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Predicting geographically distributed adult dental decay in the greater Auckland region of New Zealand

C.M. Rocha[1], E. Kruger[1], R. Whyman[2] and M. Tennant[1]

[1]*International Research Collaborative – Oral Health and Equity, Department of Anatomy, Physiology and Human Biology, The University of Western Australia, Australia;* [2]*Oral Health Service, Hawke's Bay District Health Board, Hastings, New Zealand*

Objective: To model the geographic distribution of current (and treated) dental decay on a high-resolution geographic basis for the Auckland region of New Zealand. ***Basic research design:*** The application of matrix-based mathematics to modelling adult dental disease-based on known population risk profiles to provide a detailed map of the dental caries distribution for the greater Auckland region. ***Results:*** Of the 29 million teeth in adults in the region some 1.2 million (4%) are suffering decay whilst 7.2 million (25%) have previously suffered decay and are now restored. ***Conclusions:*** The model provides a high-resolution picture of where the disease burden lies geographically and presents to health planners a method for developing future service plans.

Key words: *dental caries, distribution, public health infomatics, Auckland, New Zealand*

Introduction

New Zealand (NZ) is a country of approximately four million people distributed unevenly over a land area of about 250,000 square kilometres. As a society the NZ population continues to be linked to its local Pacific Island neighbours, its historical British and European roots as well as its more recent Asian immigrants. The original inhabitants of the land are the Maori people that make-up approximately 15% of the current population (Statistics New Zealand, 2007). The major metropolis of NZ is Auckland with approximately 1.4 million residents, a third of the national population, of which 1.1 million are adults (over the age of 18). Overall, New Zealanders are, by world standards, a very healthy nation with a highly developed health system (New Zealand Ministry of Health, 2010; 2012). However, primary health services, including dental services, have long been and continue to be an issue for New Zealand governments (New Zealand Ministry of Health, 2001; 2011). Dental services for adults are almost exclusively provided through user pay (fee for service) private practices. Previous hi-resolution geographic research has highlighted the very uneven distribution of private dental services in New Zealand, and more specifically Auckland (Kruger *et al.*, 2012; 2013). These studies clearly linked distribution of dental practices to socio-economic status (SES) and ethnicity. However, they were unable to link practice distribution directly to disease burden.

One of the two major diseases facing dentistry is dental caries. It remains the dominant disease that care providers face, although, much of the core activity of a dental practice is now focused on maintenance of previous restorative care.

Against this backdrop the present study aims to model the geographic distribution of current (and treated) dental decay on a high-resolution geographic basis for the Auckland region of New Zealand.

Materials and Methods

All data were obtained from open source reports and access. Therefore no ethics approval was required. The data were collected in the last quarter of 2012. All population data, including ethnicity, were obtained from the 2006 New Zealand Census. The groups included in this study were those of European origin (including British), Maori origin, Pacific Islander origin and Asian origin. Population data were sub-divided by area unit (AU) and the geographic boundary of each AU was obtained from the Statistics New Zealand website (Statistics New Zealand, 2006). Additional geographic and population data (including boundary files) for district health boards were obtained from the New Zealand Ministry of Health website. Population data was limited to only people aged 18 years and over, hereafter referred to as the adult population.

The New Zealand Index of Deprivation (NZDep2006) aggregated to AU level was used as a basis of the measure of SES (Salmond *et al.*, 2007). The NZDep2006 is a composite measure derived from multiple weighted socioeconomic variables collected in the 2006 NZ Census. This index includes nine variables that either reflect or measure material and social disadvantage. NZDep2006 values were ranked into deciles ranging from one (least deprivation) to 10 (greatest deprivation).

Dental decay data were extracted from the most recent national oral health survey report (2009) to provide the incidence of dental caries by SES, ethnicity and age.

In generating the incidence matrix, the approach taken was consistent with previously published methods (Kruger *et al.*, 2006). To drive the calculations in this

Correspondence to: Professor Estie Kruger, The Centre for Rural and Remote Oral Health, The University of Western Australia, 35 Stirling Highway, Crawley, 6009, Australia. Email: ekruger@crroh.uwa.edu.au

study, the national level statistics were used to form three incidence matrices of the numbers of teeth, decayed teeth and filled teeth. It is noted that missing teeth were not included in the study as the cause of loss was not clearly identifiable and this could be a confounder in the study. Each of the three matrices were sub-divided into seven five-year age groups of the adult population (18-24 years, 25-34, etc. to 65-74, 75 and over), the four ethnic groups (European, Asian, Pacific and Maori) and the five SES groups (decile pairs 1-2, 3-4 etc. to 9-10). In summary there was an incidence calculated for each of the 140 possible combinations (7 age groups × 4 ethnic groups × 5 SES groups, Figure 1). A small number (under 20%) of all incident assumptions were extrapolated from the base data using the nearest incidences in the matrix to provide the estimate. This approach was only used when data were missing.

When modelling, each of the three incidence matrices (number of teeth, decayed teeth and filled teeth) was applied sequentially to the population data for each AU in Auckland. All modelling was completed using Microsoft Excel (v14.2.2). Analysis of geographic measures was completed using Quantum GIS v1.7.4 (Open Source Geographic Information System -GIS, licensed under the GNU General Public License).

Results

The total adult population of the Auckland region was 1.13 million people of which 0.68 million, 60%, were of European descent. The remaining 447,000 people were 44% Asian, 31% Pacific Islander and 25% Maori. The numbers of teeth, decayed teeth and filled teeth overall and for each of these ethnic groups are presented in Table 1. The greatest proportions of decayed teeth were in the Pacific Islander population (7.1% vs 4.1% overall) and the greatest proportion of filled teeth was for Europeans (29%, vs 24.6% overall, Table 2). Figure 2 presents the variation by age group for those proportions of decayed and filled teeth by ethnic group.

A steady gradient was noted in the proportion of decayed teeth rising from a base of 2.3% of all teeth in the highest SES decile to 6.8% in the lowest SES decile (Table 2). The mean number of teeth per person remained relatively stable across socioeconomic deciles at 26 as did the proportion of filled teeth (range 20.1-28.1).

The distributions of teeth, decayed teeth and filled teeth for each area unit of the Auckland region are depicted in Figure 3, whilst Figure 4 depicts the SES of

Table 1. Number (and proportion) of decayed and filled teeth for each ethnic group in Auckland, New Zealand

	Teeth	*Decayed teeth*		*Filled teeth*	
Europe	17.655	0.604	(3.4%)	5.087	(28.8%)
Asia	5.180	0.159	(3.1%)	0.802	(15.5%)
Pacific Islander	3.704	0.264	(7.1%)	0.697	(18.8%)
Maori	2.889	0.191	(6.6%)	0.664	(23.0%)
Overall	29.428	1.218	(4.1%)	7.249	(24.6%)

Note: Numbers of teeth are in millions.

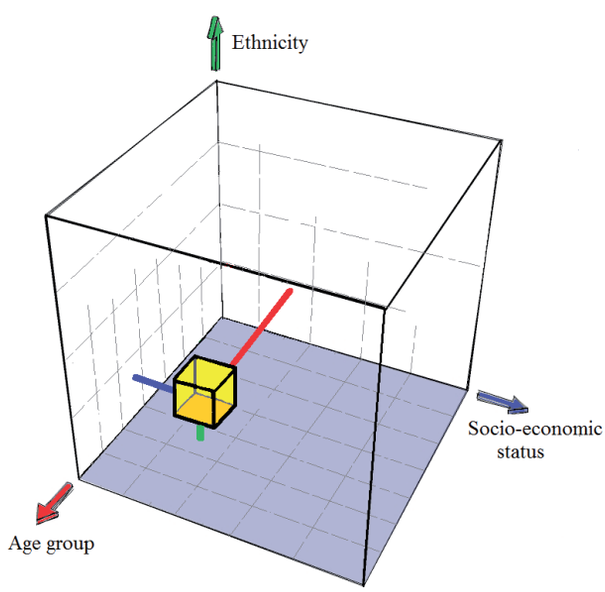

Figure 1. *A diagrammatic representation of the study's incidence matrixes based on the three variables: Age group, Ethnicity and Socio-economic status*

Note: Each Area Unit was allocated to a position in the matrix based on its measures of age group, ethnicity and SES as illustrated here by the yellow cell

Table 2. Population, number of teeth and decayed and filled number of teeth (thousands) and proportion (percentage) for each socio-economic decile in Auckland, New Zealand

Socio-economic Decile	*Population n*	*Teeth n (,000s)*	*Decayed n (,000s)*	*Filled n (,000s)*	*Proportion Decayed %*	*Proportion Filled %*	*Teeth per Person*
Affluent 1	92,924	2,389	54	537	2.3	22.5	26
2	155,339	4,023	93	810	2.3	20.1	26
3	115,055	2,985	100	702	3.4	23.5	26
4	93,652	2,437	83	549	3.4	22.5	26
5	106,254	2,764	95	734	3.5	26.5	26
6	117,732	3,070	108	786	3.5	25.6	26
7	92,300	2,424	115	682	4.7	28.1	26
8	108,175	2,832	136	762	4.8	26.9	26
9	107,948	2,858	184	795	6.4	27.8	26
Deprived 10	136,326	3,647	248	893	6.8	24.5	27
Overall	1,125,705	29,428	1,218	7,249	4.1	24.6	26

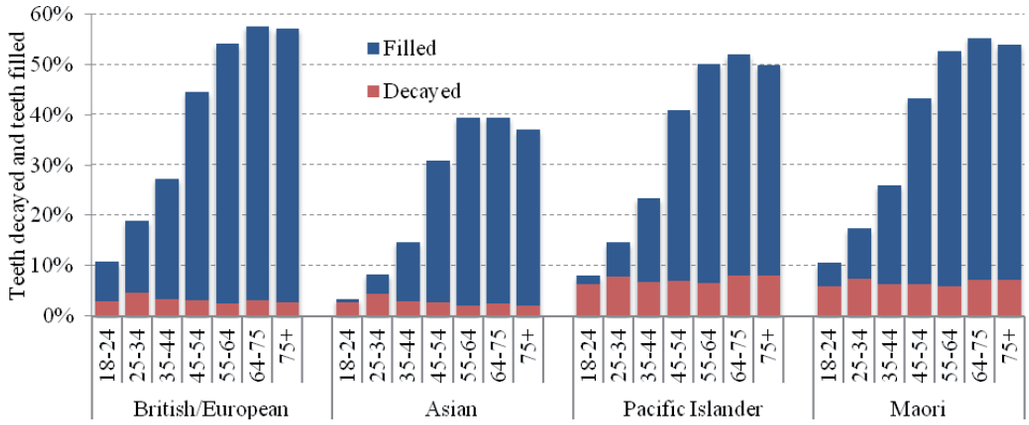

Figure 2. *The proportion of teeth decayed and filled teeth for each age group and each ethnicity*

Table 3. The number of area units (AU) for each socio-economic decile with ranges of number of total decayed teeth.

Number of decayed teeth	*Socio-Economic Decile*										
	Affluent									*Deprived*	
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*All*
0-1,000	5	3		1	1	2	1	1		1	15
1,001-2,000	18	10	10	4	4	3	2	1		1	53
2,001-3,000	15	24	10	11	10	7	1	2	1	1	82
3,001-4,000	1	10	10	7	11	7	9	4	7	9	75
4,001-5,000		1	6	4	8	7	8	7	5	5	51
5,001-6,000			4	4	1	7	5	5	3	10	39
6,001-7,000						1	3	5	5	5	19
7,001-8,000								4	6	9	19
8,001-9,000							1	1	3	3	8
9,001-10,000									1	1	2
over 10,000									2	2	4
Total	39	48	40	31	35	34	30	30	33	47	367

Table 4. The number of Area Units with different number of teeth suffering decay or having a filling (in each dwelling) within each socio-economic decile

Number of decayed / filled teeth	*Socio-Economic Decile*										
	Affluent									*Deprived*	
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*Total*
12		2									2
13	2	5		1		2				1	11
14	6	16				1				1	24
15	8	15	6	7		1			1		38
16	18	7	11	6	2						44
17	4	3	7	11	3	2					30
18	1		10	1	8	6	1			1	28
19			3	3	7	5	5	3	1		27
20			2	2	7	10	2	2			25
21			1		4	3	3	8		1	20
22					3	3	5	6	1		18
23					1		7	6	2	1	17
24							7	5	1	3	16
25									4	6	10
26									8	6	14
27									6	4	10
28									3	8	11
29									4	8	12
30									1	4	5
31										2	2
32									1	1	2
Total	39	48	40	31	35	33	30	30	33	47	366

Note: One area unit was not allocable in this calculation

each area unit in inner Auckland. Of the 367 AUs with modelled data, the proportion of teeth with decay ranged from 2.0% to 7.6% and 13.8% to 46.1% of teeth were filled. The estimated number of decayed teeth per person ranged from an AU mean of 0.51 to 2.04 while for filled teeth that range was 3.67 to 11.47. A frequency distribution of area units with different numbers of decayed teeth found that more affluent area units have lower numbers of decayed teeth (Table 3). For example in the most affluent SES decile of AUs more than half, 23 of 39, have under 2,000 decayed teeth in each AU and there was no AU in that SES decile that had more than 4,000 decayed teeth. Adjusting each AU for the number of dwellings provided an opportunity to reveal the number of decayed (and filled) teeth in each dwelling by AU (Table 4). These data found the numbers of decayed teeth per dwelling increased with increasing deprivation.

Discussion

The ability of planners to detail the absolute extent of disease in a community is a vital part of health planning. The use of national (and/or local) average data has the tendency to give results that tend to the centre. Modelling at higher resolution reduces regression to the mean. This study used nationally collected population and oral health data transformed by matrix mathematics to risk profile the disease of different sub-groups of the Auckland, New Zealand, population to produce a high-resolution map of dental disease and history of disease. The outcome of the study can, at a very local level of area units, provide planners with estimates of the total number of decayed and filled teeth. These data could inform the development of service arrangements to address the disease burden.

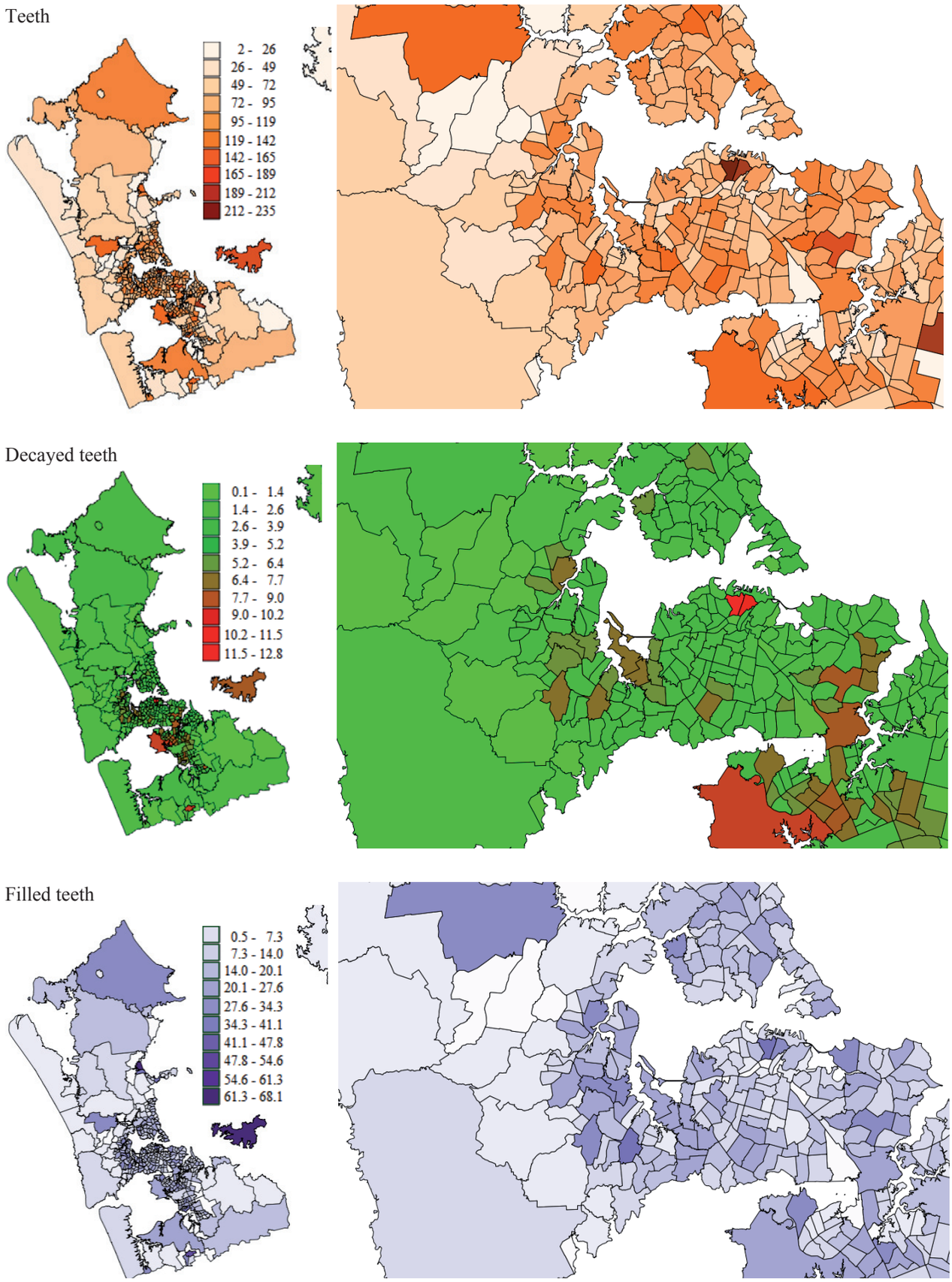

Figure 3. *The modelled absolute numbers (in thousands) of teeth, decayed teeth and filled teeth for the Auckland region at low magnification (left) and high magnification (right) for each area unit (black boundaries)*

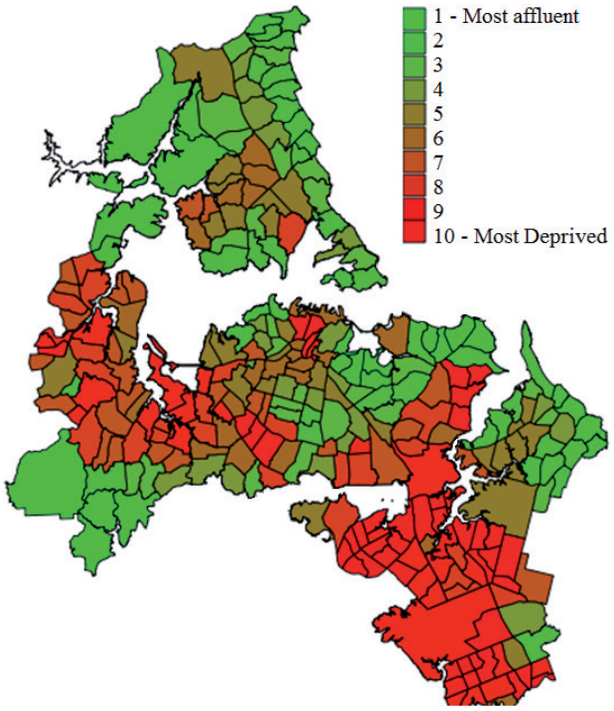

Figure 4. *The socio-economic decile distribution of each area unit (black boundaries) within the inner core of Auckland New Zealand*

The study builds on previously published techniques and moves towards the ability to predict at near street level the incidence of decay. The application of another mathematical approach (Monte Carlo simulations) has been shown to be an effective modelling approach in simulations where a full data set is not available. The integration of these two methods – Monte Carlo and matrix mathematical derived risk distribution would lead to a powerful high-resolution tool for local disease prediction. The integration of these two approaches would require significantly larger computational models and large scale computing to run full population predictions.

Comparing the outputs of the model to what was measured in the National Oral Health survey is possible at a gross level. However, it needs to be acknowledged at the outset that the national level data will differ from the local Auckland data as there are differences in population mix and therefore the model (that rests on population factors) will produce different results. Nevertheless, absolute numbers coming from the model are not grossly dissimilar. Total number of teeth, decayed teeth and filled teeth was 29 million, 1.2 million and 7.3 million respectively. Distributing these numbers evenly across all 1.1 million adults in the Auckland sample produces an overall average 26.7 standing teeth of which 1.1 were decayed and 6.5 filled. We did not model the missing teeth component as the available baseline data was insufficiently accurate. So to complete the calculation of an "average" DMFT for each person from the model we can take the 4.6 missing teeth from the national report. Together these produce a total DMFT of about 12.2 (1.1+6.5+4.6) which is a reasonably similar to the national oral health report's 13-14 with the difference probably being accounted for by the Auckland population mix not being representative of the national population.

At a dental level the outcomes of this study clearly find a number of areas where the extent of raw decay is significantly higher than others. These areas are outcomes of congregations within society of those at high risk of dental disease (those of various ethnicities and deprivations). Although not explicitly presented here, it is clear that socioeconomic disadvantage is a significant driver of the distribution of disease. This is highlighted in Tables 2, 3 and 4, but the number of persons per dwelling is a potential confounder and should be taken into account in future research. Many previous studies in NZ and elsewhere have concluded the same effect. The opportunity these data present is for current health planners to strategically target treatment at communities with high direct need and aim strong public health measures at those most at risk. Closer targeting makes better use of limited resources for disease prevention. This study's tool clearly highlights specific areas for targeting.

Dental decay presents a very skewed distribution. With current technology the treatment of dental decay with fillings requires ongoing lifetime maintenance. This study also provides a clear picture of modelled need for this maintenance care. From the data, the location of services and the mix of care needed can be estimated. Health planners can use these sorts of models to be strategic with their limited resources. Clearly, a parallel model can be developed for children to assist planners of school dental services in their workforce and capital planning. In practice, it would be possible to predict the amount and type of dental decay treatment needed for a given population, over a period of time. These would result in valuable data for dental professionals, private and public, when they are planning the location and capacity of their services.

Conclusion

The application of matrix-based mathematics to modelling adult dental disease-based on known population risk profiles has provided a detailed map of the dental caries distribution for the greater Auckland region. Of the 29 million teeth in adults in the region some 1.2 million (4%) are suffering decay whilst 7.2 million (25%) have previously suffered decay and are now restored. The model provides a high-resolution picture of where the disease burden geographically lies and presents to health planners a method for developing future service plans.

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