1.31) for all subjects and 2.04 (SD = 2.06) for the 114 subjects who lost teeth. The 233 teeth lost over the three-year period constituted 2.5% of the teeth present at baseline.

The incidence of edentulism was low. Only six individuals, or 1.2% (95% confidence limits: 0.2% to 2.2%) of subjects overall, became edentulous. In addition, nine subjects became edentulous in the maxilla and six in the mandible.

Associations between baseline factors and the incidence of tooth loss

Table 2 shows that there were significant associations between seven baseline personal characteristics and the probability of tooth loss over the three-year observation period. No associations were observed between tooth loss and the following variables: education, place of birth (Canada *vs.* elsewhere), community of residence (metropolitan *vs.* non-metropolitan), general health status (including limitations in activities of daily living), life stress, and dental insurance coverage (not shown). The incidence of tooth loss did not differ according to smoking history or use of dental services. However, there were differences in the mean number of teeth lost according to these variables.

Significant associations were observed between tooth loss and the majority of the baseline clinical indicators (Table 3). As before, two variables which did not show significant differences in terms of the proportions losing one or more teeth showed significant differences when the mean numbers of teeth lost were examined.

Logistic regression analysis

With use of the criteria outlined above, the non-clinical variables entered into the logistic regression analysis were sex, age, household income, marital status, self-rating of oral health, self-perceived need for dental treatment, and frequency of flossing. Because of high correlations between/among some variables, only four clinical indicators were entered: the number of teeth present at baseline, the number of decayed crown surfaces, the number of decayed root surfaces, and mean periodontal attachment loss.

An initial model was generated including all of these independent variables. The analysis indicated that the probability of losing one or more teeth over the three-year observation period was higher among males, those not now married, those rating their oral health as only fair or poor, those with two or more decayed root surfaces, and those with a mean periodontal attachment loss of 4 mm or more. These five variables were then entered into a second logistic regression analysis, the results of which are shown in Table 4. This included the 429 subjects for whom complete information was available. The associated odds ratios showed that root caries had the strongest independent effect. Those with two or more decayed root surfaces at baseline were more than three times at risk of losing one or more teeth than those with zero or one decayed root surface.

The sensitivity of the model (the proportion of those with tooth loss correctly identified) was 29.0%, and its specificity (the proportion of those without tooth loss correctly identified) was 96.4%. Positive and negative predictive values were 69.2% and 82.8%, respectively.

This analysis was repeated including smoking history, the two variables describing the use of dental services, the number of decayed and filled root surfaces, and the percent of remaining teeth with calculus. These variables showed significant associations with the mean number of teeth lost. However, none entered the final model, and the regression coefficients and odds ratios remained unchanged.

Table 1. Differences in baseline clinical characteristics of subjects successfully followed and lost to follow-up

	Followed (n = 491)	Lost (n = 208)	p[a]
Mean number of decayed crown surfaces	0.7 (1.5)[b]	1.1 (2.1)	< 0.05
Mean periodontal attachment loss (mm)	2.8 (1.3)	3.2 (1.5)	< 0.01
Mean percent of sites with 5 mm or more of loss	16.7 (24.7)	20.9 (24.9)	< 0.05

[a] Differences in means: *t* test.
[b] Figures in parentheses are standard deviations.

Adjusting estimates for loss to follow-up

Non-response bias analysis was undertaken to estimate the incidence of tooth loss assuming full coverage of the 699 dentate subjects from whom data were collected at baseline. It was undertaken based on 11 baseline personal and clinical variables on which responders and non-responders differed. These variables were selected because these differences were statistically significant or of sufficient magnitude to give rise to concerns about non-response bias. The adjusted estimates ranged from 22.6% (standard error = 1.9%; 95% confidence interval = 20.7% to 24.5%) to 24.9% (standard error = 1.6%; 95% confidence interval = 21.8% to 28.0%).

Discussion

Of 699 dentate older adult subjects from whom data were collected at baseline, three-year follow-up data were collected from 491. Although those who remained in the study had better oral health and made more use of dental

services than those who did not, the differences were not large. Consequently, non-response bias analysis suggested that loss to follow-up did not have a major effect on the estimated incidence of tooth loss in this population.

A second source of bias stems from our exclusion of third molars from the clinical examinations. This means that subjects who lost only this tooth type would not have been counted in the incidence rate. We believe that the effect of this exclusion on the estimated incidence rate is likely to be low. In a recently completed study of tooth extractions in a random sample of Ontario dental practices, only 1.9% of older adults attending during a reference week lost third molars, and half of these lost other tooth types as well (Murray *et al.*, 1996).

The three-year incidence rate of persons experiencing tooth loss in this older adult population was 23.2%, giving an annualized rate of 7.7%. However, the incidence of edentulism was very low, with only 1.2% losing all their remaining teeth over the observation period, giving an annualized rate of 0.4%. These rates are very similar to those reported by Hand *et al.* (1991) for older Iowans and by Drake *et al.* (1995) for North Carolina Whites. However, these US studies were of individuals aged 65 years and over, so that a comparison of age-specific incidence rates suggests slightly higher rates of loss in Canadians compared with their US counterparts. As with the US studies, tooth loss in this Canadian population was highly skewed, with a minority accounting for a substantial proportion of teeth lost.

Table 2. Associations between baseline personal characteristics and the incidence of tooth loss (n = 491)

	n[a]	% Losing One or More Teeth	p[b]	Relative Risk	Mean # of Teeth Lost	p[c]
Sex						
Female	268	19.4	< 0.05	1.0	0.41	ns
Male	223	27.8		1.4	0.56	
Age						
50-64 years	305	20.0	< 0.01	1.0	0.42	ns
65-74 years	137	23.4		1.2	0.45	
75+ years	49	42.9		2.2	0.82	
Marital status						
Married	277	19.5	< 0.05	1.0	0.37	< 0.05
Not now married	210	28.1		1.4	0.61	
Household income						
$40,000+	149	18.8	< 0.05	1.0	0.29	< 0.01
$20-39,000	131	24.4		1.3	0.46	
< $20,00	113	32.7		1.7	0.80	
Smoking history						
Never smoked	232	22.4	ns	1.0	0.36	< 0.05
Previous smoker	166	22.3		1.0	0.46	
Current smoker	89	27.0		1.2	0.79	
Dental visiting pattern						
Regular	341	22.0	ns	1.0	0.39	< 0.05
Not regular	145	26.9		1.2	0.69	
Last dental visit						
Within last year	374	23.0	ns	1.0	0.38	< 0.05
More than one year	115	24.3		1.1	0.80	
Self-rated oral health						
Excellent/good	361	17.7	< 0.0001	1.0	0.25	< 0.05
Fair/poor	124	38.7		2.2	1.13	
Self-perceived need for dental care						
No	311	19.3	< 0.01	1.0	0.34	< 0.01
Yes	170	30.0		1.6	0.72	
Flossing						
Yes	185	16.2	< 0.01	1.0	0.28	< 0.01
No	302	27.8		1.7	0.59	

[a] Varies due to missing values.
[b] Differences in proportions: Chi-square test.
[c] Differences in means: *t* test for dichotomous variables and one-way analysis of variance for multi-category variables.

The regression analysis also confirmed the results of other studies in suggesting that both clinical and social factors were important in predicting tooth loss. The social factors were sex, marital status, and self-rated oral health status. These are likely to exert an influence through their relationship to attitudes and the kinds of decisions patients and dentists make regarding preferred treatment options. Nevertheless, it is difficult to explain why those not now married were more likely to lose teeth than those who were married. Numerous studies have shown a relationship among marital status, social support, and health (Morgan, 1980), and this may be an example of this general trend. Since those not now married were significantly older and poorer than those who were married, an alternative explanation is that marital status is acting as a proxy interaction term for age and income. The two clinical factors showing independent effects were the number of decayed root surfaces and a mean periodontal attachment loss of 4 mm or more. These had the highest odds ratios of the five

Table 3. Association between baseline clinical characteristics and the incidence of tooth loss (n = 491)

	n	% Losing One or More Teeth	p[a]	Relative Risk	Mean # of Teeth Lost	p[b]
Number of teeth remaining						
22-28	249	17.2	< 0.05	1.0	0.26	< 0.001
15-21	113	31.0		1.8	0.61	
8-14	69	29.0		1.7	1.04	
1-7	59	27.1		1.6	0.51	
DMFS						
≤ median	248	18.5	< 0.05	1.0	0.30	< 0.01
> median	242	28.1		1.5	0.60	
Number of decayed crown surfaces						
0	323	20.4	< 0.01	1.0	0.34	< 0.001
1	87	19.5		0.9	0.45	
2 or more	80	38.8		1.9	1.04	
Number of decayed root surfaces						
0	360	17.8	< 0.0001	1.0	0.25	< 0.0001
1	64	26.6		1.5	0.61	
2 or more	66	50.0		2.8	1.60	
Number of decayed and filled root surfaces						
≤ median	253	19.8	ns	1.0	0.33	< 0.05
> median	237	27.0		1.4	0.63	
Mean periodontal attachment loss						
< 4 mm	370	18.4	< 0.0001	1.0	0.27	< 0.001
≥ 4 mm	68	45.6		2.5	1.46	
Proportion of sites with LPA 5 mm or more						
≤ median	225	16.4	< 0.01	1.0	0.58	< 0.001
> median	213	29.1		1.8	1.72	
Proportion of teeth with calculus						
≤ median	242	20.5	ns	1.0	0.29	< 0.01
> median	248	26.1		1.3	0.66	

[a] Differences in proportions: Chi-square test.
[b] Differences in means: *t* test for dichotomous variables and one-way analysis of variance for multi-category variables.

factors entering the model. Assessing the relative influence of clinical and social factors is important from a preventive point of view, so that tooth loss can be minimized.

The sensitivity of the final model was low at 29%. This may have been because important explanatory variables were not included in the analysis. Different variables were included by Drake et al, (1995), who achieved a model with a sensitivity of 66%. However, it is important to understand that the factors entering the model do not 'cause' tooth loss in the same way that risk factors such as smoking cause disease. Rather, they reflect aspects of a complex process whose outcome is the loss of one or more teeth. Second, these factors document the characteristics of individuals losing teeth rather than the characteristics of teeth that are lost. A heavily restored tooth in an otherwise healthy mouth may fracture and be lost because it is too difficult or expensive to restore or has a poor prognosis. Events such as this would tend to weaken the associations between whole-mouth measures of oral disease and tooth loss. What this may mean is that only a partial understanding of tooth loss can be achieved by epidemiological studies of this kind. Research into the decision-making processes used by dentists and patients in actual clinical situations is needed to cast further light on this issue.

Two other issues warrant research attention. First, studies have not included data on the outcomes of tooth loss, so we know little about its functional and social consequences. This has been addressed in a limited number of cross-sectional studies (Leake *et al.*, 1994) but has not been assessed in longitudinal studies. Given the discussion surrounding the concept of the shortened dental arch (Kayser, 1981) and the increasing attention paid to patient outcomes in both medical and dental research (Maklan *et al.*, 1994; Locker, 1995), such data are essential for full understanding of the phenomenon of tooth loss and where interventions to reduce the extraction of teeth should be directed. We need to understand when tooth loss becomes problematic in functional and psycho-social terms and for whom. It has been argued, for example, that 20 well-spaced teeth are compatible with adequate oral function (Kayser, 1990). This literature raises the question of whether the levels of tooth loss revealed in this and

Table 4. Results of the logistic regression analysis (n = 429[a])

Independent Variable:	Dependent variable: Tooth loss over three years (None = 0, One or more = 1) B	p	Odds Ratio	95% CI[b]
Sex				
(Female = 0, Male = 1)	0.5378	< 0.05	1.7	1.0-2.9
Marital status				
(Married = 0; not now married = 1)	0.5820	< 0.05	1.8	1.1-3.1
Self-rated oral health				
(Excellent/good = 0; fair/poor = 1)	0.7385	< 0.01	2.1	1.2-3.6
Decayed root surfaces				
(0 or 1 = 0, 2 or more = 1)	1.1551	< 0.001	3.2	1.7-5.9
Mean PAL				
(Less than 4 mm = 0; 4 mm or more = 1)	0.8288	< 0.01	2.3	1.2-4.2
Constant	-2.3986	< 0.0001	—	—
Model Chi-square = 52.941; df = 5; p < 0.0001.				

[a] Sixty-two subjects for whom medical conditions contraindicated periodontal probing were excluded.
[b] 95% confidence interval around the odds ratio.

previous studies are in fact consequential in terms of patient well-being.

In a study including data on outcomes, those who reported losing one or more teeth in the previous year also reported significantly more functional, social, and psychological problems related to oral disorders than those who reported losing no teeth (Miller and Locker, 1994). This may have been because those losing teeth had fewer teeth to begin with, and these problems pre-dated the loss reported in the study. The study design did not allow the temporal sequence of these events to be determined.

Second, studies which use multiple, rather than two, data collection points would be useful in documenting the natural history of individual teeth and when and why they are lost (Eklund and Burt, 1994).

From an epidemiological perspective, further research is needed to identify other factors implicated in tooth loss in older adult populations, to improve the predictive power of multivariate models of the kind developed here (Drake *et al.*, 1995). Research into dentists' belief and practice philosophies with respect to tooth extractions is also needed, to furnish a comprehensive understanding of why teeth are lost. Identifying people at high risk for tooth loss is important in terms of clinical interventions to preserve the natural dentition and ensure that it remains adequately functional and socially acceptable for the duration of the natural life-span.

Acknowledgments

This research was supported by Ontario Ministry of Health Grant no. 04170. The Community Dental Health Services Research Unit, under whose auspices the study was conducted, is a joint project of the Faculty of Dentistry, University of Toronto, and the North York Public Health Department.

References

Ahlqwist M, Bengtsson C, Gröndahl H-G, Halling A (1986). Tooth mortality in women in a 12-year follow-up of a population sample in Gothenburg, Sweden. *Community Dent Oral Epidemiol* 14:358-361.

Ahlqwist M, Bengtsson C, Gröndahl H-G, Lapidus L (1991). Social factors and tooth loss in a 12-year follow-up study of women in Gothenburg, Sweden. *Community Dent Oral Epidemiol* 19:141-146.

Battistuzzi P, Käyser A, Peer P (1987). Tooth loss and remaining occlusion in a Dutch population. *J Oral Rehabil* 14:541-547.

Brown LJ, Meskin LH (1988). Sociodemographic differences in tooth loss patterns in U.S. employed adults and seniors, 1985-86. *Gerodontics* 4:345-362.

Burt BA, Ismail AI, Morrison EC, Beltran ED (1990). Risk factors for tooth loss over a 28-year period. *J Dent Res* 69:1126-1130.

Drake CW, Hunt RJ, Koch GG (1995). Three-year tooth loss among black and white older adults in North Carolina. *J Dent Res* 74:675-680.

Eklund SA, Burt BA (1994). Risk factors for total tooth loss in the United States; longitudinal analysis of national data. *J Public Health Dent* 54:5-14.

Halse A, Molven O, Riordan PJ (1985). Number of teeth and tooth loss of former dental school patients. Follow-up study after 10-17 years. *Acta Odontol Scand* 43:25-29.

Hand JS, Kohout FJ, Cunningham MA (1988). Incidence of edentulism in a non-institutionalized elderly population. *Gerodontics* 4:13-17.

Hand JS, Hunt RJ, Kohout FJ (1991). Five-year incidence of tooth loss in Iowans aged 65 and older. *Community Dent Oral Epidemiol* 19:48-51.

Heft MW, Gilbert GH (1991). Tooth loss and caries prevalence in older Floridians attending senior activity centers. *Community Dent Oral Epidemiol* 19:228-232.

Hoover JN, McDermott RE, Singer DL, Neufeld B (1989). Tooth loss in a selected population in Saskatoon. *J Can Dent Assoc* 55:551-554.

Hunt RJ, Hand JS, Kohout FJ, Beck JD (1988). Incidence of tooth loss among elderly Iowans. *Am J Public Health* 78:1330-1332.

Hunt RJ, Drake CW, Beck JD (1995). Eighteen-month incidence of tooth loss among older adults in North Carolina. *Am J Public Health* 85:561-563.

Kayser AF (1981). Shortened dental arches and oral function. *J Oral Rehabil* 8:457-462.

Kayser AF (1990). How much reduction of the dental arch is functionally acceptable for the ageing patient? *Int Dent J* 40:183-188.

Leake JL, Hawkins R, Locker D (1994). Social and functional impact of reduced posterior dental units in older adults. *J*

Oral Rehabil 21:1-10.

Locker D (1993). Effects of non-response on estimates derived from an oral health survey of older adults. *Community Dent Oral Epidemiol* 21:108-113.

Locker D (1995). Health outcomes of oral disorders. *Int J Epidemiol* 24:S84-S89.

Locker D, Leake JL (1993a). Risk indicators and risk markers for periodontal disease experience in older adults living independently in Ontario, Canada. *J Dent Res* 72:9-17.

Locker D, Leake JL (1993b). Coronal and root decay experience in older adults in Ontario, Canada. *J Public Health Dent* 53:158-164.

Locker D, Slade GD, Leake JL, Wu A (1990). The response rate problem in oral health surveys of older adults in Ontario. *Can J Public Health* 81:210-214.

Maklan CW, Greene R, Cummings MA (1994). Methodological challenges and innovations in patient outcomes research. *Med Care* 32:13-21.

Miller Y, Locker D (1994). Correlates of tooth loss in a Canadian adult population. *J Can Dent Assoc* 60:549-555.

Morgan M (1980). Marital status, health, illness and service use. *Soc Sci Med* 14(A):633-643.

Murray H, Locker D, Kay E (1996). Patterns of and reasons for tooth extractions in general dental practices in Ontario, Canada. *Community Dent Oral Epidemiol* (in press).

Takala L, Utriainen P, Alanen P (1994). Incidence of edentulousness, reasons for full clearance, and health status of teeth before extractions in rural Finland. *Community Dent Oral Epidemiol* 22:254-257.

Weintraub JA, Burt BA (1985). Oral health status in the United States: Tooth loss and edentulism. *J Dent Educ* 49:368-378.