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Geographic modelling of jaw fracture rates in Australia: a methodological model for healthcare planning

Estie Kruger, Lisa J. A. Heitz-Mayfield, Irosha Perera, Marc Tennant

The Centre for Rural and Remote Oral Health, The University of Western Australia, Crawley, WA, Australia

Correspondence to: Estie Kruger, The Centre for Rural and Remote Oral Health, The University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia
Tel.: +61 8 9346 7248
Fax: +61 8 9346 7237
e-mail: ekruger@crroh.uwa.edu.au

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Abstract – *Background/Aim*: While Australians are one of the healthiest populations in the world, inequalities in access to health care and health outcomes exist for Indigenous Australians and Australians living in rural or urban areas of the country. Hence, the purpose of this study was to develop an innovative methodological approach for predicting the incidence rates of jaw fractures and estimating the demand for oral health services within Australia. *Materials and methods*: Population data were obtained from the Australian Bureau of Statistics and was divided across Australia by statistical local area and related to a validated remoteness index. Every episode of discharge from all hospitals in Western Australia for the financial years 1999/2000 to 2004/2005 indicating a jaw fracture as the principle oral condition, as classified by the International Classification of Disease (ICD-10AM), was the inclusion criterion for the study. Hospitalization data were obtained from the Western Australian Hospital Morbidity Data System. *Results*: The model estimated almost 10 times higher jaw fracture rates for Indigenous populations than their non-Indigenous counterparts. Moreover, incidence of jaw fractures was higher among Indigenous people living in rural and remote areas compared with their urban and semi-urban counterparts. In contrast, in the non-Indigenous population, higher rates of jaw fractures were estimated for urban and semi-urban inhabitants compared with their rural and remote counterparts. *Conclusions*: This geographic modelling technique could be improved by methodological refinements and further research. It will be useful in developing strategies for health management and reducing the burden of jaw fractures and the cost of treatment within Australia. This model will also have direct implications for strategic planning for prevention and management policies in Australia aimed at reducing the inequalities gap both in terms of geography as well as Aboriginality.

Australia is the sixth largest country in the world with a total area of more than 7 million square kilometres but has a population of only 21 million people (1). Australia remains one of the most sparsely populated nations on earth, with only 2 people per square kilometre, and most of the population (87%) concentrated in the eight capital cities and urban areas (defined as cities with populations of 250 000 or more). Only 34% of the Australian population live in the vast non-urban areas but this includes the majority of the Indigenous people (1). The term Indigenous Australians includes both the Torres Strait Islanders (from the Torres Strait Islands between Australia and New Guinea) and the Aboriginal people. Although they encompass two distinct cultural groups with different histories, languages and cultural norms (2), combined they make up about 2.5% of Australia's modern population.

Australians are one of the healthiest populations in the world, but significant inequalities exist with regards to many health outcomes. This is dependent on a number of factors, including Indigenous status and whether living in rural or urban areas (3, 4). Those who are Indigenous can expect to die 17–20 years younger than other Australians (5). Indigenous people have injury death rates three times as high as for other Australians (4). Most Indigenous Australians live in rural and remote areas (1).

On an average, Australians (Indigenous and non-Indigenous) who have lived all their lives in rural areas, die 4 years younger than other Australians, and this increases with greater remoteness (6). The health concerns of rural Australians relate directly to their living conditions, social isolation, socioeconomic disadvantage and distance from health services. These people have

death rates that are double the urban rates because of injury, triple because of road accidents, and in the aged, double as a result of falls (1). This inequality is compounded by the fact that rural people have lower access to health care, because of shortages of health facilities and health professionals, compared with their metropolitan counterparts. This shortage of health professionals extends to oral health professionals as well. The supply shortage is more keenly felt in rural/remote areas and the public sector. The uneven distribution of dentists between capital cities and rural areas is a significant feature of the labour force, with practising rates for capital cities averaging 55.7 dentists per 100 000 population, compared with 31.4 for rural areas (7, 8).

Geographic Information Systems (GIS) consists of a computer-based system for the input, storage, maintenance, management, retrieval, analysis and output of geographic- or location-based information (9). By illustrating juxtaposed multiple layers of information, GIS is emerging as an important novel tool in healthcare planning (10, 11). Nevertheless, there is very limited use of GIS in planning of oral healthcare services and to the best of our knowledge no published study modelled incidence of a given health outcome at a country level. Against this backdrop it is important that Australia has methods for understanding the distribution of demand for oral health services, to enable policy development and service planning, not only for management of jaw fractures but for the development of strategies for other oral health conditions as well. Previously published research from our group (12) examined a similar dataset for risk indicators for jaw fractures. In summary, these previous findings showed that more than 90% of fractures occurred between the ages of 10 and 50 years with female gender and Indigenous status being other very significant factors associated with jaw fractures (12). Indigenous males were 7.7 times more likely to be admitted for jaw fractures than non-Indigenous males, whereas Indigenous females were 22.3 times more likely to be admitted for jaw fractures than non-Indigenous females (12). Hence, Indigenous people especially the females carried a remarkably higher burden of disease related to jaw fractures compared with their non-Indigenous counterparts.

This provided clear evidence to support the use of age, gender and Indigenous status as predictors in relatively valid model estimations. The present study was designed to develop an innovative model based on our previous work (12), for predicting the incidence rates of jaw fractures in Australia using Western Australian data as the basis for the model. It was also aimed to retain its potential for further improvements as a decision support tool to plan the spatial configuration of oral healthcare services.

Materials and methods

The modelling was targeted at developing a schema that could be applied to small subunits of population, thus allowing the model to be sustainable at all levels, from health service regions through to a nation wide level.

Jaw fracture data

The inclusion criterion was every episode of discharge from all private and public hospitals in Western Australia for the financial years 1999/2000 to 2004/2005 indicating a jaw fracture as the principal oral condition, as classified by the International Classification of Disease (ICD-10AM). This was pooled to form the base data for this analysis. (13). Hospitalization data were obtained from the Western Australian Hospital Morbidity Data System (HMDS). The diagnosis of all types of fractures of the mandible, maxilla, or both was included in the analyses. Primary place of residency at the time of hospitalization, age and self-reported Aboriginality were also analysed.

Rate calculations

All Australian population data were obtained from the Australian Bureau of Statistics' (ABS) last national Census (2001) (1). Data were obtained by age, gender, Indigenous status and Accessibility/Remoteness Index (ARIA) category. The ARIA index is the nationally accepted coding of remoteness in Australia developed by the ABS (14, 15). This index uses distances to population centres as a basis for quantifying service access and, hence, remoteness. ARIA categories are: highly accessible (HA), accessible (A), moderately accessible (MA), remote (R) and very remote (VR) (14, 15).

Based on the previously published Western Australian morbidity-data (16) the fracture dataset were analysed to determine the rates of jaw fractures for Indigenous and non-Indigenous Australians, males and females for the four age groups: 10–19, 20–29, 30–39 and 40–49 years old in each of the five ARIA defined remoteness regions. Ages < 10 years and > 49 years were not included as negligible fractures occurred in these age groups. Based on the previously identified risk indicators, a total of 80 distinct rates of jaw fractures were computed dependent on the mix of the variables gender (2 sub-sets), age (4 sub-sets), Indigenous status (2 sub-sets) and ARIA (5 sub-sets) [$2 \times 4 \times 2 \times 5$]. SPSS (version 15.0; SPSS Inc., Chicago, IL, USA) were used to produce the required population-based rates of fracture.

Dataset integration

All Australian population data was divided geographically into statistical local areas (SLAs). In Australia, the SLA is the base spatial unit used to collect and disseminate statistics other than those collected from the Population Censuses. SLA is the smallest unit defined in the Australian Standard Geographical Classification (ASGC) (15). Statistical local areas cover the whole of Australia without gaps or overlaps, and there are a total of 1353 of them.

Population data across each of the 1353 SLAs was distributed by gender, age, Aboriginal status and ARIA in the same way as the fracture data was distributed across Western Australia. Using Excel, the fracture rate for each population subset derived from the Western Australian morbidity data was applied across Australia

to the appropriate population subset (gender, age Indigenous status, ARIA) within each SLA.

Geographic boundary data for each SLA was obtained form the ABS, and the fully integrated database was then geo-coded using ARCGIS (version 9.1; ESRI, Redlands, CA, USA) (16) to allow the visualization of the fully integrated data model.

Results

Figure 1 illustrates the proportional distribution of Indigenous people for all statistical local areas in Australia. Accordingly, the Northern territory has the highest proportion of Indigenous Australians while the State of Tasmania records the lowest. Results are presented as the projected jaw fractures (absolute numbers and rates) for all of Australia based on Western Australian jaw fracture data.

Validation of the model

The mathematical model was validated by comparing projected Western Australian jaw fracture data with real reported data in Western Australia. It was known from the morbidity dataset that in Western Australia over the 6-year period (1999/2000–2004/2005) an average of 658 fractures occurred per annum, with 593 of these happening within the 10–50 age-group. Consequently, the mathematical modelling approach developed and presented in this study to calculate the projected numbers of Western Australian total fractures produced an outcome that was within 2.5% of the reported (real) data for Western Australia.

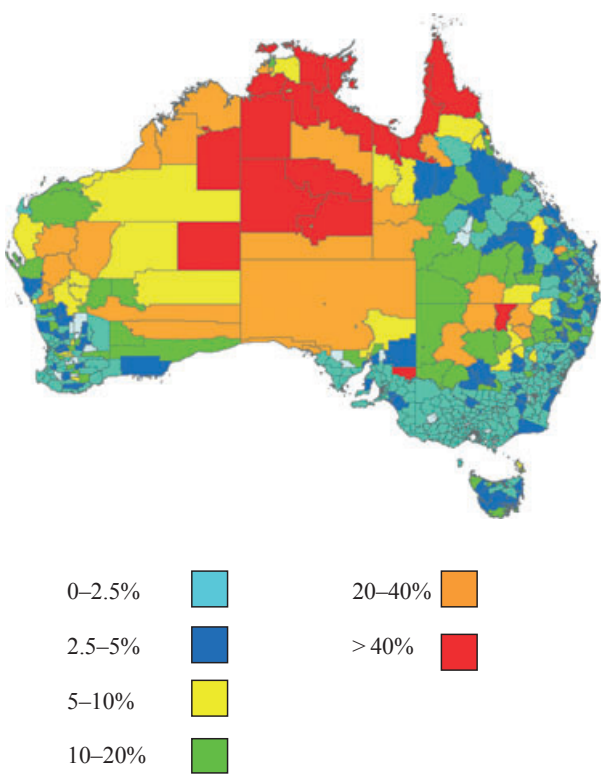

Fig. 1. The proportional distribution of Indigenous people for every statistical local area in Australia.

National modelling extrapolations

Using the model, national results were estimated for both Indigenous and non-Indigenous populations. Fig. 2 illustrates the absolute numbers of jaw fractures in Indigenous people distributed across SLAs in Australia. In the remote areas of Australia, higher modelled numbers of fractures were observed, than in urban areas in the Indigenous population. This is in contrast to the situation in the non-Indigenous population where higher modelled numbers were found in urban areas (Fig. 3). In addition to absolute numbers of jaw fractures, fracture rates were estimated. Figs 4 and 5 represent the population rate of fractures weighted by age and gender in the Indigenous and non-Indigenous populations respectively.

In general, higher rates of jaw fractures were observed in rural and remote areas among Indigenous people (Fig. 3). Fig. 4 shows higher rates of jaw fractures in the urban and semi-urban areas in the non-Indigenous population.

Discussion

The present study demonstrates the first attempt to use GIS in estimating a population-based health outcome, i.e. jaw fractures as applied to a whole country. Moreover, the within 2.5% agreement between projected and actual jaw fracture rates in Western Australia substantiates the high level of validity of the mathematical model developed and presented in this paper.

The findings of the present study painted a picture of a higher burden of jaw fractures and inequalities in the incidence of jaw fractures among Indigenous Australians and Australians living in rural and urban areas of the country. The model estimated an almost 10 times higher incidence of jaw fracture rates for the Indigenous populations (Figs 4 and 5). The present model also estimated higher rates of jaw fractures among Indigenous people in rural and remote areas compared with their urban and semi-urban counterparts. In contrast, in the non-Indigenous population, higher rates of jaw fracture were estimated for urban and semi-urban inhabitants compared with their rural and remote counterparts.

In 2006, results of our previous study on the incidence of jaw fractures among the Indigenous and non-Indigenous population of Western Australia were published (12). The current study has used a geographic modelling technique to utilize this unique data set and merge it with the population distribution data. The result of this modelling is mapped to visualize the outcome as a decision support tool to plan the spatial configuration of healthcare services. Nevertheless, the results need to be interpreted cautiously because of two obvious reasons. Firstly, the present findings were based on hospital discharge data with potential underestimation as a small number of jaw fractures may not receive inpatient

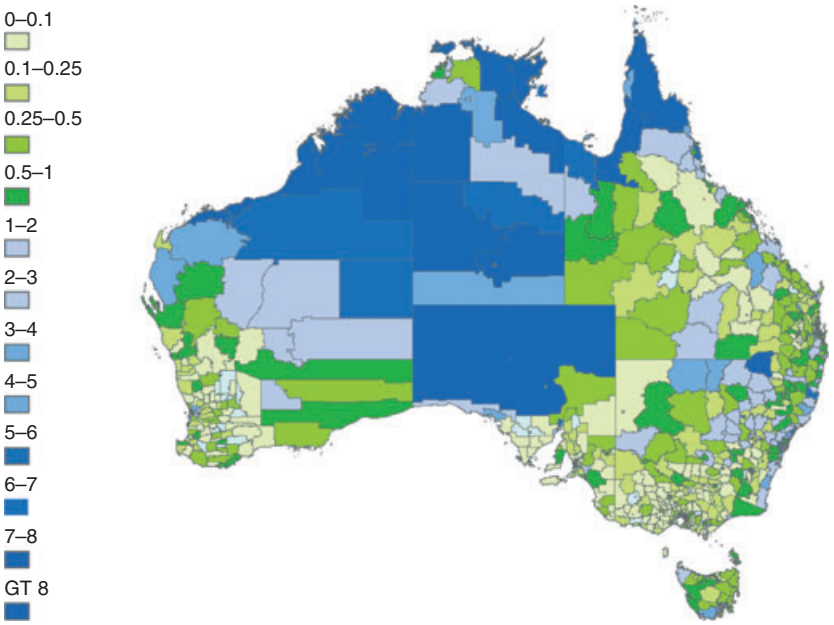

Fig. 2. Absolute numbers of fracture cases per annum in Indigenous people across statistical local areas* in Australia by ARIA classification from 1999/2000 to 2004/2005. Note: Absolute numbers include decimals as the fracture rates were computed per annum. In some instances, for example, two cases of jaw fractures for 6 years in a given local statistical area equals to 0.3 cases per annum. GT, greater than. *Boundaries in the map presented correspond to geographic boundaries of statistical local area.

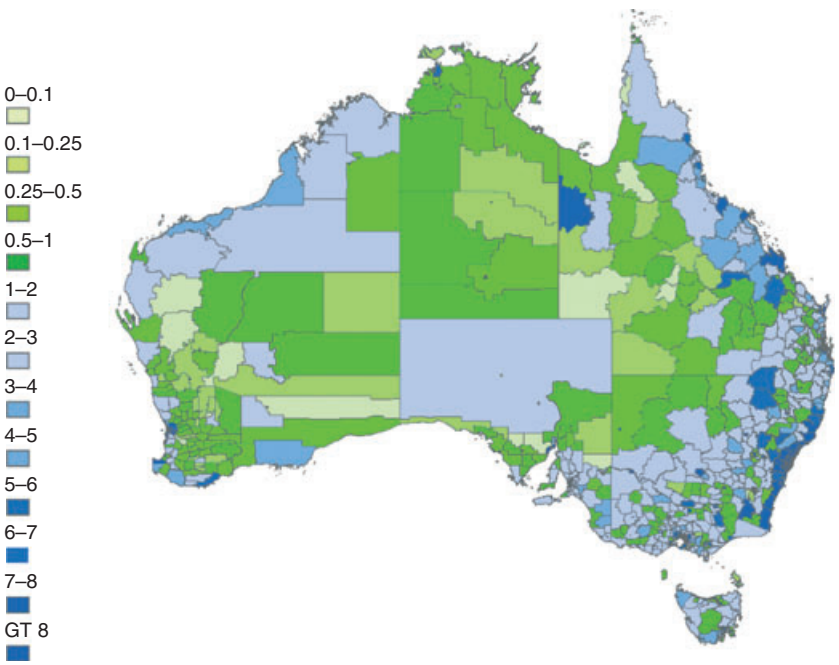

Fig. 3. Absolute numbers of fracture cases per annum in non-Indigenous people across statistical local areas* in Australia by ARIA classification from 1999/2000 to 2004/2005. Note: Absolute numbers include decimals as the fracture rates were computed per annum. For example, two cases of jaw fractures for 6 years in a given local statistical area equals to 0.3 cases per annum. GT, greater than. *Boundaries in the map presented correspond to geographic boundaries of statistical local areas.

treatment but outpatient care. Nevertheless, the distribution of jaw fracture cases treated at outpatient clinics would have shown similar picture of disparities with regards to Aboriginality and urban-rural inhabitation. Secondly, the present model used Western Australian jaw fracture data as the basis for estimation of jaw fracture rates in four age groups for the rest of the Australia. It is noteworthy that modelling extrapolation of one geographic area to others is at risk from variations in distribution of socio-demographic and other potential risk modifiers. However, the present model illustrates clear inequalities between Indigenous and non-Indigenous populations at a magnitude that would largely reduce this risk.

This has been supported by a recent publication in an ethnic comparison of mandibular jaw fractures in Queensland, Australia (17). In this study, the Indigenous population represented only 7.6% of the total population in Cairns, the major city in Queensland, and only 17.9% in the Far North region, and yet they accounted for 49% of all patients presenting with mandibular fractures. Furthermore, they reported a high rate of violence sustained by Indigenous females, with 94% of mandibular fractures as arising from an assault, of which 57% were a consequence of domestic violence (17).

Jaw fractures may severely compromise mastication, respiration and speech. Diagnosis and management of jaw fractures usually requires an interdisciplinary

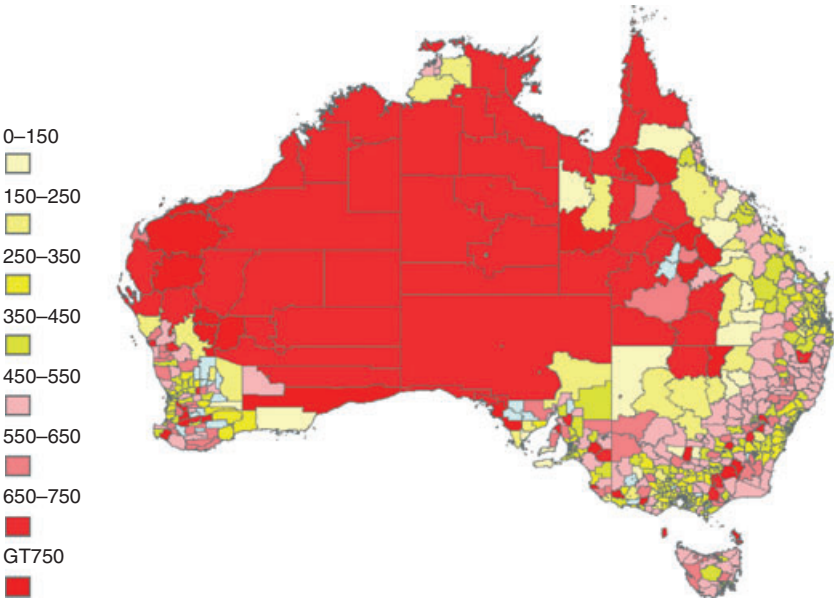

Fig. 4. Rate (per 100 000) of fractures in Indigenous people across statistical local areas* in Australia by ARIA classification from 1999/2000 to 2004/2005 weighted by age and gender. **Scale difference between figures 3 and 4 is a result of the near 10 times difference in rates of jaw fracture incidence among Indigenous populations compared with their non-Indigenous counterpart. Note the scale difference between Fig. 3 and Fig. 4. GT, greater than. *Boundaries in the map presented correspond to geographic boundaries of statistical local areas.

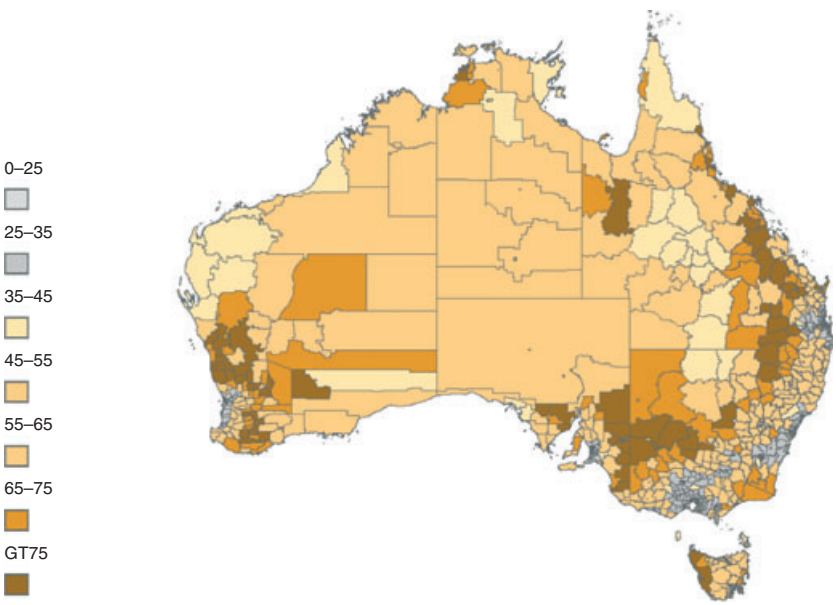

Fig. 5. Rate (per 100 000) of fractures in non-Indigenous people by statistical local areas* in Australia from 1999/2000 to 2004/2005 weighted by age and gender. GT, greater than. *Boundaries in the map presented correspond to geographic boundaries of statistical local areas. **Note the scale difference between Fig. 3 and Fig. 4. Scale difference between Figs 3 and 4 is a result of the near 10 times difference in rates of jaw fracture incidence among Indigenous populations compared with their non-Indigenous counterpart.

approach involving specialists from a number of related fields. The length of hospitalization may vary from 1 to 72 days, with an average stay of 2.3 days (12). Rural patients required a longer period of hospitalization. The average diagnostic-related group cost (where the principle diagnosis is recorded as jaw fracture) per patient (in US dollars) has been previously estimated as $4184 (12). Over the 4-year study period of that study (12), the total direct costs for all jaw fracture hospitalizations was about $7.6 million, which was estimated at 7% to the total direct costs of all oral health-related hospitalizations.

The current treatment centres are located predominantly in urban areas. This means the distances rural patients need to travel for treatment of jaw fractures can be in excess of 250 km which contributes substantially to the overall cost. This may also result in a delay in accessing medical care for those in remote areas. In addition, Oberdan and Finn (17) found that in the Indigenous population there was a significant delay in seeking medical attention from 3 days to in excess of 7 days, whereas most of the non-Indigenous population (90%) had sought medical attention within 2 days of injury in Queensland.

Conclusions

Our current study has clearly indicated disparities in projected incidence of jaw fractures among Australians by Aboriginality and geographic location. In general, the rates of jaw fractures were almost 10 times higher among Indigenous people compared with non-Indigenous

Australians, respectively. Similarly, a higher incidence of projected jaw fractures was evident in remote areas compared with urban areas. Moreover, among Indigenous people, the incidence of jaw fractures was higher among those who lived in rural and remote areas compared with their urban and semi-urban counterparts. In contrast, in the non-Indigenous population, higher rates of jaw fractures were estimated for urban and semi-urban inhabitants compared with their rural and remote counterparts.

Our model could be used in planning for the establishment of medical treatment centres equipped with staff proficient in management and handling of jaw fractures. The modelling approach designed in this research has the potential for refinement and expansion to other conditions to develop a decision making tool relevant to health planners. This model will also have direct implications for strategic planning for prevention and management policies in Australia aimed at reducing the inequalities gap both in terms of geography as well as Aboriginality.

References

1. Australian Bureau of Statistics. 2001 Census basic community profiles and snapshots: 2002. Canberra, ACT: ABS; 2002.
2. Aboriginal and Torres Strait Islander Commission. As a matter of fact, Office of Public Affairs. Canberra: ATSIC; 1998.
3. Golds M, King R, Meiklejon B, Campion S, Wise M. Healthy aboriginal communities. Aust NZ Public Health 1997;21:386–9.
4. Hetzel BS. Historical perspectives on indigenous health in Australia. Asia Pacific Clin Nutr 2000;9:157–63.
5. Australian Institute of Health and Welfare. Australia's health 2006. AIHW cat.no. AUS73. Canberra: AIHW; 2006.
6. Australian Bureau of Statistics. Deaths, Australia: 2003, cat. no. 3302.0. Canberra: ABS; 2003.
7. Smith KL, Tennant M. Registration of dentists in Western Australia. Aust J Rural Health 2006;14:126–8.
8. Teusner DN, Spencer AJ. Dental Labour Force, Australia 2000. AIHW Cat. No. DEN 116. Canberra: Australian Institute of Health and Welfare (Dental NCCH. Statistics and Research Series No. 28; 2003.
9. Environmental Systems Research Institute Inc. Introduction to arc View GIS: two-day course note book with exercises and training data. Redlands, CA: Environmental Systems Research Institute; 1998. p. 1–3.
10. Albert DP, Gesler WM, Wittie P. Geographic information systems and health: an educational resource. J Geogr 1995; 94;1:314–21.
11. Borell LN, Northridge ME, Miller DB, Golembeski CA, Spieman SE, Sclar ED et al. Oral health and health care for older adults: a spatial approach for addressing disparities and planning services. Spec Care Dentist 2006;26:252–6.
12. Kruger E, Smith KL, Tennant M. Jaw fractures in the indigenous and non-indigenous populations of Western Australia: 1999–2003. Int J Oral Maxillofac Surg 2006;35:658–62.
13. National Centre for Classification in Health. The international classification of diseases and related health problems, 11th revision, Australian modification *(ICD-10-AM)*, Vol I–V. Lidcombe: National Centre for Classification in Health; 2000.
14. Australian Bureau of Statistics. Australian Standard Geographical Classification (ASGC) – 2005. Cat. no. 1216.0. Canberra: ABS; 2005.
15. Measuring remoteness: Accessibility/Remoteness Index of Australia (ARIA). Canberra (ACT): Department of Health and Aged Care, Occasional Papers: New Series No.: 14; 2001.
16. ArcGIS9. ESRI GIS and mapping software. http://www.esri.-com/software/arcgis/about/overview.html [accessed on 10 June 2009].
17. Oberdan W, Finn B. Mandibular fractures in far north Queensland: an ethnic comparison. Aust N Z J Surg 2007;77:73–9.