DOCTOR

ALYSSA ZHANG

A thesis submitted in partial fulfilment of the requirements for the degree of

Doctor of Clinical Dentistry (Dento-maxillofacial Radiology)

School of Dentistry

Faculty of Health Science

The University of Queensland

OCTOBER 2017

DECLARATION BY AUTHOR

I, DR. ALYSSA ZHANG of Brisbane, Queensland, do solemnly and sincerely declare that this thesis and research projects-derived published research papers have been composed by myself and have not been accepted in part or in full for another degree. I make this declaration conscientiously believing the same to be true before a Justice of the Peace.

Declared by:

DR. ALYSSA ZHANG

14/08/2017

Date

Witnessed by:

Date

STATEMENT BY RESEARCH SUPERVISOR

Candidate: DR. ALYSSA ZHANG

Thesis Title: The adoption and usage of cone beam computed tomography and panoramic radiography machines across Australia

Scientific Report Titles:

1. Comparative adoption of cone beam computed tomography and panoramic radiography machines across Australia
2. Effects from changes to the Medicare Benefits Schedule in 2014 on cone beam computed tomography and panoramic radiography scans across Australia

Department/School: Faculty of Health and Behavioural Sciences, School of Dentistry

Research Supervisor: PROFESSOR PAUL MONSOUR

Statement:		Tick Box
1.	I have read the thesis in final form	☐
	I have read the thesis in either final form or draft form	☒
	I have not read the thesis in either final form or draft form	☐
2.	I agree that the thesis is an appropriate form for submission	☒
	I do not agree that the thesis is an appropriate form for submission	☐

Word Count: 16,274

Additional Comments:

14 August 2017

PROFESSOR PAUL MONSOUR   Date

ACKNOWLEDGMENTS

First and foremost, I would like to express my gratitude and thanks to my supervisor, Professor Paul A. Monsour, for his ongoing support and encouragement not only during this research project, but throughout my entire Dento-maxillofacial Radiology training program. He is a constant source of inspiration and I enormously value his high calibre of supervision, advice and mentoring.

The research paper which makes up Chapter 2 of this thesis was prepared partially in collaboration with co-author Mr. Simon Critchley. Mr. Critchley sourced valuable information and contacts essentially required from Australian radiation regulators, to all of whom I am indebted for the information and/or raw data about extraoral radiography machines to date that they have provided. The research paper which makes up Chapter 3 of this thesis was prepared partially in collaboration with co-author Honorary Associate Professor Louise F. Brown, who provided valuable insight and suggestions. I wish to thank both co-authors for their enthusiasm, technical support and academic contributions.

My sincerest thanks go to Dr. Alannah Freer and the Dent8 Dental team who have provided me with unwavering support during the course of my postgraduate studies. Words cannot express how much appreciation I have for their understanding and constant encouragement while I was juggling both full-time postgraduate studies and part-time clinical dental work.

Additionally, I would also like to thank my friends and fellow postgraduate registrars, colleagues, and clinical and academic staff with the University of Queensland's School of Dentistry and Queensland Health Metro-North who have rendered me with assistance, support and motivation.

Last but not least, I would like to express my deepest gratitude to my parents Dr. Xianguang Zhang and Mrs. Xiaolan Li, my younger sister Sophia Zhang, my partner Mr. Seva Shorin, and my extended family, for their love, patience, support and encouragement throughout my postgraduate studies. I am especially grateful that Xianguang and Seva made available their valuable time to read preliminary versions of my research papers, participating in the exchange of ideas and in editorial work.

TABLE OF CONTENTS

LIST OF TABLES

Appendix Tables

LIST OF FIGURES

Appendix Figures

LIST OF ABBREVIATIONS

2D = two-dimensional

3D = three-dimensional

AAE = American Association of Endodontists

AAOMR = American Academy of Oral and Maxillofacial Radiology

ABS = Australian Bureau of Statistics

ACT = Australian Capital Territory

ADIA = Australian Dental Industry Association

AHPRA = Australian Health Practitioner Regulation Agency

ARPANSA = Australian Radiation Protection and Nuclear Safety Agency

ART = algebraic reconstruction technique

CBCT = cone beam computed tomography

CT = computed tomography

DBA = Dental Board of Australia

DIAS = Diagnostic Imaging Accreditation Scheme

DMFR = dento-maxillofacial radiology

EADMFR = European Academy of Dental and Maxillofacial Radiology

EO = extraoral

FPD = flat-panel detector

FOV = field-of-view

GDP = general dental practitioner

GP = general practitioner

GSP = gross state product

HU = Hounsfield Units

IAC = inferior alveolar canal

IAN = inferior alveolar nerve

IIT/CCD = Image intensifier/charge-coupled device

MBS = Medicare Benefits Schedule

MPR = multiplanar reformation

MSAC = Medical Services Advisory Committee

mSv = millisieverts

N = number

NHS-GDP = National Health Service-general dental practices

NK = denotes X-ray machine older than 10 years

Nov = November

NSW = New South Wales

NT = Northern Territory

Oct = October

OMFS = Oral and maxillofacial surgery

OPG = orthopantomogram

PHI = private health insurance

PPP = principal place of practice

PR = panoramic radiography

QLD = Queensland

SA = South Australia

SD = standard deviation

TAS = Tasmania

TMJ = temporomandibular joint

UK = United Kingdom

USA = United States of America

VIC = Victoria

WA = Western Australia

Dec = December

μSv = microsieverts

% = Percent or Percentage

ABSTRACT

Extraoral (EO) diagnostic radiography is an essential part of clinical dentistry. It is widely used as part of the clinical repertoire for diagnosis and treatment planning. Panoramic radiography (PR) is the mainstay of 2D EO imaging and cone beam computed tomography (CBCT) is now becoming widely adopted for 3D EO imaging.

This research is composed of a literature review and special project investigations. The review focuses on the general development of extraoral radiography modalities, the diagnostic uses of such modalities, the medical and legal ramifications of ionising radiation, and summarises the legislations and regulations for operation of CBCT and PR machines across Australian jurisdictions. Project investigations were conducted to analyse the baseline number of PR and CBCT machines across Australian jurisdictions for the year ending 2014, and to examine the distribution of Medicare-rebated PR and CBCT scans after changes to the Medicare Benefits Schedule (MBS) in 2014 in limiting access to CBCT rebated scans. The main research results include:

1. A total number of 1,913 EO X-ray machines made up of 1,681 PR machines and 232 CBCT machines were recorded nationally in 2014.
2. Based on gross data, Queensland recorded the largest number of CBCT and PR machines, whereas NT recorded smallest number of CBCT and PR.
3. The Australian Capital Territory had the highest accessibility to CBCT machines and Western Australia (WA) had the highest accessibility to PR machines relative to both the population size and the number of dental practitioners.
4. The use-licensing regulations set out by each Radiation Regulator influences the adoption of CBCT and PR machines across Australian states and territories, particularly notable in WA.
5. Increases in either the population size or the number of dentists could contribute to a positive growth in the adoption of PR and CBCT modalities.
6. The underlying rationales imposed for restricting access to rebates for CBCT scans in the 2014 MBS were controversial, but were effective in reducing the number of rebated CBCT scans.
7. During December 2014–November 2015 (under the new MBS), females received on average more Medicare-rebated CBCT and PR scans than males.
8. Overall, the reduction in the number of Medicare-rebated CBCT scans provided significant cost savings for Medicare and also helped to reduce the ionisation load to the community during December 2014–November 2015.

PREFACE

This thesis is composed of three Chapters. Chapter 1 discusses the context of cone beam computed tomography (CBCT) and panoramic radiography (PR) machines in clinical dentistry, summarises the legislations and regulations for operation of these modalities, and reviews the current adoption and usage rate of these extraoral modalities both in Australia and overseas. Chapter 2 provides an introduction, research data, analyses and discussion on the number of CBCT and PR machines across Australia for the year 2014. Chapter 3 provides an introduction, research data, analyses and discussion on the number of Medicare rebated CBCT and PR scans for four 12-month periods between November 2011 and November 2015.

Those two research papers constituting Chapters 2 and 3 have been published in 2016 and 2017, respectively. For both research papers I was the lead author and undertook the majority of the research load. Mr. Simon Critchley and Professor Paul A. Monsour were my co-authors for the research paper given in Chapter 2. Honorary Associate Professor Louise F. Brown and Professor Paul A. Monsour were my co-authors for the research paper given in Chapter 3. In my role as the principal investigator of the research projects depicted on these two research papers, I performed reviews of literatures, collation of data, analyses of data, discussion of results, and submission of research manuscripts to relevant journal boards and revision of papers till their accepted publications.

Some related information used for data analyses in the research paper given in Chapter 2 is provided in Appendix 1. Similarly, some related information used for data analyses in the research paper given in Chapter 3 is provided in Appendix 2.

To facilitate the understanding of the research papers and their contexts, I have also listed those tables and figures, which are placed sequentially within each chapter where relevant and labelled accordingly. The collated *List of Tables* can be found on page [vii] and the collated *List of Figures* can be found on page [ix]. Furthermore, a single list of *References* (pages [55–66]) is provided, consisting of references from all three chapters. The arrangement of the list of *References* corresponds to the order of the in-text literatures referenced and cited.

PUBLICATIONS DERIVED FROM THE RESEARCH PROJECT

1. Zhang A, Critchley S, Monsour PA. Comparative adoption of cone beam computed tomography and panoramic radiography machines across Australia. Aust Dent J 2016; 61: 489-496.
2. Zhang A, Brown LF, Monsour PA. Effects from changes to the Medicare Benefits Schedule in 2014 on cone beam computed tomography and panoramic radiography scans across Australia. J Med Imaging Radiat Oncol 2017; [Epub ahead of print].

RESEARCH CLASSIFICATIONS

Australian and New Zealand Standard Research Classifications (ANZSRC)

ANZSRC code: 110501, Dental Materials and Equipment, 50%

ANZSRC code: 111708, Health and Community Services, 30%

ANZSRC code: 160508, Health Policy, 20%

Fields of Research (FoR) Classification

FoR code: 1105, Dentistry, 50%

FoR code: 1117, Public Health and Health Services, 30%

FoR code: 1605, Policy and Administration, 20%

CHAPTER 1

Literature Review

1.1 Introduction

Diagnostic radiography is an essential part of clinical dentistry. Where traditionally extraoral (EO) radiography was dominated by conventional two-dimensional (2D) tomography, advancements in technology over the past few decades have enabled the inclusion of more specialised modalities that allow for three-dimensional (3D) radiographic visualisation of dento-maxillofacial structures.[1, 2]

Since its commercial introduction in the 1950's, the pronounced rise in usage of EO 2D curved-planar tomography, otherwise known as panoramic radiography (PR), has been noted in a number of countries worldwide.[3-5] Benefits of PR include reasonable acquisition time, relatively low dose, a single projection that provides broad analysis of the dento-maxillofacial structures, affordability of scans for patients, suitability of machine size for the dental clinic and reasonable cost of acquisition of this modality for dental practices. However, there are shortfalls with 2D tomography and as such there are a number of limitations with PR such as extensive superimposition, ghost images, distortions and variable image quality.[3, 6, 7]

Research during the 1960's and 1970's led to the development of computed tomography (CT), also known as conventional CT, which for the first time allowed for non-invasive three-dimensional (3D) radiographic imaging free of superimposition of structures in the acquisition zone.[2] However, factors including high cost of scans, a large footprint, high radiation exposure and poor ease of access for the dental community, encouraged the development of 3D radiography technology better suited to the dental community. Subsequently, further advancement in CT technology in the 1990's has resulted in the development and application of cone beam CT (CBCT), which aims at providing detailed scans of dento-maxillofacial hard tissue structures. Cone beam CT has been commercially available overseas since 1998,[1] and there is anecdotal evidence suggesting a significant increase in the adoption of machines in Australia and elsewhere within the last decade. Popularity of this type of imaging among the Australian dental industry has been documented since the commercial availability of CBCT machines in Australia in 2006.[8] However, both in Australia and internationally, there is a lack of research regarding the adoption of PR and CBCT machines and the usage rate of these modalities. To a certain extent in Australia, Medicare statistics provides a glimpse of the usage of these devices in medical radiology practices.

Australia has a large number of dental schools considering the size of the population, producing relatively large numbers of dental graduates every year. In recent years, the fundamentals of CBCT technology have been incorporated into dental curriculums so that dental graduates would be more likely to incorporate CBCT as part of their extraoral diagnostic repertoire in addition to PR imaging.[9] That said, the use-licensing criteria for extraoral dental radiography varies across Australian state and territory regulators. The use-licensing criteria set for CBCT and PR imaging would ultimately reflect on the usage of these modalities in each Australian state or territory.

1.2 Review of the literature

1.2.1 Background on panoramic radiography and cone beam computed tomography modalities

Panoramic radiography (PR) has been the mainstay of extraoral diagnostic imaging since the 1950's.[3] The basic configuration of PR is the use of a collimated, vertical X-ray beam which rotates behind the patient's head, where the exit beam is then captured on a digital (solid state sensor or photostimulable phosphor plate) or analogue (film) receptor which travels in synchronisation on the opposite side of the patient. There is no other dental imaging modality that is able to provide such an abundance of information at a relatively limited radiation exposure to the patient. Panoramic radiography provides a broad overview of the dento-maxillofacial structures. The use of PR encompasses and is not limited to the jaws, dentition, nasal region, orbits, temporomandibular joints (TMJ), and the airways. However, PR is a construct of 3D structures that are portrayed as 2D and is thus inherently susceptible to distortion, magnification, variable image quality, extensive superimposition and phantom imaging.[3, 6, 7]

Diagnostically, CT (both conventional multislice and CB) has many advantages over PR. The benefits of having dimensionally precise 3D imaging is undisputed for complex cases within dentistry. Multislice CT provides short scan times and is capable of soft and hard tissue imaging.[3] However, multislice CT is not designed for ease of use within the dental environment. Drawbacks of multislice CT include lack of access to equipment for the dental community, high cost of machinery, large machinery unsuitable for a dental practice, the patient is required to lie supine, large field-of-views, historic machines that obtain data with anisotropic voxels, excessive radiation dosage to the patient, increased footprint, higher usage costs and most importantly, the ordinary dental practitioner does not have the knowledge to interpret data outside of the dento-alveolar regions.[3, 10]

To account for some of these drawbacks in multislice CT and to adapt this technology for dentistry, CBCT was developed. The first set of CBCT machines developed for dental use was in Italy[11] in 1997 and Japan[12] in 1998. The first type of CBCT machines approved for use in the USA was the NewTom DVT9000 on 8th March 2001; and by the end of 2003, three other types of units had been approved for use in the USA.[13] Parashar *et al.*[9] reported in 2011 that there were at least 24 types of CBCT machines in use worldwide. In just over a decade, the demand for this technology is high, as reflected by the development of such a wide range of modality types by various companies.

Cone beam computed tomography is synonymous with computerised axial tomography, computerised reconstruction tomography, and computed tomographic scanning, cone beam volumetric tomography, cone beam volumetric imaging and dental volume tomography.[14, 15] Instead of the fan-beam used by CT, this device uses a conical X-ray beam which performs a single 360° rotation around a patient centred on the area of interest and information (ranging from 160 to 599 basis images) is received on a two-dimensional receptor. [3, 6, 16, 17] Two types of detector setups are used for CBCT, one of which is the combination of image intensifier/charge-coupled device (IIT/CCD), and the other is a flat-panel detector (FPD). It is reported that at an equivalent pitch, the FPD produces less geometric distortion and less noise than the IIT/CCD.[18] Algorithms for reconstruction of the imaging dataset are based on the modified Feldkamp or algebraic reconstruction technique (ART).[6] The dataset can then be digitally manipulated through multiplanar reformatting programs to obtain desired orthogonal and serial cross-sectional views.[3, 6]

When comparing these two modes of 3D imaging, some advantages of CBCT over CT include: greater spatial resolution of osseous structures, submillimetre isotropic voxel resolution as low as 0.076 mm, reduced radiation exposure, limited field-of-view (FOV), superior hard tissue detail, flexibility for patients (who can either stand or sit within certain machines), and smaller machines better suited to placement in the dental practice.[16, 17]

However, all equipment comes with limitations and those of CBCT include: increased fogging of image from scattered radiations, longer acquisition time compared to multislice CT, inability to convert CT units to Hounsfield Units (HU), poor soft tissue contrast and lack of standardisation of radiation dosages due to the varying qualities of different machines (with varying sizes of FOV and exposure controls).[3, 17, 19]

1.2.2 Cone beam computed tomography in clinical dentistry

Cone beam CT has been widely adopted across many dental fields and this type of imaging has been used for and is not limited to assessment for dento-alveolar anomalies and pre- and/or post-assessment in periodontics, endodontics, implant surgery, orthodontics, oral and maxillofacial surgery (OMFS) and otolaryngology. This type of imaging is also useful in forensic dentistry.[20]

One of the most in-depth evidence-based guidelines for CBCT use has been produced in Europe from the European Commission's SEDENTEXCT project–a collaboration from six European countries, with the main stakeholder being the European Academy of Dental and Maxillofacial Radiology (EADMFR).[21, 22] Various clinical indications for CBCT are provided along with FOV recommendations.

One of the main indications for CBCT imaging is pre-implant assessment of osseous structures; assessment of the width and height of the alveolar ridge, the quality of alveolar bone, the location of such vital structures as the inferior alveolar nerve, mental foramen and floor of maxillary sinus, so as to aid in construction of surgical guides.[6, 20] The American Academy of Oral and Maxillofacial Radiology (AAOMR) recommends "that cross-sectional imaging [derived from CBCT] be used for the assessment of all dental implant sites".[23 (817)]

In orthodontics, CBCT imaging is widely used for assessment of root resorption, tooth localisation and cleft palate management.[24, 25] A study of three hospitals in the United Kingdom (UK) documenting the use of CBCT imaging in a young population reported a peak among those 12–15 years old, showing that the most frequent request for CBCT examinations was localisation of teeth and assessment of root resorption.[26] Although controversial, a small percentage of practitioners substitute conventional 2D tomography in their general orthodontic radiography protocol with CBCT imaging.[24, 25] One reason may be that CBCT reformations provide a higher degree of accuracy for orthodontic measurements of TMJ and related osseous structures, compared to conventional cephalograms.[27] However, it would seem that in a large number of cases there is no strong evidence in the literature to support the benefits of CBCT imaging assessment over more conventional 2D imaging for an ordinary orthodontic case, therefore, CBCT imaging should not be used routinely in orthodontics.[25] Additionally, some CBCT machines are calibrated for adult dosages and cannot be altered; the excessive radiation dosage would be unnecessary for imaging children, who are a population group more likely to seek orthodontic assessment and treatment.[17]

Cone beam CT is also used as an adjunct to intraoral radiography during endodontics to assess tooth morphology, apical pathology, root fracture, root resorption, and post-operative assessment.[13]

However, CBCT has the inherent disadvantage of reduced spatial resolution compared to conventional intra-oral radiography.[13] The American Association of Endodontists (AAE) surveyed their active members online and found one-third of responding members reported to using CBCT in practice.[28] They deemed this as "a significantly increased use",[28 (234)] although baseline data was not provided. However, as a direct sequelae of these survey results, the AAE and the AAOMR produced a joint statement on the recommendations for CBCT use in endodontics. Two important aspects of the recommendations are the use of CBCT only as an adjunct to conventional 2D radiography for diagnostically difficult cases (specific endodontic conditions were referred to) and the use of a small FOV. A small FOV both reduces patient radiation exposure and limits the amount of data that the practitioner is responsible for interpreting.[28, 29]

In the field of OMFS, CBCT imaging is useful for assessment of trauma, osseous pathology, orthognathic surgery and dental extractions. Cone beam CT is increasingly used for pre-operative assessment of third molars to determine root morphology and the proximity of mandibular third molar root systems to the respective adjacent inferior alveolar canal (IAC).[7] Cone beam CT is more reliable than PR for assessing the relationship of the mandibular third molar root system with the IAC, as the determination of risk level for inferior alveolar nerve (IAN) injury tends to be exaggerated when assessed from the PR.[7, 30] Using CBCT for pre-operative assessment of impacted mandibular third molars also facilitates better surgical extraction planning for those third molars regarded as high risk.[30] For impacted mandibular third molars with initial surgical treatment plans derived from PR, one study showed that a small percentage of treatment plans (12%) was altered, with clinicians favouring the more conservative coronectomy procedure after viewing a subsequent CBCT.[31] However, studies comparing PR and CBCT for predicting the likelihood of IAN injuries in moderate-to-high risk impacted mandibular third molar surgical cases demonstrate conflicting results, thus no conclusions were made.[32-34] This is likely due to differences in samples collected and used in these studies. It is more prudent to assess the bucco-lingual relationship of the IAC with the mandibular third molar root system, as the lingually positioned IAC is at a higher risk for IAN injury, which is better clarified from CBCT than from PR.[33]

As an excellent modality for assessing osseous structures, CBCT has been reported to be comparable to bone scintigraphy, and is better than PR, multislice CT, or MRI for detecting bone invasion for oral cancers.[35] Cone beam CT is also very useful for assessing osseous changes in the TMJ such as osteophyte formation, subchondral cyst formation, resorption of the condylar head, fractures, ankylosis, synovial chondromatosis, benign tumours, and rare malignancies.[36] This type of imaging has been found to be superior to linear tomography for intraobserver reliability in TMJ assessment.[37]

1.2.3 Why has CBCT not replaced PR in clinical dental practices?

Despite the many diagnostic benefits of CBCT, critical factors prevent the absolute replacement of PR by CBCT in everyday clinical dental practice. Most notably, cost of owning and operating CBCT machines is higher, interpretation of CBCT data is more complex and time-consuming, and ionising radiation dose delivered to the patient is much higher for CBCT on average than for PR.[8, 16, 38]

Petersen *et al*.[38] compared the financial burden of pre-operative CBCT and PR imaging to patients undergoing third molar surgery in the UK, which showed a three-fold to four-fold difference of CBCT over PR. In a Swedish study, Christell *et al.*[39] also demonstrated an average of 50% increase in total examination cost of impacted maxillary canines when the radiographic method included CBCT versus only using conventional 2D imaging. In Australia, CBCT imaging or PR imaging is provided by dental and radiology clinics, hospitals, or teaching faculties. Extraoral diagnostic imaging taken at accredited radiology centres and hospitals may be subsidised by Medicare Australia through a rebate for eligible patients with permitted referrals.[40] Accreditation of these facilities is through the national Diagnostic Imaging Accreditation Scheme (DIAS).[40] The Medicare subsidy for a CBCT examination is 1.4 times as high as for a PR.[8] For those patients ineligible for Medicare rebates or without a permitted referral, the cost of imaging would be subsequently covered by the patient with or without a private health fund contribution. Likewise, the cost of EO diagnostic imaging taken at non-DIAS radiology facilities would be covered by the patient or by the relevant hospital funding.

The ownership and use-licensing protocols for CBCT and PR machines vary across Australian states and territories. All of the radiation regulators recommended and/or required additional training in the operational aspects of these modalities, although the level of proficiency required for interpretation of these images is not fully addressed (refer to Tables 1-1, 1-2, and 1-3).[41-51] Dental practitioners (general and specialist) are responsible for the interpretation of all radiographic imaging obtained, however, there is generally less expertise when it comes to interpretation of non-dental areas, which are quite often captured in larger FOV CBCT scans.[52, 53]

1.2.4 Ionising radiation in diagnostic radiography

Ionising radiation is received from a combination of natural and artificial sources, with Australians receiving on average 1.5 mSv of background radiation a year.[54] Guidelines from the Australian Radiation and Nuclear Protection Agency (ARPANSA) on accepted levels of ionising radiation exposure above background are as follows: the public may receive 1 mSv per year above background radiation, although this may be exceeded provided that the average dose over 5 years is only 1 mSv; and radiation workers may receive up to 20 mSv per year above background radiation, if averaged over 5 years with no more than 50 mSv in any single year.[55]

The effective ionising radiation dose received from a CBCT examination is on average higher than that from a conventional PR. However, it is accepted that the effective dose varies significantly for CBCT examinations according to the resolution and FOV selected, and also across studies conducted. The effective ionising radiation dose from a set of intra-oral bitewings is in the range of 2–16 µSv,[56] with PR examinations ranging 9–24 µSv; CBCT examinations ranging 11–674 µSv for a small-to-medium FOV or 30–1,073 µSv for a large FOV.[57, 58] Comparatively, multislice CT ranges from 474 µSv to 2,270 µSv.[17, 59] For a similar FOV, multislice CT delivers up to ten times more radiation than CBCT does.[59]

Diagnostic radiographs should only be prescribed when it can feed additional information to a clinical case.[60] X-rays are such a type of ionising radiation which can contribute to both direct and indirect damage on biological tissues (somatic and genetic) that may lead to non-stochastic (deterministic) or stochastic effects. Deterministic effects have a threshold under which no lasting biological damage will occur; this type of effect is not a concern within dental diagnostic radiography. However, there is no safe threshold for stochastic damage; and it is this type of radiation effect that is of concern in dental radiography. As radiation dose increases, the likelihood of cancerous development from stochastic changes rises.[54, 61] The ALARA principle of radiology states that ionising radiation should always be *As Low As Reasonably Achievable*.[56]

There have long been suggestions of a causal link between dental radiation and increased development of cancer; such as thyroid cancers and brain tumours, although these changes are hard to detect and account for in scientific studies.[62, 63] Females are reported to have a greater radiation risk than males, with a 40% greater cancer risk following full body irradiation.[64] Additionally, the lifetime cancer risk from high doses of radiation is also greater for the younger population, for whom maxillofacial radiography in the paediatric population (aged 0–19 years) was reported to have as many as four times the chances of cancer risk compared for adults.[64] One of the more publicised articles in recent years is a population-based case-control study by Claus and Calvocoressi (2012), who compared the radiation history of 1,433 intra-cranial meningioma patients with a control group of 1,350 people.[65] Their findings strongly suggested a likely link between dental radiography and intra-cranial meningioma development in all age groups: in children under the age of 10 years who had received at least one panoramic radiograph, the statistical risk was at least 4.9 times for meningioma development. However, Claus and Calvocoressi's studies did not prove a causal link. Studies regarding cancer causation are difficult to control for bias and errors, and as the authors concede, errors introduced into the study arise from under or over-reporting of dental X-ray history by participants and the genetic predisposition towards meningioma development could not be controlled for at all.[65] Moreover, some environmental factors affecting the population groups unaccounted for in their studies include lifestyle factors (eg. recreational and drugs) and varying levels of background radiations across the American states surveyed.

Some practitioners have adopted PR for screening purposes, however similar to CBCT examinations, using PR in this manner is inappropriate due to the increase in the average amount of radiation delivered when compared with intra-oral radiography.[66] Additionally, PR has a reduced image quality compared with intra-oral radiography. A study tracking PR usage in a UK dental accident and emergency department found that over half the radiography requests should have been reconsidered and that intra-oral film would have sufficed.[66] There is anecdotal suggestion of the same issue surrounding CBCT usage.[8]

The general consensus across international bodies is that CBCT is not recommended as a complete replacement for PR and that clinicians should refrain from using CBCT or PR examinations for general dental screening.[8, 21, 22, 66-70]

1.2.5 Legal aspects of panoramic radiography and cone beam computed tomography examinations

The Australian Radiation Protection and Nuclear Agency has clear guidelines regarding radiation protection in dentistry.[56] Some important aspects include the prescription of radiographs, operation of X-ray equipment, interpretation of radiographs, and storage of radiographs. The general view is that dental practitioners should be responsible for the prescription of radiographs, operation of dental radiography machines and the interpretation of radiographs.[21, 22, 29, 56, 68, 71] Deviation from any of these aspects increases the risk of dental malpractice claims for the practitioner. It is important that dental practitioners undertaking PR and CBCT services should familiarise themselves with ARPANSA's principles to avoid potential litigation. Regardless of the issue under claim, it cannot be disputed that dental malpractice claims are costly, in terms of both time and finance, and practitioners should justify the necessity of radiographic imaging for patients after a thorough clinical examination and then prescribe for the appropriate imaging where indicated.[60]

In any medical or dental malpractice suit there needs to be proof of 1) negligent medical or dental treatment, and 2) a causal relationship between the treatment and an injury or harm. The validity of claims is further examined according to specific rules instituted across the relevant Australian state or territory legal body, such as a clause regarding the level of injury or harm sustained.[72] As mentioned previously, a causal link between dental radiation and increased development of cancer is hard to establish and within the limits of this literature review, no relevant malpractice suits have been retrieved. Conversely, litigation becomes more credible when a lack of pre-operative radiographs is linked to a failure of surgery or post-operative complications. In the cases of *Delphin vs. Martin* and *Jung vs. Son*,[73, 74] Australian court rulings indicated a lack of pre-operative radiographs (especially extraoral radiographs) as a contributing factor to post-operative surgical complications. Similar litigation cases are noted internationally, where inadequate prescription of diagnostic imaging in areas such as oral surgery, implant placement and orthodontic treatment was claimed to have contributed to harm.[75, 76] The above-mentioned evidence supports strongly the correct use of radiographic examinations by dental practitioners wherever relevant and applicable. In a report by Brown and Monsour,[5] there is some evidence indicating that within the field of invasive oral surgery, there has been a preference of CBCT to PR among Australian practitioners in recent years.

The onus is on the health practitioner to make a diagnostically sound judgement for any radiographic examinations prescribed, based on the ALARA principle. With increased access to PR and CBCT modalities, there have been concerns about inappropriate prescription and/or over-prescription of these radiographic examinations.[8, 56] Since CBCT examinations on average produce higher levels of ionising radiation than PR examinations, there is an increased risk of radiation overexposure. Again, there does not appear to be any Australian judicial dental malpractice claim hinged on X-ray overexposure, although claims settled out of court are difficult to account for. Nevertheless, this actuality has been referred to in medical malpractice. In the case of *Adams v Yung and Others*,[77] it was concluded that the medical practitioner demonstrated inappropriate practice, and one of the documented reasons was the over-prescription of X-rays for cases externally reviewed as not requiring radiographs.

Advanced imaging technology also imposes a greater risk of liability to the dental professional in interpretation of data, with 3D imaging in particular posing challenges for the dental practitioner in manipulation and understanding of the dataset obtained. Dental practitioners are advised to use a smaller FOV where appropriate when prescribing 3D radiographic examinations.[76, 78] Overseas studies have reported misdiagnosis as being responsible for the majority of litigation cases involving radiologists.[75] Incidental radiographic findings for the dento-maxillofacial region have shown as high as 93.42% for non-dental pathology.[79] However, there is generally a lack of consistency in the literature accounting for incidental findings, largely due to different study designs used.[14, 80, 81] In a study performed with orthodontic residents and orthodontists, even after a short course of CBCT, up to 43% of total incidental lesions was still overlooked.[82] These facts highlight the importance of adequate knowledge for interpretation of PR and CBCT data. In Australia, diagnostic imaging performed at DIAS-accredited radiology practices are reported by qualified radiologists. For dental practitioners who own and operate extraoral radiography machines in private practice, it would be within their interest to attach the services of a dento-maxillofacial radiologist (DMFR) to help interpret radiological data.

Furthermore, dental practitioners in Australia are legally required to store radiographic records for a minimum of 7 years, with a variation of this regulation for those patients under the legal age of 18 years, in which the radiographic records are required to be kept for 7 years after a patient attains the legal age.[56]

1.2.6 Regulations for the operation of extraoral radiography machines across Australian states and territories

Use-licensing for extraoral radiography differs across Australian states and territories dictated by the relevant radiation regulator. There is no national guideline available, although consideration could be given to the provision of a national guideline by the Australian Health Practitioner Regulation Agency (AHPRA) or Dental Board of Australia (DBA). The Australian radiation regulators include: Australian Capital Territory (ACT) Radiation Safety Health Protection Service; Queensland (QLD) Radiation Health Unit; South Australia (SA) Radiation Protection; Tasmania (TAS) Radiation Protection Unit; Victoria (VIC) Radiation Safety; Northern Territory (NT) Radiation Protection Section; New South Wales (NSW) Hazardous Materials, Chemicals and Radiation Section; Western Australia (WA) Radiological Council; and AHPRA for the Commonwealth.

The use-licensing regulations across Australian states and territories for extraoral radiography as of July 2017 are summarised for dentists (Table 1-1); dental hygienists, dental therapists and oral health therapists (Table 1-2); and dental assistants (Table 1-3).[41-51] With a few exceptions, nearly all dental practitioners can obtain a use-license for PR and CBCT as long as regulation requirements set out by the relevant radiation regulator have been fulfilled. However, the stringency of training prerequisites varies across jurisdictions.

Table 1-1. Dentists: training prerequisites for operation of CBCT and PR machines across Australian jurisdictions as of July 2017

Dental practitioners		
	CBCT	PR
NSW	*IA24 licence condition* 1. AHPRA registration, and 2. Completion of a CBCT course for the relevant apparatus	*IA20 licence condition* 1. AHPRA registration
TAS	*RPA001 ionising radiation licence* 1. AHPRA registration, and 2. Completion of a CBCT course	*RPA001 ionising radiation licence* 1. AHPRA registration
NT	*Radiation licence for dental practitioners* 1. AHPRA registration, and 2. Completion of a CBCT course	*Radiation licence for dental practitioners* 1. AHPRA registration, and 2. Evidence of appropriate PR training
ACT	*Licence to deal with a radiation Source – Specialist Dental X-Ray Sources* 1. AHPRA registration, and 2. Completion of a CBCT course	*Licence to deal with a radiation Source – General Dental X-Ray Sources* 1. AHPRA registration
WA	*Licence for irradiating apparatus and/or electronic products* 1. AHPRA registration, and 2. Dentist with Master degree in Oral and/or Maxillofacial Radiology (OMFR) or equivalent	*No specific radiation licence required* 1. AHPRA registration
QLD	*Licence to use a radiation source*	*Licence to use a radiation source*

	1. AHPRA registration, and 2. Certificate of Proficiency from a recognised CBCT course run by a DMFR specialist or equivalent	1. AHPRA registration, and 2. Evidence of appropriate PR training
VIC	*Radiation – Use license* 1. AHPRA registration, and 2. Completion of DEN4 course (within the last 12-months), and 3. Completion of DEN5-1 or DEN5-2 or DEN5-3 or DEN5-4 or DEN5-5 or DEN5-6 or DEN5-7 or DEN5-8 or DEN5-9 or DEN5-10 course (within the last 12-months)	*Radiation – Use license* 1. AHPRA registration
SA	*Licence to operate ionising radiation apparatus – CBCT* 1. AHPRA registration, and 2. SA license to operate ionising radiation apparatus (OPG), and 3. Completion of a CBCT course	*Licence to operate ionising radiation apparatus – OPG with/without cephalometry* 1. AHPRA registration, and 2. SA license to operate ionising radiation apparatus (intra-oral), and 3. University of Adelaide graduate within the last 5-years or evidence of appropriate PR training within the last 5-years

ACT = Australian Capital Territory; AHPRA = Australian Health Practitioner Regulation Agency; CBCT = cone beam computed tomography; DMFR = dento-maxillofacial radiology; NSW = New South Wales; NT = Northern Territory; OPG = orthopantomogram; PR = panoramic radiography; QLD = Queensland; SA = South Australia; TAS = Tasmania; VIC = Victoria; WA = Western Australia

Table 1-2. Dental hygienists, dental therapists and oral health therapists: training prerequisites for operation of CBCT and PR machines across Australian jurisdictions as of July 2017

Dental hygienists, dental therapists and oral health therapists		
	CBCT	PR
NSW	*IA24 licence condition* 1. AHPRA registration, and 2. Completion of a CBCT course for the relevant apparatus	*IA20 licence condition* 1. AHPRA registration
TAS	*RPA001 ionising radiation licence* 1. AHPRA registration, and 2. Completion of a CBCT course	*RPA001 ionising radiation licence* 1. AHPRA registration
NT	*Radiation licence for dental practitioners* 1. AHPRA registration, and 2. Completion of a CBCT course	*Radiation licence for dental practitioners* 1. AHPRA registration, and 2. Evidence of appropriate PR training
ACT	*Licence to deal with a radiation Source – Specialist Dental X-Ray Sources* 1. AHPRA registration, and 2. Completion of a CBCT course	*Licence to deal with a radiation Source – General Dental X-Ray Sources* 1. AHPRA registration
WA	*Not eligible*	*No specific radiation licence required* 1. AHPRA registration
QLD	*Licence to use a radiation source* 1. AHPRA registration, and 2. Certificate of Proficiency from a recognised CBCT course run by a DMFR specialist or equivalent	*Licence to use a radiation source* 1. AHPRA registration, and 2. Evidence of appropriate PR training

VIC	*Radiation – Use license* 1. AHPRA registration, and 2. Completion of DEN4 course (within the last 12-months), and 3. Completion of DEN5-1 or DEN5-2 or DEN5-3 or DEN5-4 or DEN5-5 or DEN5-6 or DEN5-7 or DEN5-8 or DEN5-9 or DEN5-10 course (within the last 12-months)	*Radiation – Use license* 1. AHPRA registration, and 2. Evidence of appropriate PR training
SA	*Licence to operate ionising radiation apparatus – CBCT* 1. AHPRA registration, and 2. SA license to operate ionising radiation apparatus (OPG), and 3. Completion of a CBCT course (within the last 5 years), and 4. In-house applications training provided by licensed and experienced senior staff and/or equipment supplier	*Licence to operate ionising radiation apparatus – OPG with/without cephalometry* 1. AHPRA registration, and 2. SA license to operate ionising radiation apparatus (intra-oral), and 3. University of Adelaide graduate from 2009 onwards or evidence of appropriate PR training within the last 5-years

ACT = Australian Capital Territory; AHPRA = Australian Health Practitioner Regulation Agency; CBCT = cone beam computed tomography; DMFR = dento-maxillofacial radiology; NSW = New South Wales; NT = Northern Territory; OPG = orthopantomogram; PR = panoramic radiography; QLD = Queensland; SA = South Australia; TAS = Tasmania; VIC = Victoria; WA = Western Australia

Table 1-3. Dental assistants: training prerequisites for operation of CBCT and PR machines across Australian jurisdictions as of July 2017

Dental assistants		
	CBCT	PR
NSW	*IA24 licence condition* 1. Certificate IV in Dental Assisting – Radiography, and 2. Completion of a CBCT course for the relevant apparatus	*IA20 licence condition* 1. Certificate IV in Dental Assisting – Radiography
TAS	*RPA001 ionising radiation licence* 1. Certificate IV in Dental Assisting – Radiography, and 2. Completion of a CBCT course	*RPA001 ionising radiation licence* 1. Certificate IV in Dental Assisting – Radiography
NT	*Not Eligible*	*Not Eligible*
ACT	*Not Eligible*	*Licence to deal with a radiation Source – General Dental X-Ray Sources* 1. Certificate IV in Dental Assisting – Radiography
WA	*Not eligible*	*No specific radiation licence required* 1. Certificate IV in Dental Assisting – Radiography
QLD	*Licence to use a radiation source* 1. Certificate IV in Dental Assisting – Radiography, and 2. Certificate of Proficiency from a recognised CBCT course run by a DMFR specialist or equivalent	*Licence to use a radiation source* 1. Certificate IV in Dental Assisting – Radiography, and 2. Evidence of appropriate PR training

VIC	*Radiation – Use license* 1. Certificate IV in Dental Assisting – Radiography, and 2. Completion of DEN4 course (within the last 12-months), and 3. Completion of DEN5-1 or DEN5-2 or DEN5-3 or DEN5-4 or DEN5-5 or DEN5-6 or DEN5-7 or DEN5-8 or DEN5-9 or DEN5-10 course (within the last 12-months)	*Radiation – Use license* 1. Completion of DEN1 and DEN2 courses, or 2. Completion of DEN3 course
SA	*Not eligible*	*Licence to operate ionising radiation apparatus – OPG without cephalometry* 1. Certificate IV in Dental Assisting – Radiography, and 2. SA license to operate ionising radiation apparatus (intra-oral), and 3. Evidence of appropriate PR training within the last 5-years

ACT = Australian Capital Territory; AHPRA = Australian Health Practitioner Regulation Agency; CBCT = cone beam computed tomography, DMFR = dento-maxillofacial radiology; NSW = New South Wales; NT = Northern Territory; OPG = orthopantomogram; PR = panoramic radiography; QLD = Queensland; SA = South Australia; TAS = Tasmania; VIC = Victoria; WA = Western Australia

The DBA announced a broad policy on March 11th 2011 as part of the National Registration and Accreditation Scheme stating that:

> "Dental practitioners using CBCT must be adequately trained in the safe use of CBCT and should abide by the Code of Practice and Safety Guide for Radiation Protection in Dentistry (2005) produced and published [by ARPANSA]. In addition, all dental practitioners

associated with the ownership or use of CBCT must ensure ownership, licensing and operation of CBCT equipment complies with the legislation of the relevant state, territory and commonwealth jurisdiction." [83] [(1)]

This policy was removed from the National Registration and Accreditation Scheme on February 20th 2015 as regulations for CBCT were being implemented by individual Australian state and territory radiation regulators, which negated a national policy.[84] However, the drawback of differing regulations across the jurisdictions is that radiation licenses are generally not transferable across Australian states and territories.

Of particular note, the radiation regulator of WA has implemented the strictest licensing guidelines for CBCT, where only medical radiologists or DMFRs are able to own and operate CBCT machines.[49] This would undoubtedly impact on the number of CBCT machines that are located in Western Australia, as it would be reasonable to assume that health practitioners will only buy the machines if they are able to use it. It has previously been estimated that less than one per cent of the CBCT machines accounted for nationally are located in WA.[85]

1.2.7 Machine quantities and usage: panoramic radiography and cone beam computed tomography

There is a lack of established data both nationally and internationally regarding the adoption of PR and CBCT machines. The Australian Regulation Protection and Nuclear Agency estimated a total of 1,120 PR machines in Australia in 2005.[86] The Australian Dental Industry Association estimated a total of 420 CBCT machines in Australia in 2013, with less than one per cent of the machines located in WA.[85] It is unclear how these PR and CBCT estimates were made and whether the estimates are reliable. It is possible that these organisations obtained the data from radiation regulators or from equipment suppliers. A brief summary of the approximate number of PR and CBCT machines in a number of overseas countries is provided in Table 1-4.

Table 1-4. The approximate number of panoramic radiography and cone beam computed tomography machines worldwide by timeline and distribution range

Country	Year	Distribution	Approximate number (*N*)
PR			
USA[87]	1979	Nationwide	25,000
Australia[88, 89]†	1988	General dental practices	377
UK[4]	1994	Nationwide	3,250
Australia[86]	2005	Nationwide	1,120
Switzerland[15]	2008	Nationwide	1,832
UK[90]‡	2008~2011	Nationwide	3,483
Ireland[90]‡	2008~2011	Nationwide	450
CBCT			
Switzerland[15]	2008	Nationwide	49
Norway[91]	2012	General dental practices	39
Australia[85]	2013	Nationwide	420

†Approximately 6,291 Australian general dentists that year, with 6% of general dentists in private practice owning PR machines

‡63% of UK and 20% of Ireland dental practices were surveyed; stating 2,195 PR machines in the UK and 90 PR machines in Ireland, respectively

CBCT = cone beam computed tomography; PR = panoramic radiography; UK = United Kingdom; USA = United States of America

Similarly, there is limited data to account for the number of CBCT and PR scans performed in Australia or overseas. Brown and Monsour[5] evaluated the number of CBCT scans rebated across the three financial years from July 2011 to June 2014 through Medicare, the Australian national public healthcare system. A total of 226,232 CBCT scans were rebated during these three financial years, with a 42.3% increase demonstrated from 2011 to 2014.[5] This statistic does not include non-rebatable scans or scans taken in the private healthcare sector. Within the literature search performed, no information could be gathered for the number of CBCT scans performed in overseas countries.

The Australian Radiation Protection and Nuclear Agency estimated the rate of PR scans performed in 2005 to be "10/week/X-ray unit" across Australia.[86] [(3)] The estimate of 1,120 PR machines for the same year equalled 582,400 PR scans performed nationally. This was seen to be an underestimate for PR scans performed during 2005 as data extrapolated from Brown and Monsour's[5] study approximated 800,000 PR scans in 2005 rebated through Medicare Australia alone, even without accounting for non-rebatable ones or scans taken through the private sector. From July 2011 to June 2014, Medicare recorded 2,881,351 PR scans rebated, at a steady rate of approximately 960,000 PR scans per year.[5] Overall, across nine consecutive financial years from July 2005 through to June 2014, there was an 18% increase in the number of Medicare rebated PR scans.[5]

Table 1-5 provides a summary of some of the findings reported in the literature on the approximate number of PR scans performed in various countries. The calculated data in this table should be viewed with reservations as methodologies used in these studies varied considerably. It can be observed however that per 1,000 population in Australia, the rate of PR scans performed increased by approximately 3.43 times from the year 1984 to year 2005. Overseas, the rate of PR scans performed per 1,000 population in Switzerland increased by 1.68 times over a decade; and for the same period, the rate of PR scans performed per 1,000 population in the UK decreased by 0.06 times.

In 2008, it was reported that nearly all dental radiographs (intra-oral, panoramic, and cephalometric) in the UK could be attributed to three main sectors: The National Health Service–general dental practices (NHS-GDP); NHS-hospitals; and private dental practices, with majority of radiographs taken in the NHS-GDP sector. The average number of PR scans taken in the NHS-GDP sector from 1992 to 2005 is shown in Table 1-6.[92] A decrease in PR scans taken in the NHS-GDP in England and Wales in recent years was attributed to the patients seeking dental treatment from the private sector instead of resorting to the public system.[92]

Table 1-5. Approximate number of panoramic radiographs taken worldwide

Country or Region	Year	Distribution	Number of Scans (*N*)	Number of scans per 1,000 population
Great Britain[93]	1981	England, Scotland & Wales	910,000	-
Australia[94]†	1984	General dentists	168,258	10.80
France[95]†	1989	Nationwide	1,650,000	28.40
England/Wales[4]	Prior to 1993	General dentists	1,500,000	-
France[4, 95]†	Prior to 1993	General dentists	1,700,000	28.80
Switzerland[96]	1998	Nationwide	236,662	32.54
Netherlands[96, 97]†	1998	General dentists and orthodontists	123,071	7.87
UK[96, 98]†	1998	Nationwide	3,316,980	56.22
USA[99]	1999	340 dental practices across 40 USA states	2,722,720	-
Australia[86]†	2005	Nationwide	582,400‡	37.00
Switzerland[15]†	2008	Nationwide	417,000	54.53
UK[92]†	2008	Nationwide	3,252,991	52.63

†Population number used for calculations: Australia (1984)[100] = 15,579,400; France (1989)[101] = 58,182,702; France (1993)[102] = 59,106,766; Netherlands (1998)[96, 97] = 15,638,000; UK (1998)[96, 98] = 59,000,000; Australia (2005)[103] = 23,577,900; Switzerland (2008)[104] = 7,647,675; UK (2008)[105] = 61,806,995

‡ Likely underscored

UK = United Kingdom; USA = United States of America

Table 1-6. Number of panoramic radiographs taken in the NHS-GDP in England and Wales from 1992–2005

Country or Region	Year	Coverage	Number of panoramic radiographs (*N*)
England and Wales	1992/93	NHS-GDP†	1,425,293
	1993/94		1,443,959
	1994/95		1,515,477
	1995/96		1,615,264
	1996/97		1,707,187
	1997/98		1,871,995
	1998/99		2,029,268
	1999/00		2,074,155
	2000/01		2,196,700
	2001/02		2,121,707
	2002/03		1,998,840
	2003/04		1,976,306
	2004/05		1,809,809

†This excludes NHS-hospitals, private dental practices, and other facilities
NHS-GDP = National Health Service-general dental practices

1.2.8 The Australian Medicare Benefits Schedule

Under the Medicare Benefits Schedule (MBS) of Australia, both PR and CBCT examinations can attract a rebate through Medicare Australia for eligible patients when scans are taken at Medicare approved radiology practices and reported by a radiologist.

Rebates for PR examinations have been available through the MBS for nearly three decades, noted as far back as 1st August 1988 under the service code 9341 for "ORTHOPANTOMOGRAPHY and Report".[106] [(26)] All medical and dental practitioners were able to refer for a Medicare rebatable PR scan. Overtime, there have been adjustments to the PR service code in subsequent amendments of the MBS. The most recent MBS specifies eight different service codes for PR examinations.

Brown and Monsour[5] in their study categorised the MBS PR services codes into four broad groups: Surgical, General Dental, Orthodontic, and TMJ. The item codes and descriptions for the four PR groups are shown in Table 1-7.[107]

Table 1-7. The Medicare Benefits Schedule item codes and descriptions for panoramic radiography

Category	Item codes	Service descriptions
Surgical	57959 (NK) & 57960	Orthopantomography, for diagnosis and/or management of trauma, infection, tumours, congenital conditions or surgical conditions of the teeth or maxillofacial region
General dental	57962 (NK) & 57963	Orthopantomography, for diagnosis and/or management of impacted teeth, caries, periodontal or periapical pathology where signs or symptoms of those conditions are evident
Orthodontic	57965 (NK) & 57966	Orthopantomography, for diagnosis and/or management of missing or crowded teeth, or developmental anomalies of the teeth or jaws
Temporomandibular joint	57968 (NK) & 57969	Orthopantomography, for diagnosis and/or management of temporomandibular joint arthroses or dysfunction

NK = machines older than 10 years attract a reduced rebate from Medicare

In contrast, CBCT has only been included in the MBS since 1st July 2011, initially under service codes 56025 and 56026. Referrals from all medical and dental practitioners were eligible for Medicare rebatable CBCT scans. However, changes were introduced to the MBS from 1st November 2014 limiting CBCT rebates to referrals made by dental specialists (oral and maxillofacial surgeons, prosthodontists, periodontists, endodontists, pedodontists, orthodontists, and oral medicine and oral pathology specialists). Consequently, general dental practitioner (GDP) referrals did not attract a Medicare rebate for patients anymore. The new service codes are 57362 and 57362.

Additional criteria stipulate that CBCT scans are only to be taken on non-hybrid machines and same-day claims are limited to a single claim per patient, not in conjunction with another PR scan or CT.[107] Descriptions for the CBCT item service codes are provided in Table 1-8.[107]

Table 1-8. Medicare Benefits Schedule item codes and descriptions for cone beam computed tomography

Item codes	Period active	Service descriptions
56025 & 56026 (NK)	1st July 2011–30th October 2014	Dental & temporo-mandibular joint imaging for diagnosis and management of mandibular and dento-alveolar fractures, dental implant planning, orthodontics, endodontic, periodontal and temporo-mandibular joint conditions: without contrast medium.
57362 & 57363 (NK)	1st November 2014 onwards	
NK = machines older than 10 years attract a reduced rebate from Medicare		

Changes for CBCT rebates were introduced into the MBS after the Medical Services Advisory Committee (MSAC) reviewed the MBS in November 2013 and April 2014.[8, 108-110] Concerns raised by the MSAC regarding CBCT scans centred around inappropriate prescription and over-prescription for an imaging service that produced on average higher radiation dosage compared to PR. They took steps in restricting CBCT examinations after noticing rapid growth of Medicare-funded CBCT services among the younger population, numerous co-claims between CBCT and PR or another CBCT in the same episode of service, restricted FOV adjustments in hybrid CBCT machines, and potential self-referral by GDPs. The MSAC believed CBCT scans should have similar restrictions to that stipulated for multislice CT scans. From the 2011–2013 Medicare data, MSAC also made projections for the number CBCT scans rebated or to be rebated each financial year until 2018 and the notable positive growth signified a heavy financial burden.[8]

The 2014 MBS restrictions impact most on GDPs, as GDPs are unable to access Medicare rebatable CBCT scans for their patients. So where does this leave the GDPs and their patients? Resultant alternatives would be: a patient obtaining a non-rebatable scan, referral of the patient to a specialist dentist, having the patient obtain a CBCT referral from a medical practitioner or in the extreme scenario, the GDPs may decide to install their own CBCT machine for the service to be sought. With increasing numbers of EO radiography devices being installed in private dental practices, it is then important that dental practitioners are reminded of the radiological responsibilities.

1.3 Hypotheses

For this thesis, two independent hypotheses have been developed concentrating on the adoption and usage of CBCT and PR machines.

Hypothesis 1: The number of CBCT and PR machines in each Australian state and territory is influenced by the use-licensing criteria set out by each radiation regulator.

Hypothesis 2: Restrictions for CBCT in the 2014 MBS will result in reduced numbers of rebated CBCT scans in the subsequent year when compared with that in previous years, whereas no significant change will be observed in the number of rebated PR scans.

1.4 Aims of the research

To date, there is no collective national data on the number of EO radiography machines. Consequently, this research project aims to assess the number of CBCT and PR machines across Australian states and territories; to provide baseline data that can be used with follow-up studies for mapping the trend in adoption of these modalities.

Closely associated with adoption of EO radiography machines is concurrent usage. The national usage rate of these modalities is difficult to account for across both public and private health sectors. Subsequently, Medicare data will be sourced to represent the usage scenario across Australian medical radiology practices, with particular focus on potential changes to usage following Medicare policy changes.

CHAPTER 2

Comparative adoption of cone beam computed tomography and panoramic radiography machines across Australia

A Zhang BDSc; * **S Critchley**; † **PA Monsour** BDSc, PhD (Qld), MDSc (Qld), FICD.*
*School of Dentistry, The University of Queensland, Herston, Queensland, Australia.
†Health Protection Branch, Queensland Department of Health, Herston, Queensland, Australia.

Key words: cone beam computed tomography, correlative analysis, extraoral radiography, panoramic radiography, X-ray machines.

Short title: Comparative adoption of CBCT and PR machines

Paper published in:
Australian Dental Journal, 2016; 61: 489–496

2.1 Abstract

Background: The aim of the present study was to assess the current adoption of cone beam computed tomography (CBCT) and panoramic radiography (PR) machines across Australia.

Methods: Information regarding registered CBCT and PR machines was obtained from radiation regulators across Australia. The number of X-ray machines was correlated with the population size, the number of dentists, and the gross state product (GSP) per capita, to determine the best fitting regression model(s).

Results: In 2014, there were 232 CBCT and 1,681 PR machines registered in Australia. Based on absolute counts, Queensland had the largest number of CBCT and PR machines whereas the Northern Territory had the smallest number. However, when based on accessibility in terms of the population size and the number of dentists, the Australian Capital Territory had the most CBCT machines and Western Australia had the most PR machines. The number of X-ray machines correlated strongly with both the population size and the number of dentists, but not with the GSP per capita.

Conclusions: In 2014, the ratio of PR to CBCT machines was approximately 7: 1. Projected increases in either the population size or the number of dentists could positively impact on the adoption of PR and CBCT machines in Australia.

2.2 Introduction

Extraoral (EO) radiography in dental clinical practice comprises rotational panoramic radiography (PR) and, more recently, cone beam computed tomography (CBCT). PR acquires a curved planar tomogram whereas CBCT produces a volumetric dataset, enabling multiplanar reformations (MPR) and volumetric renderings.[20, 111]

Panoramic radiography has been the mainstay of EO imaging for many years, but this modality has a number of limitations including extensive superimposition, ghost images, distortions and variable image quality.[111] Often, one or more of these limitations can be addressed by CBCT, which has now been incorporated into most dental fields.[20] However, the average radiation exposure is greater for a CBCT examination than for a PR examination; as a result, PR has remained very popular amongst dentists as the initial EO imaging of choice.[111]

Cone beam computed tomography is routinely compared with conventional computed tomography (CT), as both modalities are capable of providing information in three dimensions, although CT uses different digital geometric processing methods to acquire volumetric data.[16] Compared with CT, CBCT allows for a limited field-of-view (FOV), smaller voxel size, improved spatial resolution and a lower average radiation dose to the patient. Furthermore, the CBCT radiation detectors are less expensive to manufacture than the ceramic detectors used in CT machines and the CBCT machines are generally more compact.[16]

Cone beam computed tomography machines have been commercially available since 1998,[1] with anecdotal evidence suggesting a significant increase in the adoption of machines in Australia and elsewhere within the last decade. A recent report by Brown and Monsour[5] examining the usage and growth in Medicare rebatable CBCT and PR services in Australia over the past three financial years ending June 2014 demonstrated an increase of 42.3% in CBCT services per 100,000 population compared with a relatively steady rate in PR services. However, Medicare is part of the public health care system and does not capture data from the private dental sector where a similar growth in CBCT services may be expected.

The adoption of EO X-ray machines is influenced by the regulations set out by each Australian state or territory radiation regulator. Therefore, there exists some variation in the regulations for obtaining use licenses.[112-120] By and large, all Australian registered general and specialist dentists can own and operate PR machines provided the criteria set out by the relevant regulators are met. General and specialist dentists can also own and operate CBCT machines in all states and territories, with the exception for Western Australia (WA), where CBCT licenses are restricted to dento-maxillofacial radiologists (DMFRs) and medical radiologists.[120] Consequently, the WA regulations will influence the number of CBCT machines in that state.[121]

For this project, we hypothesized that the number of both CBCT and PR machines used across Australian states and territories is associated with and/or influenced by: (i) population size; (ii) number of dental practitioners; (iii) gross earnings per capita; and (iv) licensing regulations. This on-going research project is aimed at examining the adoption of CBCT and PR machines in Australia and the factors that may influence the adoption of these imaging modalities.

2.3 Materials and methods

This project was granted ethics approval from the University of Queensland, School of Dentistry Research Ethics Committee.

Data collection was undertaken during the period September to December 2014. Correspondence was sent via email on 14 September 2014 to the radiation regulators in Australia: Australian Capital Territory (ACT) Radiation Safety Health Protection Service; Queensland (QLD) Radiation Health Unit; South Australia (SA) Radiation Protection; Tasmania (TAS) Radiation Protection Unit; Victoria (VIC) Radiation Safety; Northern Territory (NT) Radiation Protection Section; New South Wales (NSW) Hazardous Materials, Chemicals and Radiation Section; and WA Radiological Council. Information was also obtained from the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), as this organization also has EO machines not recorded by the other radiation regulators. Anonymous information was requested regarding the number of CBCT and PR machines registered in each state and territory, and the relevant specifications for each machine such as manufacturer and model. Raw data returned from each Australian radiation regulator was then processed.

Additionally, information was obtained from the Australian Bureau of Statistics (ABS) website regarding state and territory populations for the September quarter 2014.[122] Information on the number of registered dentists was sourced from the Dental Board of Australia website for the September quarter 2014.[123] The gross state product (GSP) per capita for 2014 was calculated from the state final demand accessed from the ABS website.[124]

The NSW radiation regulator was only able to provide a total count of CBCT and PR machines in that state. The remaining Australian radiation regulators and ARPANSA were able to provide all the information requested. Any discrepancies in the raw data (excluding NSW) were examined. A small number of machines were incorrectly recorded as CBCT or PR machines, including intraoral machines, ultrasound machines and orthopaedic radiography machines, and these were removed from the data. All EO machines were categorized subsequently as CBCT and PR machines according to the manufacturer and model, and not by their allocations in the raw data. Additionally, the number of PR machines upgradable to three-dimensional (3D) capability was recorded for each radiation regulator and ARPANSA. Descriptive statistics for the number of machines per million population and per 1000 dentists were applied for both CBCT and PR machines.

2.3.1 Statistical analysis

Using Microsoft Excel 2013 (Microsoft, Redmond, WA, USA), regression analyses was undertaken to assess the relationship between CBCT and PR machines against one of the three variables: (i) the population size per state or territory; (ii) number of dentists per state or territory; and (iii) GSP per capita. It was necessary to exclude ARPANSA from certain analyses. Regarding the number of dentists, those that do not have a principal place of practice were also excluded from the analyses. It is worth noting for clarification that the ownership of CBCT and PR machines is not limited to dentists; however, this project assessed the number of machines against the number of dentists as a leading driver of the demand. Regarding correlation assessment, as the number of machines provided by NSW was well below what would be expected considering the population of NSW, the NSW figures were omitted from a comparative set of PR regression models. Additionally, the CBCT licensing regulations also differed significantly in WA from those in the other states and territories.[120] Therefore, further correlative analyses for CBCT machines were made by excluding both NSW and WA in a comparative set of regression models.

2.4 Results

The population size and the number of dentists for each state or territory for the September quarter 2014 are summarised in Table 2-1.[122, 123]

Table 2-1. Number of dentists and population size for the September quarter 2014

State or territory	Dentists (*N*)	Population (*N*)
ACT	283	387,100
QLD	3,013	4,740,900
SA	1,161	1,688,700
TAS	222	515,000
VIC	3,716	5,866,300
NT	104	246,300
WA	1,635	2,589,100
NSW	5,016	7,544,500
No PPP	481	N/A
Total	15,631	23,577,900

Dentist refers to general and specialist.

ACT = Australian Capital Territory; NSW = New South Wales; NT = Northern Territory; PPP = Principal Place of Practice; QLD = Queensland; SA = South Australia; TAS = Tasmania; VIC = Victoria; WA = Western Australia.

Figure 2-1 gives a geographical distribution of the number of CBCT and PR machines across Australian states, territories and ARPANSA. As of 2014, a total number of 1,913 EO X-ray machines made up of 1,681 PR machines and 232 CBCT machines were recorded nationally, with PR machines outnumbering CBCT machines by 7.25 times. Excluding ARPANSA, QLD recorded the largest number of CBCT and PR machines (97 and 420, respectively) and NT recorded the smallest number of CBCT and PR machines (three and 14, respectively).

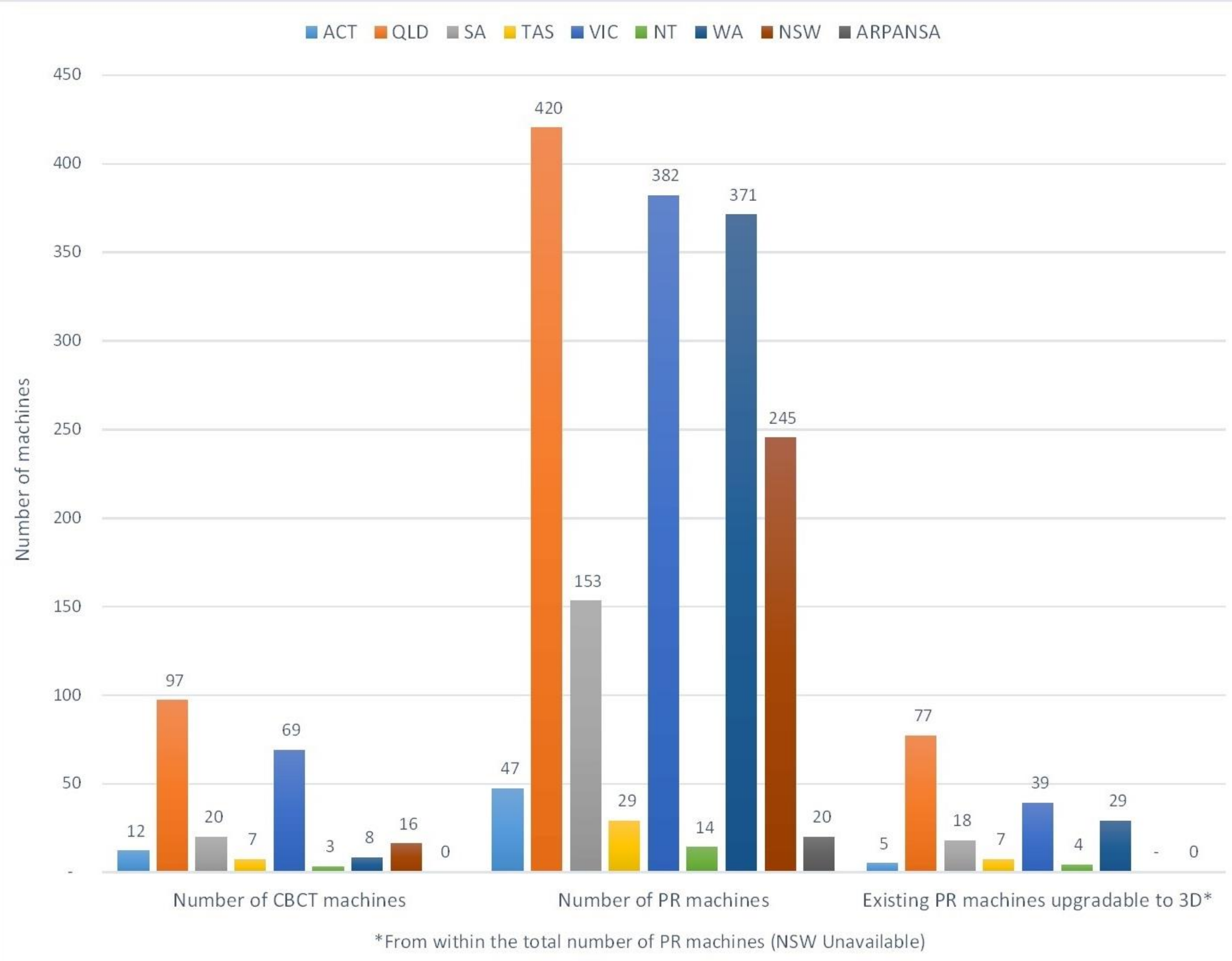


Figure 2-1. Distribution of cone beam computed tomography (CBCT) and panoramic radiography (PR) machines across Australia.

Out of a total of 1,436 PR machines (excluding NSW), 179 were upgradable to 3D capability. QLD had the largest number of existing upgradable PR machines, representing 18% of the total number of PR machines in QLD. However, based on percentage distribution, the NT had the largest percentage (29%) of upgradable PR machines.

2.4.1 Number of machines in relation to the population size and the number of dentists

For all Australian states and territories, the number of CBCT and PR machines was expressed as an average number of machines per million population (Figure 2-2) and as an average number of machines per 1,000 dentists (Figure 2-3).

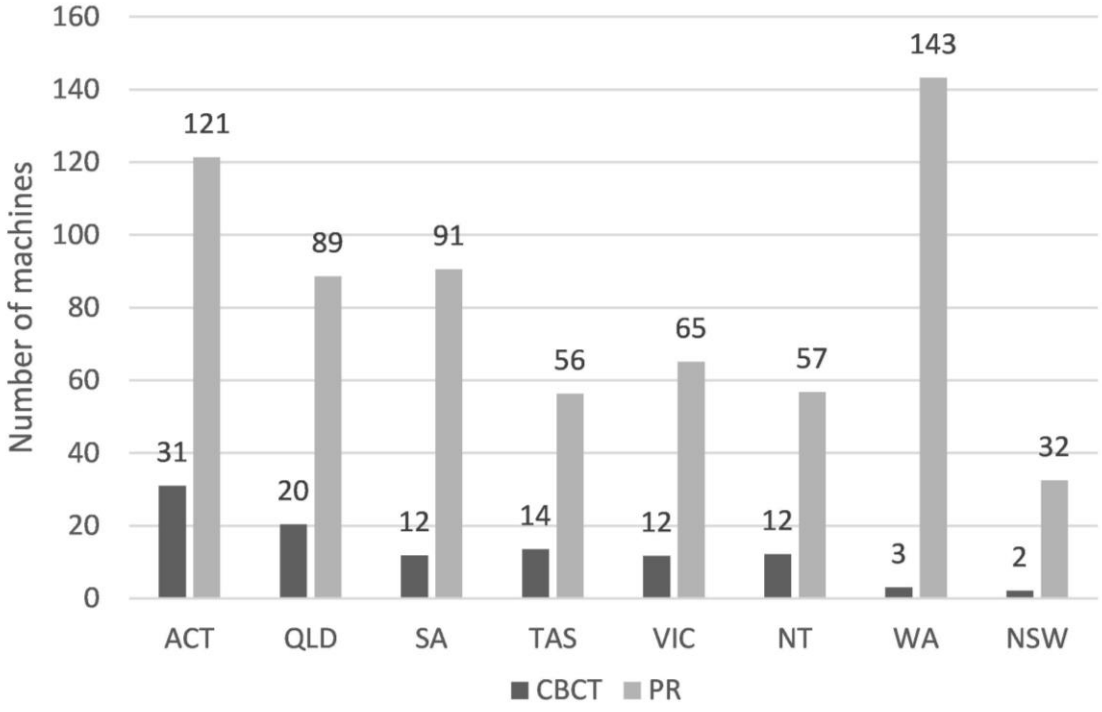


Figure 2-2. Number of cone beam computed tomography (CBCT) and panoramic radiography (PR) machines per million population.

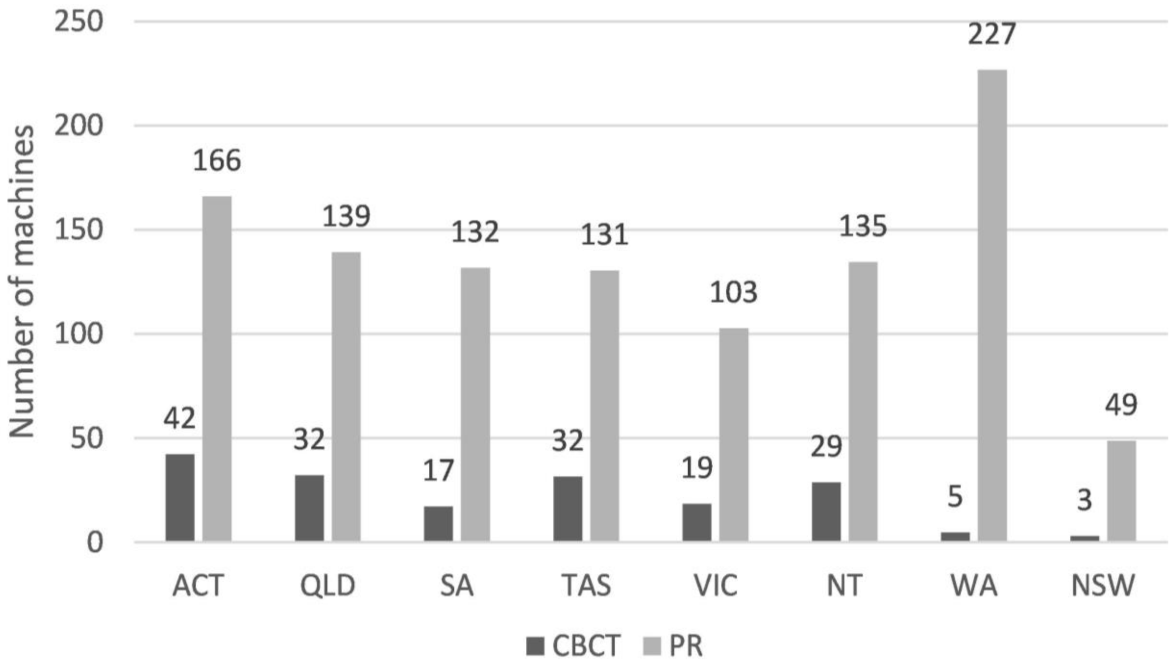


Figure 2-3. Number of cone beam computed tomography (CBCT) and panoramic radiography (PR) machines per 1,000 dentists.

In relation to both the population size and the number of dentists, the ACT had the most CBCT machines (31 per million population and 42 per 1,000 dentists), whereas NSW had the least CBCT machines (2 per million population and 3 per 1,000 dentists). Further, WA had the most PR machines in relation to both the population size and the number of dentists (143 per million population and 227 per 1,000 dentists), whereas NSW had the least PR machines (32 per million population and 49 per 1,000 dentists).

2.4.2 Correlative analyses

Correlative analyses were made on the number of PR and CBCT machines with each of the following three variables: (i) population size; (ii) number of dentists; and (iii) GSP per capita (Table 2-2). Figure 2-4 illustrates the state and territory GSP per capita for 2013–2014 collated and used for the correlative analyses.

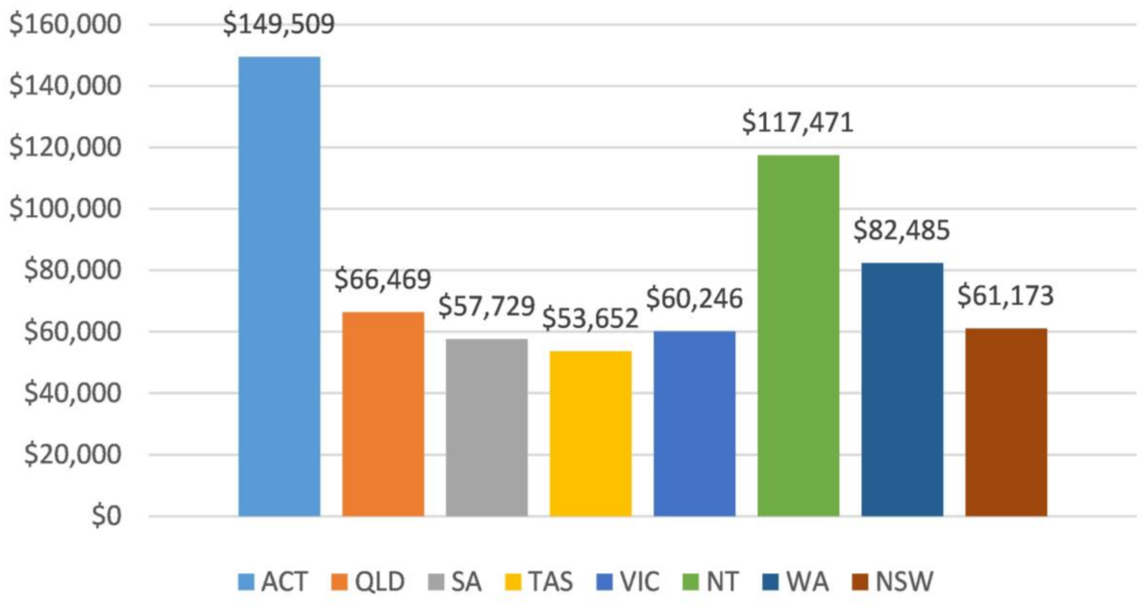


Figure 2-4. Gross state product per capita 2013–2014.

For linear regressions, the *P*-values indicated the significance of correlation (with $P > 0.05$ representing weak evidence against the null hypothesis). When all states and territories were included in the analyses, a significant correlation was found for the number of PR machines in relation to both the population size and the number of dentists ($P < 0.05$). When NSW was excluded (because of above-mentioned concerns with the data), the correlation became highly significant ($P < 0.01$). Regarding similar correlation analyses for CBCT machines, the null hypothesis could be rejected only when NSW and WA were excluded as outliers, with the subsequent magnitude of correlation being highly significant in relation to both the population size and the number of dentists ($P = 0.008 < 0.01$). No significant correlation was found between PR or CBCT machines and the GSP per capita, however.

Table 2-2. Correlative analyses between the number of PR or CBCT machines and the following variables: population, number of dentists, or GSP per capital

Variables	r	p	r^2_L	r^2_e
Panoramic radiography (PR)				
PR *vs.* population	0.74	0.04	0.54	0.59
PR *vs.* dentists	0.72	0.04	0.52	0.59
PR (per million population) *vs.* GSP per capita	0.41	0.32	0.17	0.15
(Excluding NSW) PR *vs.* population	0.91	0.004	0.83	0.73
(Excluding NSW) PR *vs.* dentists†	0.92	0.004	0.84	0.76
(Excluding NSW) PR (per million population) *vs.* GSP per capita	0.34	0.45	0.12	0.10
Cone beam computed tomography (CBCT)				
CBCT *vs.* population	0.54	0.17	0.29	0.42
CBCT *vs.* dentists	0.52	0.19	0.27	0.41
CBCT (per million population) *vs.* GSP per capita	0.60	0.12	0.35	0.16
(Excluding NSW & WA) CBCT *vs.* population‡	0.93	0.008	0.86	0.84
(Excluding NSW & WA) CBCT *vs.* dentists	0.93	0.008	0.86	0.85
(Excluding NSW & WA) CBCT (per million population) *vs.* GSP per capita	0.69	0.13	0.48	0.41

†The linear regression model determined here ($y = 11.638x + 33.803$) has been used as a predictor for the number of PR machines in NSW, where variable ‘x’ is per 100 dentists.

‡The linear regression model determined here ($y = 1.4666x + 1.804$) has been used as a predictor for the number of CBCT machines in NSW, where variable ‘x’ is per 100,000 population.

CBCT = cone beam computed tomography; GSP = gross state product; NSW = New South Wales; PR = panoramic radiography; r^2_e = coefficient of determination for exponential regression; r^2_L = coefficient of determination for linear regression

Using the best fitting regression models, the projected number of machines in NSW was approximately 618 for PR and 112 for CBCT. This equates to a total number of 2,054 PR and 328 CBCT machines nationally, using the projected NSW figures.

Exponential regressions were also made and tested. The coefficient of determination for the linear regressions (r^2_L) was slightly higher than the coefficient of determination for the exponential regressions (r^2_e) for both modalities in relation to the population size and the number of dentists, when 'outlier' states were excluded accordingly.

2.5 Discussion

In Australia, PR machines outnumbered CBCT machines by approximately 7.25 times for the year ending 2014. An Australian Dental Industry Association (ADIA) submission to the WA government in 2013 referred to industry reports that estimated the number of CBCT machines in Australia at that time to be approximately 420, with less than 1% located in WA.[121] A comparison with the findings in the current project suggests that the ADIA number was an overestimate, as 232 CBCT machines were recorded for 2014. Assuming that the credibility of the NSW data was questionable and when the predicted number of CBCT machines in NSW is accepted instead, the number of CBCT machines nationally would still be only 328.

Out of the Australian states and territories, QLD recorded the largest number of CBCT and PR machines (97 and 420, respectively) whereas NT recorded smallest number of CBCT and PR machines (three and 14, respectively). However, when adjusted for the population size and the number of dental practitioners, the results were more indicative of the true availability of these modalities.

2.5.1 Cone beam computed tomography

The highest accessibility to CBCT machines was found in the ACT with 31 CBCT machines for every million population and 42 machines for every 1,000 dentists. In contrast, the state with the largest population, NSW, had the lowest accessibility with only two CBCT machines available for every million population and three for every 1,000 dentists. It should be remembered that the data provided for NSW was not as comprehensive as the other states and territories. The number of machines recorded for NSW in the raw data is unlikely to represent the real scenario, considering there are no licensing limitations for EO X-ray machines in that state. A more reasonable projection of 112 CBCT machines was thus made for NSW using those numbers from the other states and territories, excluding WA.

Western Australia data was deemed an outlier due to the licensing regulations limiting the ownership and operation of CBCT machines to DMFRs and medical radiologists.[120] In late 2014, there were only two DMFRs practicing in WA and all CBCT machines in use were registered at medical radiology and radiography sites.[123] It is reasonable to assume that practitioners who can obtain licensing will more likely purchase machines, and so the number of CBCT machines in WA is highly indicative of the regulations. Ultimately, with the exclusion of NSW and WA data as outliers in the regression models, the coefficients of correlation turned out to be highly significant, highlighting that the adoption of CBCT machines appeared to be driven by both the population size and the number of dentists. Considering that CBCT machines are more expensive than PR machines to buy and to operate, it is reasonable to consider that more CBCT machines would be present in the states and territories with the highest gross earners. However, this assumption was not supported by the data, but verification of this assumption falls beyond the scope of this research project.

With insufficient data or information available at this stage, it is difficult to compare the adoption of CBCT machines in Australia with that overseas. It was reported that in 2012 there were 39 CBCT clinics registered in Norway[91] and Parashar *et al*.[9] reported the active use of CBCT in 50 US dental schools, 10 UK dental schools and one Australian dental school, with more schools preparing to acquire the technology. Inclusion of CBCT into undergraduate dental teaching reflects the popularity of this modality within the wider dental community.

2.5.2 Panoramic radiography

In 2005, ARPANSA released a Regulatory Impact Statement and draft Code of Practice/Safety Guide, in which an estimate of 1,120 PR machines used across Australia was made.[86] If this number was a feasible estimate, current data would suggest at least a 33% increase in the number of PR machines over the last decade.

From the data collected and collated, WA had the highest accessibility to PR machines relative to both the population size and the number of dental practitioners, with 143 machines per million population and 227 machines per 1,000 dentists. It is unknown whether the increased adoption of PR machines in WA is related to the lack of availability of CBCT machines. Similar to the trend viewed for CBCT machines, the accessibility to PR machines was the lowest in NSW, being only 32 machines per million population and 49 machines per 1,000 dentists. Again, there may be a discrepancy within the NSW dataset, as the projected number of PR machines in NSW was 618, which is 152% greater than the reported figure. Nevertheless, both the population size and the number of dental practitioners were found to be sound predictors of the adoption of PR machines across Australia.

Regarding PR services in Australia, 10.8 radiographs were taken by private dentists for every 1000 population in 1984, by estimation.[94] In 2005, ARPANSA estimated 0.5 million panoramic radiographs per year, based on “10/week/X-ray unit”.[86 (3)] Consequently, a calculated total of 1,681 PR machines for the year 2014 equates to 874,120 panoramic radiographs, approximating at 37 radiographs taken per 1,000 population (although the number of PR machines for NSW may be underscored). The rate of use provided by ARPANSA would appear to be a considerable underestimate for recent times, as PR services rebated through Medicare Australia already account for roughly 1 million radiographs per year.[5] A more realistic estimate of PR services for 2014 would have been higher if services in the private dental sector were also accounted for. Again, there is a lack of information available for comparing the number of PR services in Australia with that overseas. In 1998, Switzerland approximated 32.54 panoramic radiographs taken for every 1,000 population, the Netherlands 7.87 and the UK as high as 56.22.[96]

2.5.3 Upgradable panoramic radiography machines

Queensland had the largest number of PR machines upgradable to 3D capability based on the raw counts, but when based on percentage proportions, NT had the highest (29%). It is reasonable to assume that most upgradable PR machines were purchased with a view to their future use as CBCT machines.

2.5.4 Limitations or scopes for potential improvements

For the data collected in this research, events of inaccurately supplied information and/or incorrect registration of machines cannot be excluded. Additionally, it is not feasible to account for the exact location of X-ray machines within an individual state or territory, as the distribution varies across private dental practices, teaching institutions, radiology practices and hospitals. Nevertheless, the categorization of the EO X-ray machines (excluding NSW) is accurate to the best knowledge of the authors from information gathered in the published work[125] and from manufacturer descriptions at the time when this paper was prepared. The spread of PR and CBCT machines has only been assessed against the population size and number of dentists; it is critically noted that dentists are not the only health professionals who use these X-ray machines. Also, it is reasonable to assume that the population size and the number of dentists are not the only factors that will influence the number of EO X-ray machines. Other factors such as education and the popularity of implant dentistry will almost certainly play a significant role.

2.6 Conclusions

In Australia, PR machines outnumbered CBCT machines by 7.25 times in 2014 (assuming the NSW figures provided were accurate). Increases in either the population size or the number of dentists could positively impact on the adoption and/or use of PR and CBCT machines across states and territories. To a certain extent, the strict licensing regulations imposed in WA has restricted the adoption of CBCT machines in that state when compared with the other states and territories. The current project has attempted to establish a baseline for future relevant research. Aside from fee-based industry analyses, this project is the first of its kind to investigate the adoption of CBCT and PR machines in Australia.

2.7 Disclosure

Mr. Simon Critchley is the Director of the Radiation Health Unit, the radiation safety regulator in Queensland.

CHAPTER 3

Effects from changes to the Medicare Benefits Schedule in 2014 on cone beam computed tomography and panoramic radiography scans across Australia

A Zhang BDSc; * **LF Brown** BDSc, MDSc (Perio),* MPH, DClinDent (DMFR), PhD, MRACDS (Perio), FADI, FICD, FPFA; **PA Monsour** BDSc, PhD (Qld), MDSc (Qld), FICD.*

*School of Dentistry, The University of Queensland, Herston, Queensland, Australia.

Key words: CBCT; cone beam computed tomography, Medicare, Medicare Benefits Schedule, panoramic radiography.

Short title: Impact of MBS changes on CBCT and PR

Paper published in:

Journal of Medical Imaging and Radiation Oncology, 2017; [Epub ahead of print]

3.1 Abstract

Introduction: This study examines the effects of the new Medicare Benefits Schedule (MBS) operating from 1st November 2014 on the number of Medicare rebated panoramic radiography (PR) and cone beam computed tomography (CBCT) scans.

Methods: Data for rebated PR and CBCT scans were extracted from Medicare Australia Statistics online for four 12-month periods: November 2011–October 2012, November 2012–October 2013, November 2013–October 2014 and December 2014–November 2015.

Results: There was a reduction in the number of CBCT scans rebated across Australia under the new MBS. Nationally, December 2014–November 2015 showed a 65.3% reduction in the number of CBCT scans when compared to the peak in the previous 12 months under the old MBS. The number of rebated PR scans remained constant.

Conclusion: The new MBS implemented on 1st November 2014 resulted in a reduction in the number of rebated CBCT scans, but had no effect on rebated PR scans. Overall, there has been considerable cost savings for Medicare due to the change in MBS. Additionally, the reduction in the number of rebated CBCT scans has resulted in a substantial reduction in the ionising radiation load to the Australian community as a whole, but especially the younger age groups.

3.2 Introduction

In Australia, extraoral diagnostic imaging is provided by dental and radiology clinics, hospitals and teaching facilities. For those scans provided by radiology clinics and hospitals approved under the Diagnostic Imaging Accreditation Scheme (DIAS), Medicare Australia subsidises with a rebate for the cost of imaging for eligible patients.[40] To access rebatable radiography scans such as cone beam computed tomography (CBCT) and panoramic radiography (PR), a referral from a dental or medical practitioner registered with Medicare is required. In contrast, when these scans are obtained elsewhere, the cost of imaging may be covered under the public sector hospital funding, University teaching clinic funding or borne by the patient with or without a contribution from a private health fund.

Many fields of dentistry now incorporate CBCT into practice.[20] Rebates for CBCT scans were introduced into the Medicare Benefits Schedule (MBS) of Items on 1st July 2011, and referrals from all Australian registered medical practitioners and dentists (general and specialist) were able to attract Medicare rebates for patients attending accredited radiology practices.[126] However, new protocols were introduced on 1st November 2014 restricting CBCT rebates to those patients referred by medical practitioners and dental specialists, with additional scanning criteria stipulated.[40] The Medicare protocols relating to PR scans remained unchanged.

All rebated PR and CBCT scans are coded for the age of the machine that is used, where machines older than 10 years attract a reduced rebate from Medicare and is denoted by '(NK)' after the item code.[40] Regarding CBCT scans: item codes 56025/56026(NK) used for teeth and supporting bone structures were replaced with 57362/57363(NK) respectively,[40, 110, 126] and the new codes encompass "dental & temporo-mandibular joint imaging for diagnosis and management of mandibular and dentoalveolar fractures, dental implant planning, orthodontics, endodontic, periodontal and temporo-mandibular joint conditions: without contrast medium".[40 (101)]

Regarding PR scans, the item codes remained unchanged for the four categories surgical (SURG), general dental (DENT), orthodontic (ORTHO) and temporomandibular joint (TMJ).[40 (105-106)]

> 57959(NK)/57960: "Orthopantomography, for diagnosis and/or management of trauma, infection, tumours, congenital conditions or surgical conditions of the teeth or maxillofacial region" (SURG)

57962(NK)/57963: "Orthopantomography, for diagnosis and/or management of impacted teeth, caries, periodontal or periapical pathology where signs or symptoms of those conditions are evident" (DENT)

57965(NK)/57966: "Orthopantomography, for diagnosis and/or management of missing or crowded teeth, or developmental anomalies of the teeth or jaws" (ORTHO)

57968(NK)/57969: "Orthopantomography, for diagnosis and/or management of temporomandibular joint arthroses or dysfunction" (TMJ)

Brown and Monsour[5] assessed the number of rebated Medicare CBCT and PR scans prior to June 2014. They reported a 42.3% growth (per 100,000 population) in CBCT scans rebated from July 2011 to July 2014. The present study is a follow-up study to assess the effects of the MBS changes on Medicare rebate practices for PR and CBCT scans, with a focus on CBCT for the first 13 months following the introduction of the new MBS in Australia.

3.3 Materials and methods

Data on PR and CBCT scans and the Medicare financial outlay from these scans were obtained from Medicare Australia through its publicly accessible online statistics division.

The four 12-month periods chosen for assessment included 36 months under the old MBS and 12 months under the new MBS: November (Nov) 2011–October (Oct) 2012, Nov 2012–Oct 2013, Nov 2013–Oct 2014 and December (Dec) 2014–Nov 2015. The month of November in 2014 was excluded from the assessment as CBCT data pertaining to that month was incomplete.

For CBCT, MBS item codes 56025 and 56026 were analysed for Nov 2011–Oct 2014, and item codes 57362 and 57363 were analysed for Dec 2014–Nov 2015. For PR, MBS item codes 57959, 57960, 57962, 57963, 57965, 57966, 57968 and 57969 were analysed for Nov 2011–Nov 2015.

The number of CBCT and PR scans rebated and the Medicare benefits incurred nationally were recorded both as absolute counts and per 100,000 population. State and territory CBCT rebate analyses were also undertaken for New South Wales (NSW), Victoria (VIC), Queensland (QLD), South Australia (SA), Western Australia WA), Tasmania (TA), Australian Capital Territory (ACT) and Northern Territory (NT). The period Dec 2014–Nov 2015 was further analysed for age and gender prevalence relating to PR and CBCT scans.[127]

3.4 Results

3.4.1 CBCT items

There were 35,062 CBCT scans rebated nationally during Dec 2014–Nov 2015 under the new MBS (Table 3-1). Comparatively, a peak number of 101,059 CBCT scans were rebated during Nov 2013–Oct 2014 under the old MBS. Therefore, a 65.3% reduction in the national number of CBCT scans rebated (or a reduction of 65.9% per 100,000 population) over 12 months was demonstrated when comparing these two time periods. As a result, the total financial savings approximated $6.9 million (or approximately $29,225 per 100,000 population).

On average, the number of CBCT scans rebated nationally across the 3 years Nov 2011–Oct 2014 under the old MBS was 82,179±16,857 (standing for mean ± SD) for a given 12-month period. Compared to Dec 2014–Nov 2015 (new MBS), this showed an average reduction of 57.3% in the national number of CBCT scans rebated (or 58.7% per 100,000 population). The average financial savings across any 12-month period was $4.9 million (or $21,568 per 100,000 population).

Prior to Nov 2014, the absolute number of CBCT scans rebated under the old MBS peaked at 40,440 in NSW; 35,826 in VIC; 9,588 in QLD; 4,605 in SA; 7,516 in WA; 1,794 in TAS; 1,338 in ACT and 2,117 in NT (Figure 3-1). Fifty per cent of these peaks occurred during Nov 2013–Oct 2014, the year prior to the change in MBS. After introduction of the new MBS, every Australian state and territory showed a reduction in the number of CBCT scans rebated. When population was accounted for, the overall trend was similar to that demonstrated by the absolute counts (Figure 3-2).

Table 3-1. The number of rebated Medicare CBCT and PR scans and the MBS financial outlay over four 12-month periods

Time Period	Total scans rebated	Scans rebated per 100,000 population	Total Medicare benefits	Medicare benefits per 100,000 population
CBCT				
Nov 2011–Oct 2012	68,637	299	$7,239,740	$31,588
Nov 2012–Oct 2013	76,842	329	$8,073,641	$34,563
Nov 2013–Oct 2014	101,059	425	$10,588,439	$44,561
Dec 2014–Nov 2015	35,062	145	$3,706,291	$15,336
PR				
Nov 2011–Oct 2012	978,661	4,270	$43,113,376	$188,103
Nov 2012–Oct 2013	936,061	4,007	$41,181,124	$176,293
Nov 2013–Oct 2014	977,663	4,114	$42,974,441	$180,850
Dec 2014–Nov 2015	944,516	3,908	$41,545,704	$171,870

Rebated CBCT scans during Dec 2014–Nov 2015 (new MBS) were further differentiated on the basis of patient age and gender (Table 3-2). Females received on average 46 more CBCT scans per 100,000 population than males. The rate of scans provided was the highest for females aged 15–24 years old, followed by females aged 55–64 years old, and then females aged 45–54 years old. Between the ages of 5–74 years, females were more likely to obtain CBCT scans than males. The average rate of services for a 12-month period across the three years Nov 2011–Oct 2014 (old MBS) was 397 scans per 100,000 female population and 307 scans per 100,000 male population. Comparatively, Dec 2014–Nov 2015 showed a 57.7% and 60.3% reduction in the rate of rebated CBCT scans performed (per 100,000 population) for females and males respectively. A reduction in the rate of rebated CBCT scans was noted across all age groups between the old and new MBS.

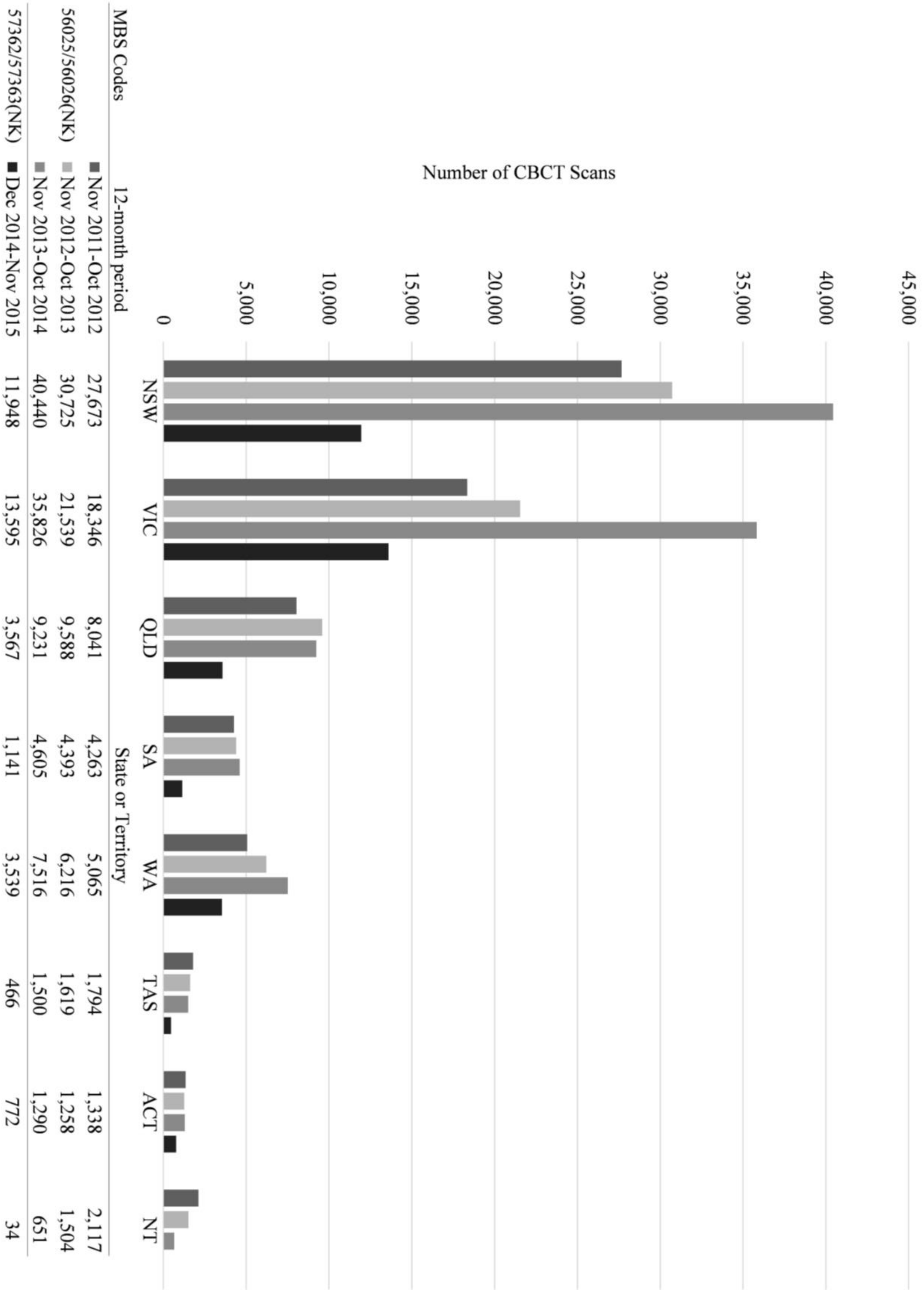


Figure 3-1. The number of CBCT scans rebated by state and territory over four 12-month periods under the relevant MBS CBCT codes.

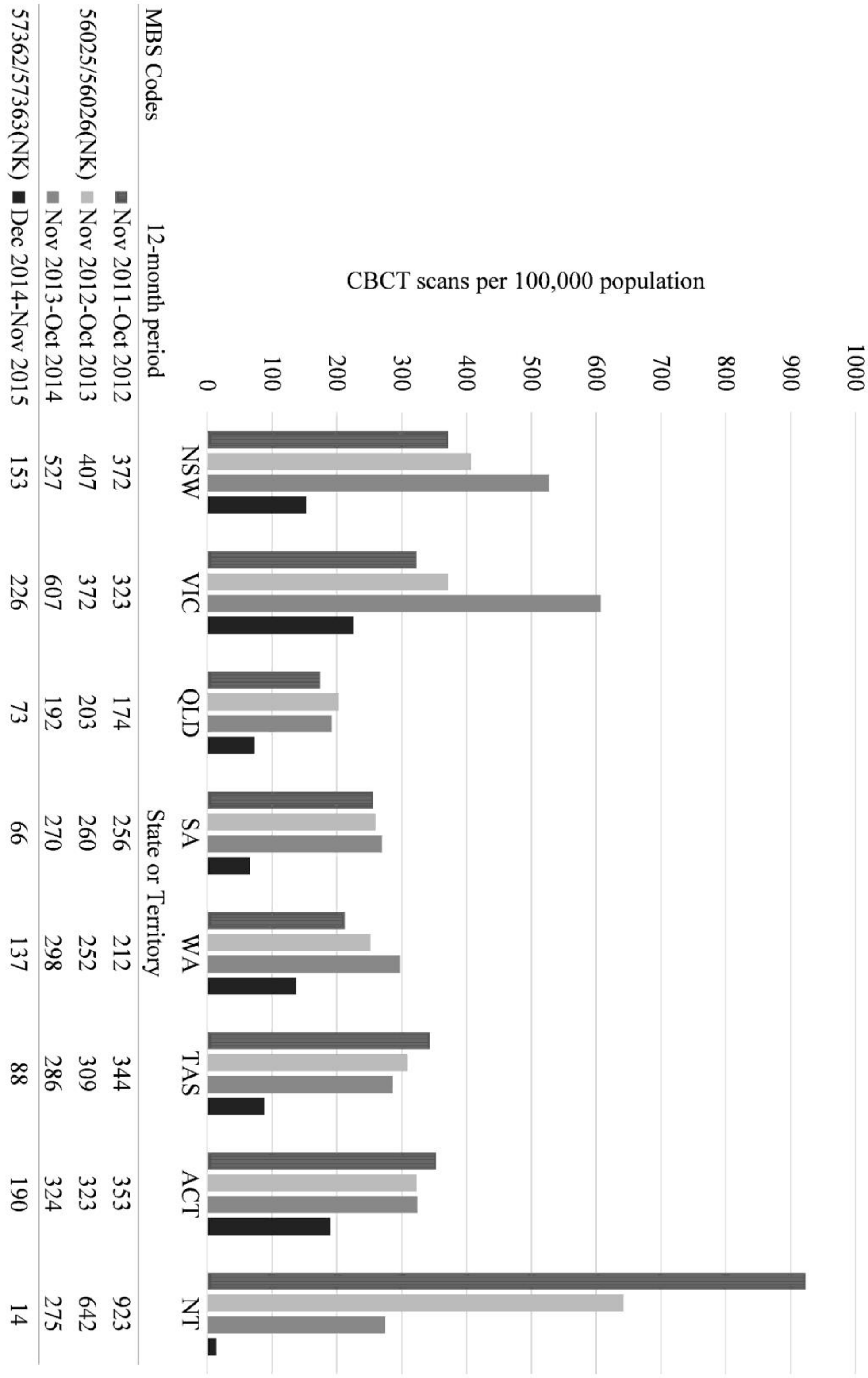


Figure 3-2. The number of CBCT scans rebated per 100,000 population by state and territory over four 12-month periods under the relevant MBS CBCT codes.

Table 3-2. The number of rebated CBCT and PR scans related to patient age and gender for the period Dec 2014–Nov 2015

Age (years old)	Total CBCT scans		CBCT scans per 100,000 population		Total PR scans		PR scans per 100,000 population	
	Male	Female	Male	Female	Male	Female	Male	Female
0–4	9	3	1	0	1,108	999	140	132
5–14	2,350	3,107	151	211	81,565	95,295	5,245	6,462
15–24	2,532	3,587	165	243	82,207	116,123	5,352	7,876
25–34	1,283	2,227	75	128	51,965	70,435	3,024	4,057
35–44	1,399	1,998	82	117	45,486	55,608	2,654	3,258
45–54	1,837	2,870	112	176	49,302	59,211	3,018	3,629
55–64	2,376	3,462	170	243	48,873	58,158	3,511	4,082
65–74	2,057	2,420	203	233	38,786	41,836	3,826	4,026
75–84	720	632	141	106	19,101	19,148	3,753	3,225
≥85	98	95	55	31	4,458	4,852	2,498	1,593
All ages	14,661	20,401	122	168	422,851	521,665	3,512	4,299

3.4.2 PR items

Across the four 12-month periods assessed, there was low variation in the national number of PR scans with a mean and SD of 959,225±22,141 for absolute counts and 4,075±155 per 100,000 population (Table 3-1).

When assessed on a categorical basis, low variation was demonstrated across all four PR categories for the four 12-month periods (Table 3-3). For both absolute counts and when adjusted for population, most PR scans rebated nationally were under the category of DENT, followed by ORTHO, SURG and TMJ.

During Dec 2014–Nov 2015 (new MBS), females received on average 787 more PR scans per 100,000 population than males (Table 3-2). The rate of scans provided was clearly highest for females aged 15–24 years old, followed by 5–14 years old. Between the ages of 5–74 years, females were also more likely to obtain PR scans than males.

Table 3-3. The number of PR scans rebated nationally over four 12-month periods under the relevant MBS PR codes

Codes	Time period	Total PR scans	PR scans per 100,000 population
SURG:	Nov 2011–Oct 2012	72,175	315
57959(NK)/57960	Nov 2012–Oct 2013	70,175	300
	Nov 2013–Oct 2014	73,547	310
	Dec 2014–Nov 2015	71,524	296
DENT:	Nov 2011–Oct 2012	723,442	3,156
57962(NK)/57963	Nov 2012–Oct 2013	688,813	2,949
	Nov 2013–Oct 2014	723,652	3,045
	Dec 2014–Nov 2015	692,181	2,864
ORTHO:	Nov 2011–Oct 2012	177,504	775
57965(NK)/57966	Nov 2012–Oct 2013	172,080	737
	Nov 2013–Oct 2014	174,962	736
	Dec 2014–Nov 2015	174,771	723
TMJ:	Nov 2011–Oct 2012	5,540	24
57968(NK)/57969	Nov 2012–Oct 2013	4,993	21
	Nov 2013–Oct 2014	5,502	23
	Dec 2014–Nov 2015	6,040	25

3.5 Discussion

The findings demonstrate a decline in the number of Medicare-funded CBCT scans across Australia and significant cost savings achieved by Medicare.

The adoption of CBCT by the Australian dental profession has been rapid and widespread since local commercial introduction of CBCT machines in 2006.[8] From 2006 to 2011, a range of existing MBS items were claimed for CBCT services in the absence of specific CBCT item numbers. These included item numbers for tomography (MBS item 60100) in combination with X-ray items for the head and face (MBS items 57901–57945) and PR items (57960–57969).[128] As these items were not specific to CBCT imaging, it was not possible to track the growth of CBCT and the costs reimbursed to the public through Medicare for these services. In July 2011, interim MBS item numbers specific to CBCT (MBS items 56025 and 56026) were introduced and in the subsequent three years, the observable increase in uptake of these new CBCT item numbers outstripped the predicted growth.[5, 8, 109]

As a publicly funded scheme, Medicare Australia regularly reviews those items funded under the MBS scheme. The Medical Services Advisory Committee (MSAC) reviewed the MBS in November 2013 and April 2014, consulting with a number of organisations including the Australian and New Zealand Association of Oral and Maxillofacial Surgeons and the Royal Australian and New Zealand College of Radiologists. MSAC listed the following concerns about Medicare-funded CBCTservices.[8, 108-110]

1. Up until 1st Nov 2014, although CBCT could be requested by any dental practitioner, registered dentists[a] composed the majority of the referral base. Concerns were also raised regarding potential self-referral by general dentists, without direct radiologist involvement and at the patient's expense. MSAC therefore proposed similar restrictions for CBCT as those already applied to medical CT items; being restricted to requests from dental specialists and medical practitioners.
2. The rapid growth of Medicare-funded CBCT services, particularly among the younger population (where 25% of scans were performed in patients under 24 years old), was a notable concern.
3. MSAC observed a significant percentage of co-claiming between CBCT and PR or another CBCT during the same episode of service. Subsequently, questions were raised regarding the appropriate use of ionising radiation and financial expenditure of this observed pattern of services and MSAC moved to prohibit this way of co-claiming.
4. MSAC indicated the use of hybrid CBCT machines was a cause for multiple CBCT claims at one session, as these machines are more likely to have a fixed or a narrow field-of-view (FOV) that may be insufficient for scans where a large FOV is more suitable.
5. MSAC were in receipt of anecdotal evidence that manufacturers were providing inexpensive CBCT machines to dental practices at no cost in return for a portion of the generated income, raising concerns about lack of discrimination in case selection and potential over-servicing. MSAC sought advice from the Australian Radiation Protection and Nuclear Safety Agency and recommended that all MBS-eligible CBCT sites must participate in the DIAS.

As a result of these concerns, and "to encourage the judicious use of CBCT in order to optimise the safety and quality of services",[110] the following changes were introduced from 1st November 2014, along with changed item numbers (discontinuation of MBS items 56025 and 56026, following the introduction of MBS items 57362 and 57363).[8, 40, 110, 129]

1. Co-claims for more than one CBCT per day are excluded,
2. Co-claims with two-dimensional imaging in the same attendance are excluded,
3. Co-claims with a medical CT in the same attendance are excluded,
4. Services must be performed on dedicated CBCT machines that are not used to perform any other diagnostic imaging service,
5. Services must be delivered in practices accredited under the DIAS, and
6. CBCT scans can only be requested by specialist dentists or medical practitioners. Dental specialists from the following disciplines are recognised: prosthodontics, oral and maxillofacial surgery, periodontics, endodontics, paedodontics, orthodontics, oral medicine and oral pathology. The specialist disciplines of oral surgery, dento-maxillofacial radiology, community dentistry, special needs dentistry and forensic odontology are not recognised under the *Health Insurance Regulations 1975 (Cth)*.[130]

The revision of the MBS in 2014 has certainly contributed to a reduction in the provision of Medicare-funded CBCT services. The reduction in the number of CBCT scans rebated was apparent for Dec 2014–Nov 2015 across all Australian states and Territories when compared to previous years. Nationally, Dec 2014–Nov 2015 showed a 65.3% reduction in CBCT scans when compared to a peak in the previous 12-months under the old MBS (Nov 2013–Oct 2014). Correspondingly, the national reduction in the Medicare CBCT financial outlay was almost $6.9 million for these two time periods. Medical Services Advisory Committee stated that limiting co-claiming of CBCT and two-dimensional imaging would both control the Medicare financial expenditure and reduce patient exposure to ionising radiation, particularly among the younger population. The effective radiation dose from PR examinations range from 9 to 24 µSv and CBCT examinations range from 19 to 1,073 µSv depending on a number of factors including the resolution and FOV required.[58] A preliminary PR (without dual CBCT referral) does help to protect the patient in some circumstances, as when given due consideration, the clinician may determine that a CBCT is not required after viewing the PR. There were significant reductions in the overall rate of rebated CBCT scans performed across age and gender groups between the old and new MBS, although very little change was noted in the distribution of CBCT services. Under the new MBS, 39% more CBCT scans were recorded for females than for males, with the highest peak shown in the 15–24 year olds. Similar age and gender discrepancies have been reported previously with the suggestion that this disparity could be due to a greater demand for orthodontic treatment by young people and by females in particular.[5, 26]

Medical Services Advisory Committee was also concerned about CBCT over-servicing to the public.[8, 109] The scope of practice of general dentists across the field of dentistry is broad[131] and many general dentists manage complex treatments like dental implant surgery, extraction of teeth, acute trauma, orthodontics and other clinical procedures that would justify the need for CBCT imaging. Most often, it is after the assessment of conventional two-dimensional radiographs that the necessity of a CBCT referral is determined. Medicare data showed little variation in the number of PR scans rebated before and after implementation of the new MBS. So the question arises, does the Medicare reduction in the number of CBCT scans rebated after 1st November 2014 reflect a true decline in overall CBCT services? It is important to note that non-rebatable CBCT scans are not recorded in the Medicare data and it is not within the scope of this study to speculate on the number of CBCT scans taken privately.

In 2014, there were at least 1,681 PR and 232 CBCT machines in Australia.[132] When PR machines first became available, general dentists referred patients to medical radiology practices to obtain radiographs. Over time, the affordability of PR machines, the productivity gains and minimising lost referral income were positive incentives for general dentists to put PR machines into their practices. With the cost of CBCT machines also falling,[53] similar incentives for owning CBCT machines would exist.

A major benefit in having diagnostic imaging performed at DIAS-accredited radiology practices is that every CBCT scan is reported on by a radiologist. General dentists are not trained to interpret non-dental areas shown on larger FOV CBCT scans and scans undertaken privately by general dentists are unlikely to be routinely interpreted by a radiologist and this removes the safety net of additional expertise.[52, 53]

There are some additional points to consider regarding the MBS CBCT restrictions. General dental practices with rebatable CBCT machines relying on access to Medicare via teleradiology services prior to 1st November 2014 are now unable to provide Medicare-funded in-house CBCT scans for patients.[129] Also, rebates cannot be obtained for scans performed on hybrid CBCT machines, which means radiology practices that had previously purchased expensive hybrid machines for the dual purpose of taking PR as well as CBCT scans, would have to acquire an additional non-hybrid CBCT machine.

As part of the MBS CBCT reforms, concerns have been raised regarding whether more suitable MBS codes should have been developed to reflect the different indications and FOV for

CBCT scans.[109] This was addressed in the latest version of The Australian Schedule of Dental Services and Glossary for private billing, and it may be beneficial for Medicare to model those changes.[131] Consideration could be given to having Medicare rebatable item numbers for general dentists when a small FOV scan is required.

Given the numerous changes introduced in 2014, it is difficult to attribute the rapid fall in the number of Medicare-funded CBCT services during the subsequent 12-month period to one particular intervention. Also, it is difficult to determine whether the reduction in CBCT services is as substantial as the data suggest. Definitely, restricting the payment of rebates to those CBCT items referred by specialist dentists would be expected to have a notable impact. However, general dentists may still refer patients for CBCT services at practices accredited under the DIAS, although that service would not be funded by Medicare. As such, these scans are not captured by the Medicare data. Private health insurance may cover a part of those costs, contingent on the level of cover. Alternatively, general dentists may elect to refer patients to their medical general practitioner (GP), who can then provide a referral for a Medicare rebatable CBCT service. Aside from being an inconvenience to most patients, there will be an additional cost to Medicare for the consultation with the medical GP and possibly some out of pocket cost to the patient.

There are limitations with the Medicare data sourced. The authenticity of the data extracted from Medicare Online Statistics cannot be fully accounted for or verified, if and when there were discrepancies or delays in processing of claims. Medicare Online also state that statistics "do not include scans provided by hospital doctors to public patients in public hospitals or scans that qualify for a benefit under the Department of Veterans' Affairs National Treatment Account".[127]

3.6 Conclusions

The reduction in the number of Medicare-funded CBCT scans recorded after 1st November 2014 has resulted in considerable cost savings for Medicare. The results also suggest a substantial reduction in the ionizing radiation load to the Australian community as a whole, but especially the younger age group. Numerous MBS CBCT limitations were implemented to bring about this rapid reduction; some not without controversy. The Medicare data may not truly reflect overall CBCT services at DIAS-accredited radiology practices as non-rebatable scans have not been captured.

3.7 Footnote

[a] It is assumed that by registered dentists, MSAC was referring to registered general dentists.

THESIS SUMMARY

Extraoral diagnostic radiography is an essential part of clinical dentistry. Panoramic radiography (PR) is the mainstay of 2D extraoral (EO) imaging and cone beam computed tomography (CBCT) is now becoming widely adopted for 3D EO imaging. In the first chapter of this thesis, the literature review examined the context of CBCT and PR modalities and imaging in current clinical dentistry. The first section of the chapter addressed the general differences in modality hardware, the diagnostic uses, and the medical and legal ramifications of ionising radiation. The second section of the chapter provided summaries on legislations and regulations for operation of CBCT and PR machines across Australian jurisdictions, and reviewed the current adoption and usage rate of these imaging modalities in Australia and overseas.

The number of CBCT and PR machines across Australia for the year 2014 was collated and reviewed in Chapter 2. Results showed that there were seven times more PR machines than CBCT machines in Australia and that increases in either the population size or the number of dentists could contribute to a positive growth in the adoption of these modalities. The use-licensing regulations set out by each Radiation Regulator was shown to have some influences on the adoption of CBCT and PR machines across Australian states and territories. This was most notable in Western Australia, where adoption of CBCT machines was particularly restricted. The published paper reproduced in Chapter 2 will establish a baseline data and continuation of this research project would be of value in mapping the change in adoption of EO imaging modalities across Australia.

The number of Medicare rebated PR and CBCT scans for four 12-month periods between November 2011–November 2015 was extracted from Medicare Australia Statistic online and analysed in Chapter 3. The published paper reproduced in this chapter also examined and discussed the underlying rationales imposed for restricting access to rebates for CBCT scans in the 2014 Medicare Benefits Schedule (MBS). Although some of these rationales were controversial, they were effective in bringing about considerable cost savings for Medicare post-2014. The new 2014 MBS did not have any notable influence on the number of rebated PR scans compared with those in previous years, however as hypothesised, a reduction in the number of rebated CBCT scans was noted. It was inferred that a reduction in the number of rebated CBCT scans benefitted the Australian community by reducing the overall ionising radiation load. Follow-up studies are recommended to assess the projected trends in Medicare rebated CBCT and PR scans.

REFERENCES

1. Pauwels R, Jacobs R, Bosmans H, Schulze R. Future prospects for dental cone beam CT imaging. Imaging in Medicine 2012;4:551.
2. Buzug TM. Computed Tomography: From Photon Statistics to Modern Cone-Beam CT: Springer Berlin Heidelberg, 2008.
3. White SC, Pharoah MJ. The evolution and application of dental maxillofacial imaging modalities. Dent Clin North Am 2008;52:689-705, v.
4. Rushton VE, Horner K. The use of panoramic radiology in dental practice. Journal of dentistry 1996;24:185-201.
5. Brown LF, Monsour P. The growth of Medicare rebatable cone beam CT and panoramic radiography in Australia. Aust Dent J 2015;60:511-519.
6. Vandenberghe B, Jacobs R, Bosmans H. Modern dental imaging: a review of the current technology and clinical applications in dental practice. Eur Radiol 2010;20:2637-2655.
7. Suomalainen A, Ventä I, Mattila M, Turtola L, Vehmas T, Peltola JS. Reliability of CBCT and other radiographic methods in preoperative evaluation of lower third molars. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology 2010;109:276-284.
8. Seil E, Jack B. Cone beam computed tomography (CBCT) for dental imaging. MSAC Reference 43, Assessment Report. Commonwealth of Australia. URL: 'http://www.msac.gov.au/internet/msac/publishing.nsf/Content/631DBB5FD5F3D282CA25778100 1F30A2/$File/Ref43-DentalCBCT-FinalContractedAssessmentReport%20(D14-1143554).pdf'. Accessed December 2015.
9. Parashar V, Whaites E, Monsour P, Chaudhry J, Geist JR. Cone beam computed tomography in dental education: A survey of U.S., U.K., and Australian dental schools. Journal of dental education 2012;76:1443-1447.
10. Dalrymple NC, Prasad SR, El-Merhi FM, Chintapalli KN. Price of isotropy in multidetector CT. Radiographics 2007;27:49-62.
11. Mozzo P, Procacci C, Tacconi A, Martini PT, Andreis IA. A new volumetric CT machine for dental imaging based on the cone-beam technique: preliminary results. Eur Radiol 1998;8:1558-1564.
12. Arai Y, Tammisalo E, Iwai K, Hashimoto K, Shinoda K. Development of a compact computed tomographic apparatus for dental use. Dentomaxillofac Radiol 1999;28:245-248.
13. Scarfe WC, Levin MD, Gane D, Farman AG. Use of Cone Beam Computed Tomography in Endodontics. International Journal of Dentistry 2009;2009:1-20.

14. Warhekar S, Nagarajappa S, Dasar PL, et al. Incidental findings on cone beam computed tomography and reasons for referral by dental practitioners in indore city (m.p). J Clin Diagn Res 2015;9:ZC21-ZC24.

15. Samara ET, Aroua A, Bochud FO, et al. Exposure of the Swiss population by Medical X-rays: 2008 Review. Health Phys 2012;102:263-270.

16. Scarfe WC, Farman AG. What is Cone-Beam CT and How Does it Work?. Dent Clin North Am 2008;52:707-730.

17. White SC. Cone-beam imaging in dentistry. Health Phys 2008;95:628-637.

18. Baba R, Ueda K, Okabe M. Using a flat-panel detector in high resolution cone beam CT for dental imaging. Dentomaxillofac Radiol 2004;33:285-290.

19. Loubele M, Maes F, Jacobs R, van Steenberghe D, White SC, Suetens P. Comparative study of image quality for MSCT and CBCT scanners for dentomaxillofacial radiology applications. Radiat Prot Dosimetry 2008;129:222-226.

20. De Vos W, Casselman J, Swennen GR. Cone-beam computerized tomography (CBCT) imaging of the oral and maxillofacial region: a systematic review of the literature. Int J Oral Maxillofac Surg 2009;38:609-625.

21. The SEDENTEXCT project. Radiation protection no. 172: cone beam CT for dental and maxillofacial radiology evidence based guidelines. European Commission. URL: 'http://www.sedentexct.eu/files/radiation_protection_172.pdf'. Accessed May 2017.

22. Brown J, Jacobs R, Levring Jäghagen E, et al. Basic training requirements for the use of dental CBCT by dentists: a position paper prepared by the European Academy of DentoMaxilloFacial Radiology. Dentomaxillofac Radiol 2014;43:20130291.

23. Tyndall DA, Price JB, Tetradis S, et al. Position statement of the American Academy of Oral and Maxillofacial Radiology on selection criteria for the use of radiology in dental implantology with emphasis on cone beam computed tomography. Oral surgery, oral medicine, oral pathology and oral radiology 2012;113:817-826.

24. Smith BR, Park JH, Cederberg RA. An evaluation of cone-beam computed tomography use in postgraduate orthodontic programs in the United States and Canada. Journal of dental education 2011;75:98.

25. van Vlijmen OJ, Kuijpers MA, Bergé SJ, et al. Evidence supporting the use of cone-beam computed tomography in orthodontics. J Am Dent Assoc 2012;143:241-252.

26. Hidalgo-Rivas JA, Theodorakou C, Carmichael F, Murray B, Payne M, Horner K. Use of cone beam CT in children and young people in three United Kingdom dental hospitals. Int J Paediatr Dent 2014;24:336-348.

27. Hilgers ML, Scarfe WC, Scheetz JP, Farman AG. Accuracy of linear temporomandibular joint measurements with cone beam computed tomography and digital cephalometric radiography. Am J Orthod Dentofacial Orthop 2005;128:803-811.

28. Use of cone-beam computed tomography in endodontics Joint Position Statement of the American Association of Endodontists and the American Academy of Oral and Maxillofacial Radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011;111(2):234-237.

29. Fayad MI, Nair M, Levin MD, et al. AAE and AAOMR Joint Position Statement: Use of Cone Beam Computed Tomography in Endodontics 2015 Update: Use of Cone Beam Computed Tomography in Endodontics 2015 Update. Oral Surg Oral Med Oral Pathol Oral Radiol 2015;120:508-512.

30. Ghaeminia H, Meijer GJ, Soehardi A, et al. The use of cone beam CT for the removal of wisdom teeth changes the surgical approach compared with panoramic radiography: a pilot study. Int J Oral Maxillofac Surg 2011;40:834-839.

31. Matzen LH, Christensen J, Hintze H, Schou S, Wenzel A. Influence of cone beam CT on treatment plan before surgical intervention of mandibular third molars and impact of radiographic factors on deciding on coronectomy vs surgical removal. Dentomaxillofac Radiol 2013;42:98870341.

32. Tantanapornkul W, Okouchi K, Fujiwara Y, et al. A comparative study of cone-beam computed tomography and conventional panoramic radiography in assessing the topographic relationship between the mandibular canal and impacted third molars. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontology 2007;103:253-259.

33. Ghaeminia H, Meijer GJ, Soehardi A, Borstlap WA, Mulder J, Bergé SJ. Position of the impacted third molar in relation to the mandibular canal. Diagnostic accuracy of cone beam computed tomography compared with panoramic radiography. Int J Oral Maxillofac Surg 2009;38:964-971.

34. Guerrero ME, Botetano R, Beltran J, Horner K, Jacobs R. Can preoperative imaging help to predict postoperative outcome after wisdom tooth removal? A randomized controlled trial using panoramic radiography versus cone-beam CT. Clin Oral Investig 2014;18:335-342.

35. Linz C, Müller-Richter UDA, Buck AK, et al. Performance of cone beam computed tomography in comparison to conventional imaging techniques for the detection of bone invasion in oral cancer. Int J Oral Maxillofac Surg 2015;44:8-15.

36. Barghan S, Merrill R, Tetradis S. Cone beam computed tomography imaging in the evaluation of the temporomandibular joint. J Calif Dent Assoc 2010;38:33-39.

37. Honey OB, Scarfe WC, Hilgers MJ, et al. Accuracy of cone-beam computed tomography imaging of the temporomandibular joint: comparisons with panoramic radiology and linear tomography. Am J Orthod Dentofacial Orthop 2007;132:429-438.

38. Petersen LB, Olsen KR, Christensen J, Wenzel A. Image and surgery-related costs comparing cone beam CT and panoramic imaging before removal of impacted mandibular third molars. Dentomaxillofacial Radiology 2014;43:20140001.

39. Christell H, Birch S, Horner K, Rohlin M, Lindh C, SEDENTEXCT consortium. A framework for costing diagnostic methods in oral health care: An application comparing a new imaging technology with the conventional approach for maxillary canines with eruption disturbances. Community Dent Oral Epidemiol 2012;40:351-361.

40. Australian Government Department of Health. Medicare Benefits Schedule Book-Category 5. Operating from 01 July 2015. The Department of Health. URL: 'http://www.mbsonline.gov.au/internet/mbsonline/publishing.nsf/Content/9B067E48C350D16BCA257DAA007C462D/$File/201501-Cat5.pdf'. Accessed August 2015.

41. ACT Health: Radiation Safety. Prerequisites for Radiation Licences: Dental. ACT Government. URL: 'http://www.health.act.gov.au/public-information/businesses/radiation-safety/licences-prerequisites'. Accessed July 2017.

42. Department of Health and Human Services. Form RPA0001-Individual: APPLICATION FOR LICENCE TO DEAL WITH RADIATION APPARATUS – IONISING. Tasmanian Government. URL: 'http://www.dhhs.tas.gov.au/__data/assets/pdf_file/0012/53040/RPA0001_individual.pdf'. Accessed July 2017.

43. Northern Territory Government Environmental Health Branch. Radiation licences for medical and dental practitioners. NT Gov. URL: 'https://nt.gov.au/industry/licences/radiation-licences-for-medical-and-dental-practitioners/dental-practitioners'. Accessed July 2017.

44. NSW Environment Protection Authority. Radiation user licence - criteria: Dental. NSW Environment Protection Authority. URL: 'http://www.epa.nsw.gov.au/radiation/licensing/licensingcriteria.htm#dental'. Accessed July 2017.

45. Queensland Radiation Health. Form 2 - Application for a Licence to Use Radiation Apparatus. Queensland Government Radiation Health. URL: 'http://www.health.qld.gov.au/radiationhealth/documents/app-use.pdf'. Accessed July 2017.

46. Queensland Radiation Health. Form 6 - Application for a Licence to Use Radiation Apparatus for Dental Purposes - FAST TRACK. Queensland Government Radiation Health. URL: 'http://www.health.qld.gov.au/radiationhealth/documents/app-use-ra-dental.pdf'. Accessed July 2017.

47. South Australia Environment Protection Authority. Licence prerequisites for operators of diagnostic X-ray apparatus. EPA South Australia. URL:

'http://www.epa.sa.gov.au/business_and_industry/radiation/operators_of_radiation_apparatus'. Accessed July 2017.

48. Department of Health & Human Services. What do I need to include with my application for a licence - use? State Government of Victoria. URL: 'https://www2.health.vic.gov.au/Api/downloadmedia/%7B14FDA6D6-AE8F-410D-87F1-582F3375ADF2%7D'. Accessed July 2017.

49. Western Australia Radiological Council. Dentists: Licensing for X-ray Equipment. Government of Western Australia. URL: 'http://www.radiologicalcouncil.wa.gov.au/Pages/FAQ/Dentists.html'. Accessed July 2017.

50. Queensland Radiation Health. Information about Applying for a Licence to Use Radiation Apparatus for Dental Purposes. Queensland Government Radiation Health. URL: 'https://www.health.qld.gov.au/__data/assets/pdf_file/0028/156169/infoshtusedental.pdf'. Accessed July 2017.

51. Australian Dental Association Queensland. Cone Beam Pre-Licensing Course ADA QLD. URL: 'https://ada-qld.worldsecuresystems.com/adaq-online-events/cone-beam-pre-licensing-course-08-july'. Accessed May 2017.

52. Wright B. Contemporary medico-legal dental radiology. Aust Dent J 2012;57:9-15.

53. Scarfe W, Farman A. Clinical Applications of Cone-Beam Computed Tomography in Dental Practice. J Can Dent Assoc 2006;72:75-80.

54. Australian Radiation Protection and Nuclear Safety Agency. ARPANSA Fact Sheet-Ionising Radiation and Heath. Yallambie, Victoria: ARPANSA, 2015. URL: ''http://www.arpansa.gov.au/pubs/factsheets/IonisingRadiationandHealth.pdf''. Accessed October 2015.

55. Australian Radiation Protection and Nuclear Safety Agency. Recommendations for Limiting Exposure to Ionizing Radiation (1995) (Guidance Note [NOHSC:3022(1995)]) and National Standard for Limiting Occupational Exposure to Ionizing Radiation [NOHSC:1013(1995)]. ARPANSA. URL: 'http://www.arpansa.gov.au/pubs/rps/rps1.pdf'. Accessed October 2015.

56. Australian Radiation Protection Nuclear Safety Agency. Code of practice & safety guide: radiation protection in dentistry. Canberra: Australian Radiation Protection and Nuclear Safety Agency, 2005.

57. The use of cone-beam computed tomography in dentistry: an advisory statement from the American Dental Association Council on Scientific Affairs. J Am Dent Assoc 2012;143:899-902.

58. White SC, Pharoah MJ, (eds). Oral Radiology: Principles and Interpretation. 7th edn. St. Louis, Mo.: Mosby; 2014. p. 32.

59. Loubele M, Bogaerts R, Van Dijck E, et al. Comparison between effective radiation dose of CBCT and MSCT scanners for dentomaxillofacial applications. Eur J Radiol 2009;71:461-468.
60. Badenoch-Jones E, White BP, Lynham A. The Australian Litigation Landscape - Oral and Maxillofacial Surgery and General Dentistry (Oral Surgery procedures): An Analysis of Litigation Cases. Aust Dent J 2015.
61. White SC, Mallya SM. Update on the biological effects of ionizing radiation, relative dose factors and radiation hygiene. Aust Dent J 2012;57 Suppl 1:2-8.
62. Memon A, Godward S, Williams D, Siddique I, Al-Saleh K. Dental x-rays and the risk of thyroid cancer: a case-control study. Acta Oncol 2010;49:447-453.
63. Wu TH, Lin WC, Chen WK, Chang YC, Hwang JJ. Predicting Cancer Risks from Dental Computed Tomography. J Dent Res 2015;94:27-35.
64. Balonov MI, Shrimpton PC. Effective dose and risks from medical X-ray procedures. Ann ICRP 2012;41:129-141.
65. Claus EB, Calvocoressi L, Bondy ML, Schildkraut JM, Wiemels JL, Wrensch M. Dental x-rays and risk of meningioma. Cancer 2012;118:4530-4537.
66. Sewell J, Drage N, Brown J. The use of panoramic radiography in a dental accident and emergency department. Dento-maxillo-facial radiology 2001;30:260-263.
67. HPA Working Party on Dental Cone Beam CT Equipment. Guidance on the Safe Use of Dental Cone Beam CT (Computed Tomography) Equipment. Health Protection Agency; Centre for Radiation, Chemical and Environmental Hazards. URL: 'https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/340159/HPA-CRCE-010_for_website.pdf'. Accessed May 2017.
68. Dula K, Bornstein MM, Buser D, et al. SADMFR guidelines for the use of Cone-Beam Computed Tomography/ Digital Volume Tomography. Swiss Dent J 2014;124:1169-1183.
69. BCCDC/EHS. Guidelines on Radiation Protection & Quality Assurance Applicable to Dental Cone Beam Computed Tomography (CBCT). Environmental Health Services. URL: 'http://www.bccdc.ca/resource-gallery/Documents/Guidelines%20and%20Forms/Guidelines%20and%20Manuals/EH/RPS/DentalCBCTRPGuidelines.pdf'. Accessed May 2017.
70. Noffke CE, Farman AG, Nel S, Nzima N. Guidelines for the safe use of dental and maxillofacial CBCT: a review with recommendations for South Africa. SADJ 2011;66:262, 264-266.
71. Noffke CE, Farman AG, Van der Linde A, Nel S. Responsible use of cone beam computed tomography: minimising medico-legal risks. SADJ 2013;68:258-259.

72. Maurice Blackburn. Medical negligence. Maurice Blackburn. URL: 'http://www.mauriceblackburn.com.au/queensland/medical-negligence'. Accessed September 2015.

73. *Delphin v Martin* [2012] TASSC 13.

74. *Jung v Son* [1998] NSWSC 698.

75. Fontana MP, Liedke GS, Fontoura HdS, Silveira HLDd, Silveira HEDd. Civil liability related to imaging exams in Brazil. Braz J Oral Sci 2015;14:10-15.

76. Macdonald-Jankowski DS, Orpe EC. Some Current Legal Issues that May Affect Oral and Maxillofacial Radiology. Part 2: Digital Monitors and Cone-Beam Computed Tomography. J Can Dent Assoc 2007;73:507-511.

77. *Adams v Yung and Others* [1998] 51 ALD 584.

78. Wright B. Contemporary medico-legal dental radiology. Aust Dent J 2012;57 Suppl 1:9-15.

79. Pette GA, Norkin FJ, Ganeles J, Hardigan P. Incidental findings from a retrospective study of 318 cone beam computed tomography consultation reports. The International journal of oral and maxillofacial implants 2012;27:595.

80. Price JB, Price JB, Thaw KL, Tyndall DA, Ludlow JB. Incidental findings from cone beam computed tomography of the maxillofacial region: a descriptive retrospective study. Clinical oral implants research 2012;23:1261-1268.

81. Cağlayan F, Tozoğlu Ü. Incidental findings in the maxillofacial region detected by cone beam CT. Diagn Interv Radiol 2012;18:159-163.

82. Ahmed F, Brooks SL, Kapila SD. Efficacy of identifying maxillofacial lesions in cone-beam computed tomographs by orthodontists and orthodontic residents with third-party software. Am J Orthod Dentofacial Orthop 2012;141:451-459.

83. Dental Board of Australia. POLICY - Use of *Cone Beam Computed Tomography* (CBCT). Australian Health Practitioner Regulation Agency. URL: 'https://www.google.com.au/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwjsnuuJ4b7TAhWCbbwKHfvSB18QFgghMAA&url=http%3A%2F%2Fwww.dentalboard.gov.au%2Fdocuments%2Fdefault.aspx%3Frecord%3DWD11%252F4668%26dbid%3DAP%26chksum%3DpppOG7jAqooe08wbgNecIg%253D%253D&usg=AFQjCNG4sZzQkbIspj-5kw7Xx6PGncKUwg'. Accessed April 2017.

84. Lockwood J. Communique - Use of Cone Beam Computed Tomography (CBCT). Dental Board of Australia. URL: 'https://www.google.com.au/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&ved=0ahUKEwj7mJiO877TAhXIebwKHQPkCQQQFggoMAE&url=http%3A%2F%2Fwww.dentalboard.gov.au%2Fdocuments%2Fdefault.aspx%3Frecord%3DWD15%252F16368%26dbid%3DAP%26chksum%3DR

n32niRZ8GKH7VINGmObeQ%253D%253D&usg=AFQjCNHJClG-uyEEQS-TtwmHZtXz2u2qWw'. Accessed April 2017.

85. Australian Dental Industry Association. ADIA Submission-CBCT & CBVT Operation In Western Australia. Australian Dental Industry Association, 2013.

86. Australian Radiation Protection and Nuclear Safety Agency. Regulatory Impact Statement-Public Consultation Draft. Australian Radiation Protection and Nuclear Safety Agency, 2005.

87. Douglass CW, Valachovic RW, Wijesinha A, Chauncey HH, Kapur KK, McNeil BJ. Clinical efficacy of dental radiography in the detection of dental caries and periodontal diseases. Oral Surg Oral Med Oral Pathol 1986;62:330-339.

88. Monsour PA, Kruger BJ, Barnes A. X-ray equipment used by general dental practitioners in Australia. Aust Dent J 1988;33:81-86.

89. Monsour PA, Kruger BJ, Barnes A, Macleod AG. A survey of dental radiography. Aust Dent J 1988;33:9-13.

90. Holroyd JR. Trends in Dental Radiography Equipment and Patient Dose in the UK and Republic of Ireland. Health Protection Agency; Centre for Radiation, Chemical and Environmental Hazards. URL: 'https://www.phe-protectionservices.org.uk/cms/assets/gfx/content/resource_3320cs36ed197b3f.pdf'. Accessed October 2015.

91. Hol C, Hellén-Halme K, Torgersen G, Nilsson M, Møystad A. How do dentists use CBCT in dental clinics? A Norwegian nationwide survey. Acta Odontol Scand 2015;73:195-201.

92. Hart D, Wall BF, Hillier MC, Shrimpton PC. Frequency and Collective Dose for Medical and Dental X-ray Examinations in the UK, 2008. Health Protection Agency; Centre for Radiation, Chemical and Environmental Hazards. URL: 'https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/340154/HPA-CRCE-012_for_website.pdf'. Accessed October 2015.

93. Wall BF, Kendall GM. Collective doses and risks from dental radiology in Great Britain. Br J Radiol 1983;56:511-516.

94. Monsour PA, Kruger BJ, Barnes A, Sainsbury A. Measures taken to reduce X-ray exposure of the patient, operator, and staff. Aust Dent J 1988;33:181-192.

95. Benedittini M, Maccia C, Lefaure C, Fagnani F. Doses to patients from dental radiology in France. Health Phys 1989;56:903-910.

96. Aroua AA, Buchillier-Decka I, Dula K, et al. Radiation exposure in dental radiology: a 1998 nationwide survey in Switzerland. Dentomaxillofac Radiol 2004;33:211-219.

97. Brugmans MJ, Buijs WC, Geleijns J, Lembrechts J. Population exposure to diagnostic use of ionizing radiation in The Netherlands. Health Phys 2002;82:500-509.

98. Hart D, Wall BF. Radiation Exposure of the UK Population from Medical and Dental X-ray Examinations. National Radiological Protection Board. URL: 'http://cloud.medicalphysicist.co.uk/nrpb_w4.pdf'. Accessed October 2015.

99. Moyal AE, Conference of Radiation Control Program Directors' Committee, American College of Radiology. NATIONWIDE EVALUATION OF X-RAY TRENDS (NEXT)-TABULATION AND GRAPHICAL SUMMARY OF THE 1999 DENTAL RADIOGRAPHY SURVEY. Conference of Radiation Control Program Directors, Inc. URL: 'http://www.crcpd.org/Pubs/NEXT_docs/NEXT99Dental.pdf'. Accessed September 2015.

100. Australian Bureau of Statistics. 1301.0 - Year Book Australia, 2006: POPULATION SIZE AND GROWTH. Australian Bureau of Statistics. URL: 'http://www.abs.gov.au/ausstats/abs@.nsf/0/A49FFD794E07339FCA2570DE00060B35?opendocument'. Accessed October 2015.

101. The World Bank. Population, total-France 1989. URL: 'http://data.worldbank.org/indicator/SP.POP.TOTL?page=5'. Accessed October 2015.

102. The World Bank. Population, total-France 1993. URL: 'http://data.worldbank.org/indicator/SP.POP.TOTL?page=5'. Accessed October 2015.

103. Australian Bureau of Statistics. Australian Demographic Statistics, Sep 2014. Australian Bureau of Statistics. URL: 'http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/3101.0Main+Features1Sep%202014?OpenDocument'. Accessed June 2015.

104. The World Bank. Population, total-Switzerland 2008. URL: 'http://data.worldbank.org/indicator/SP.POP.TOTL?page=5'. Accessed November 2015.

105. The World Bank. Population, total-United Kingdom 2008. URL: 'http://data.worldbank.org/indicator/SP.POP.TOTL?page=5'. Accessed November 2015.

106. Commonwealth of Australia Department of Health. Medicare Benefits Schedule Book-August 1988. URL: 'http://www.mbsonline.gov.au/internet/mbsonline/publishing.nsf/Content/515793D58E889BD0CA257CD100033990/$File/1988%20Aug%20MBS.pdf'. Accessed September 2015.

107. Australian Government Department of Health. Medicare Benefits Schedule Book-Category 5. Operating from 01 July 2015. Commonwealth of Australia, 2014.

108. Australian Medical Services Advisory Committee. MSAC Public Summary Document, Application 1345 - The assessment of Cone Beam Computerised Tomography for dental imaging.

MSAC. URL: 'http://www.msac.gov.au/internet/msac/publishing.nsf/Content/07164FF31B33CD83CA25801000123BE5/$File/1345-PSD-CBCT%20(D14-2140568).pdf'. Accessed August 2016.

109. Australian Medical Services Advisory Committee. MSAC Public Summary Document, Application Ref 43-Cone Beam Computed Tomography for various dental/craniofacial imaging puposes. MSAC. URL: 'http://www.msac.gov.au/internet/msac/publishing.nsf/Content/631DBB5FD5F3D282CA257781001F30A2/$File/Ref%2043%20-%20MSACPSD%20-Cone%20Beam%20CT%20%28D14-1143475%29.pdf'. Accessed December 2015.

110. Australian Government Department of Health. Cone beam computed tomography (CBCT) Medicare items fact sheet. The Department of Health. URL: 'http://www.health.gov.au/internet/main/publishing.nsf/Content/new-cone-beam-ct-medicare-items-fact-sheet'. Accessed June 2016.

111. Suomalainen A, Pakbaznejad Esmaeili E, Robinson S. Dentomaxillofacial imaging with panoramic views and cone beam CT. Insights Imaging 2015;6:1-16.

112. ACT Health; Radiation Safety. Prerequisites for Radiation Licences: Dental. Australian Capital Territory Government. URL: 'http://www.health.act.gov.au/public-information/businesses/radiation-safety/licences-prerequisites'. Accessed June 2015.

113. Department of Health and Human Services. Form RPA0001-Individual: APPLICATION FOR LICENCE TO DEAL WITH RADIATION APPARATUS – IONISING. Tasmanian Government. URL: 'http://www.dhhs.tas.gov.au/__data/assets/pdf_file/0012/53040/RPA0001_individual.pdf'. Accessed June 2015.

114. Department of Health; Radiation Protection. RADIATION PROTECTION INFORMATION SHEET: DENTIST, DENTAL HYGIENIST, DENTAL THERAPIST AND DENTAL ASSISTANT. Northern Territory Government. URL: 'http://www.health.nt.gov.au/library/scripts/objectifyMedia.aspx?file=pdf/45/52.pdf&siteID=1&str_title=Dental Information Sheet.pdf'. Accessed June 2015.

115. NSW Environment Protection Authority. Radiation user licence - criteria: Dental. NSW Environment Protection Authority. URL: 'http://www.epa.nsw.gov.au/radiation/licensing/licensingcriteria.htm#dental'. Accessed June 2015.

116. Queensland Radiation Health. FORM 2: Application for a licence to use a radiation source. Queensland Government Radiation Health. URL: 'http://www.health.qld.gov.au/radiationhealth/documents/app-use.pdf'. Accessed June 2015.

117. Queensland Radiation Health. FORM 6: Application for a licence to use radiation apparatus- Dental Purposes Queensland Government Radiation Health. URL: 'http://www.health.qld.gov.au/radiationhealth/documents/app-use-ra-dental.pdf'. Accessed June 2015.

118. South Australia Environment Protection Authority. Radiation Protection Information Sheet: Licence prerequisites for operators of diagnostic X-ray apparatus. South Australia Environment Protection Authority. URL: 'www.epa.sa.gov.au/files/4771332_dxr_licence_prerequisites.pdf'. Accessed June 2015.

119. Victoria Department of Health. What do I need to include with my application for a licence - use? Victoria Department of Health. URL: 'http://docs2.health.vic.gov.au/docs/doc/Prerequisites-for-applying-for-use-licences'. Accessed June 2015.

120. Western Australia Radiological Council. Dentists: Licensing for X-ray Equipment. Western Australia Radiological Council. URL: 'http://www.radiologicalcouncil.wa.gov.au/Pages/FAQ/Dentists.html'. Accessed June 2015.

121. Australian Dental Industry Association. ADIA Submissin-CBCT & CBVT Operation In Western Australia. Australian Dental Industry Association, 2013. URL: 'http://www.adia.org.au/Document.aspx?DocumentID=1210'. Accessed June 2015.

122. Australian Bureau of Statistics. Australian Demographic Statistics, Sep 2014. Australian Bureau of Statistics. URL: 'http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/3101.0Main+Features1Sep%202014?OpenDocument'. Accessed June 2015.

123. Dental Board of Australia. Registration Data Table - September 2014. Dental Board of Australia. URL: 'http://www.dentalboard.gov.au/About-the-Board/Statistics.aspx'. Accessed June 2015.

124. Australian Bureau of Statistics. 5220.0 - Australian National Accounts: State Accounts, 2013-14. Australian Bureau of Statistics,. URL: 'http://www.abs.gov.au/AusStats/ABS@.nsf/MF/5220.0'. Accessed June 2015.

125. Nemtoi A, Czink C, Haba D, Gahleitner A. Cone beam CT: a current overview of devices. Dentomaxillofac Radiol 2013;42:20120443.

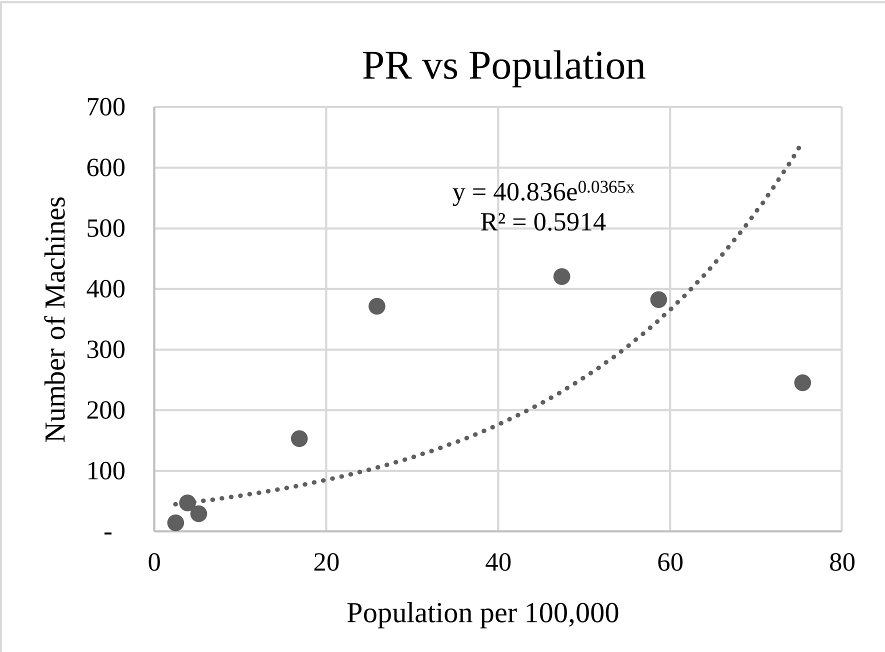
126. Australian Government Department of Health. Medicare Benefits Schedule Book Operating from 01 July 2011. The Department of Health. URL: 'http://www.mbsonline.gov.au/internet/mbsonline/publishing.nsf/Content/EB5EA830406CD939CA257CCF00051C1E/$File/201107-Cat%205.pdf'. Accessed October 2015.

127. Australian Government Department of Human Services. Medicare Item Reports. Department of Human Services. URL: 'http://medicarestatistics.humanservices.gov.au/statistics/mbs_item.jsp'. Accessed September 2016.
128. Australian Medical Services Advisory Committee. Reference 43-Consultation Decision Analytic Protocol (DAP) to guide the assessment of Cone Beam CT for dental and craniofacial imaging. MSAC. URL: 'http://www.msac.gov.au/internet/msac/publishing.nsf/Content/631DBB5FD5F3D282CA257781001F30A2/$File/Ref%2043%20-%20CBCT%20-%20Consultation%20DAP%20%20-%20Ratified.pdf'. Accessed August 2015.
129. Australian Imaging. Medicare CBCT Changes. Australian Imaging. URL: 'http://www.australianimaging.com.au/medicare-cbct-changes/'. Accessed June 2016.
130. Australian Government. Health Insurance Regulations 1975: Statutory Rules 1975 No. 80 as amended made under the Health Insurance Act 1973. Commonwealth of Australia. URL: 'https://www.legislation.gov.au/Details/F2013C00002'. Accessed August 2016.
131. Australian Dental Association. The Australian Schedule of Dental Services and Glossary. ADA. URL: 'http://www.ada.org.au/Dental-Professionals/Publications/Schedule-and-Glossary/Download-and-print-The-Australian-Schedule-of-Dent/Australian_Schedule_and_Dental_Glossary_2015_FA2_W'. Accessed June 2016.
132. Zhang A, Critchley S, Monsour PA. Comparative adoption of cone beam computed tomography and panoramic radiography machines across Australia. Aust Dent J 2016;61:489-496.

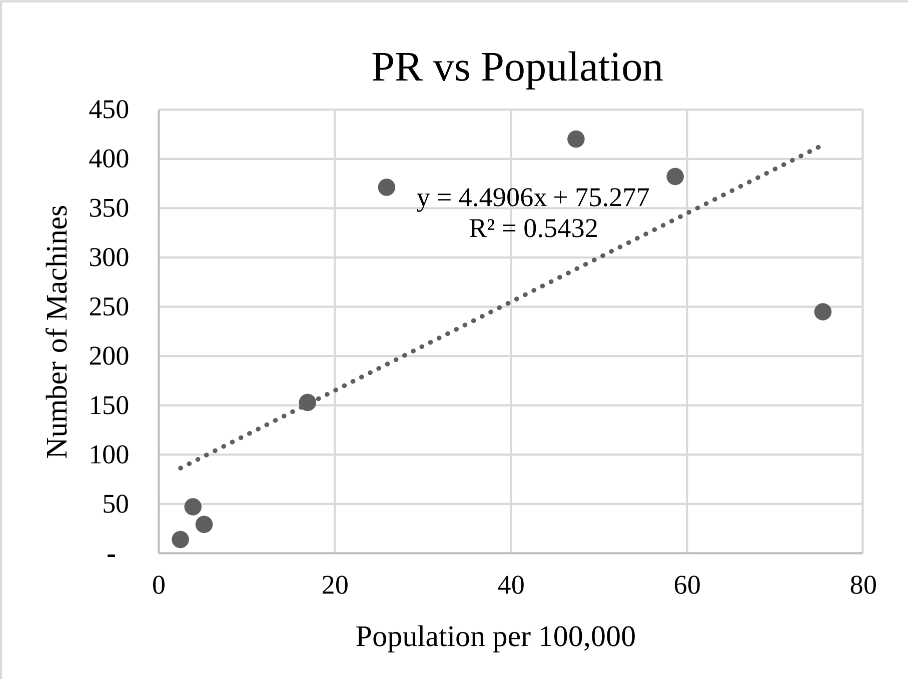
APPENDIX 1

Correlative analyses of PR and CBCT machines across Australia

1.1. Panoramic radiography machines



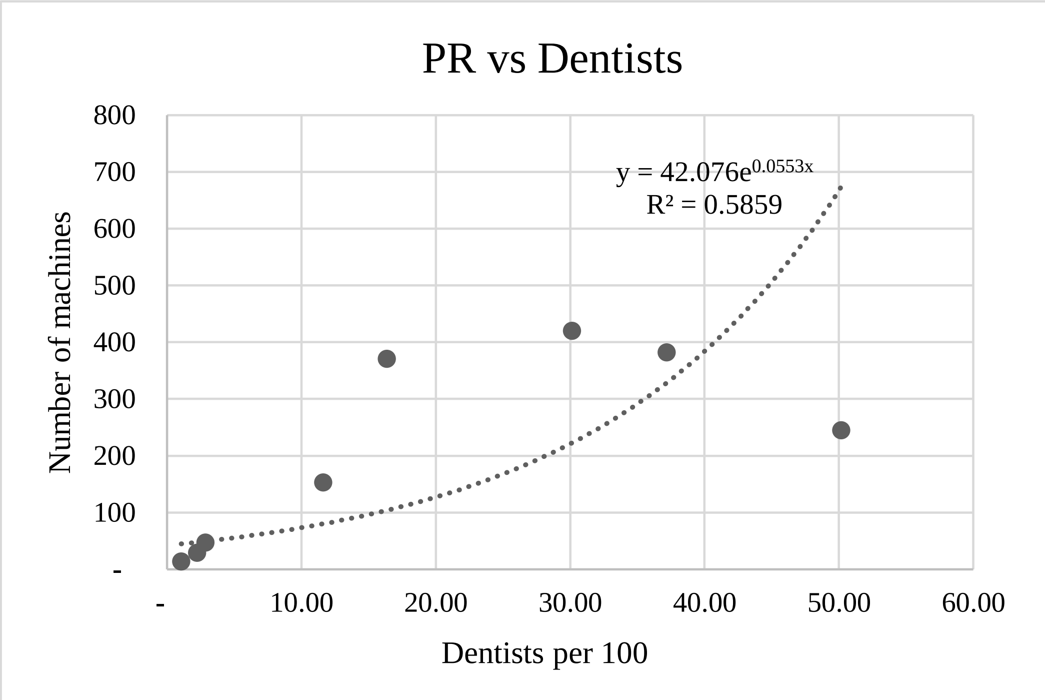
Appendix Figure 1-1. Exponential trendline of panoramic radiography machines *vs*. Australian population.



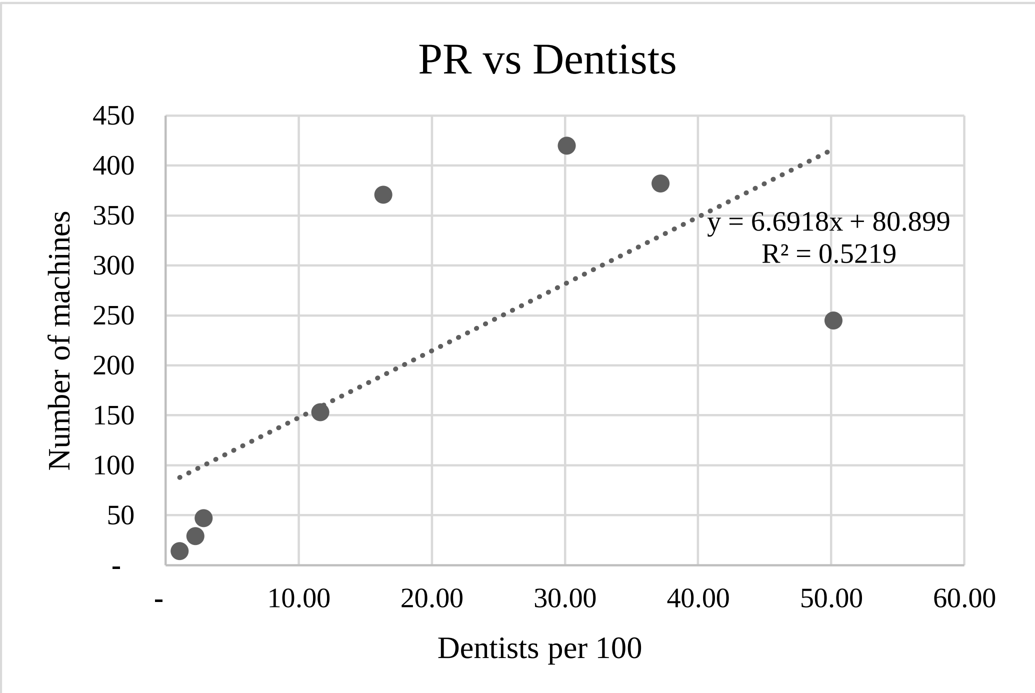
Appendix Figure 1-2. Linear trendline of panoramic radiography machines *vs*. Australian population.

Appendix Table 1-1. ANOVA analysis of panoramic radiography machines *vs*. Australian population

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.736996726							
R Square	0.543164174							
Adjusted R Square	0.46702487							
Standard Error	123.9490996							
Observations	8							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	109599.5992	109599.5992	7.133821085	0.036981098			
Residual	6	92180.27581	15363.3793					
Total	7	201779.875						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	75.27661462	66.14969294	1.137973757	0.298522672	-86.58585299	237.1390822	-86.58585299	237.1390822
Population per hundred thousand	4.490591117	1.681289135	2.670921392	0.036981098	0.376624808	8.604557427	0.376624808	8.604557427



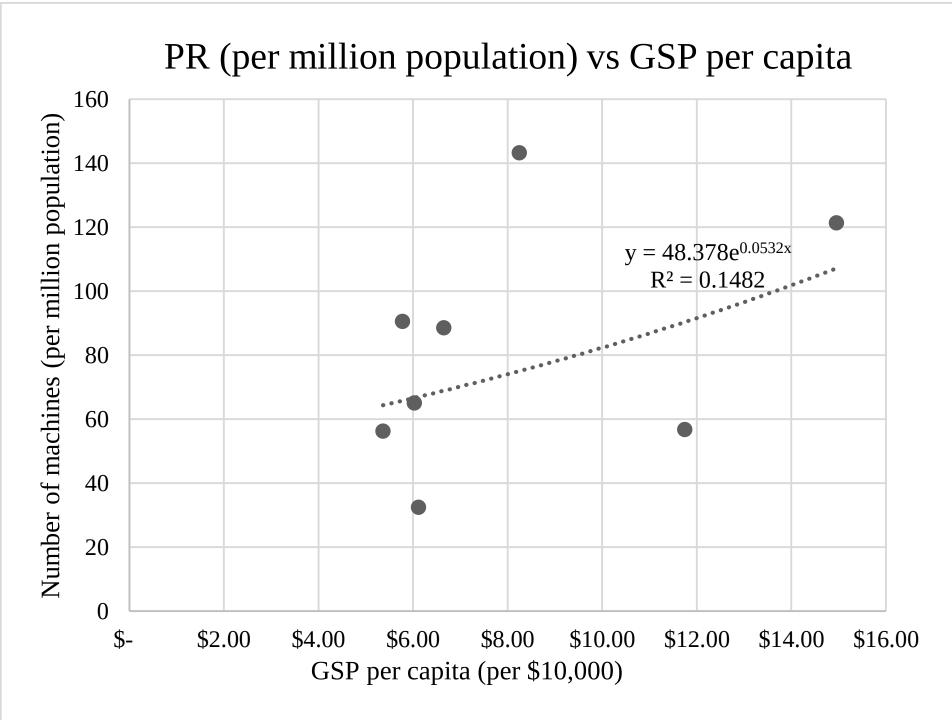
Appendix Figure 1-3. Exponential trendline of panoramic radiography machines *vs.* Australian dentists.



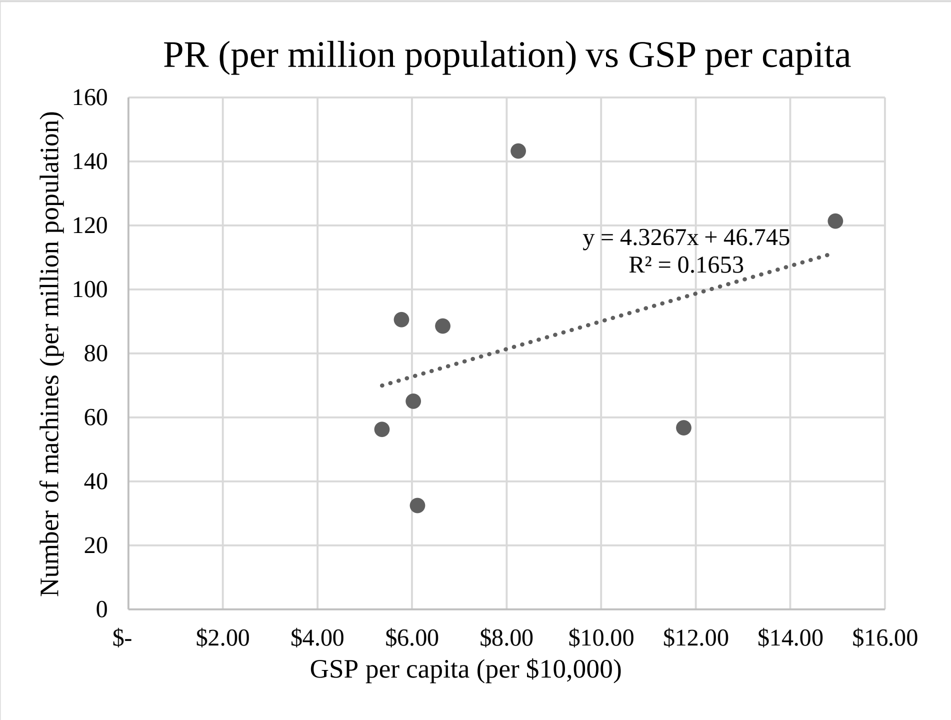
Appendix Figure 1-4. Linear trendline of panoramic radiography machines *vs*. Australian dentists.

Appendix Table 1-2. ANOVA analysis of panoramic radiography machines *vs*. Australian dentists

SUMMARY OUTPUT							
Regression Statistics							
Multiple R	0.72244647						
R Square	0.521928903						
Adjusted R Square	0.442250386						
Standard Error	126.797165						
Observations	8						
ANOVA							
	df	*SS*	*MS*	*F*	*Significance F*		
Regression	1	105314.7487	105314.7	6.550435	0.042944428		
Residual	6	96465.12627	16077.52				
Total	7	201779.875					
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	80.89889256	66.79341671	1.211181	0.271362	-82.53871037	244.3364955	-82.53871037	244.3364955
Dentists/100	6.691807654	2.614618891	2.559382	0.042944	0.294065703	13.0895496	0.294065703	13.0895496



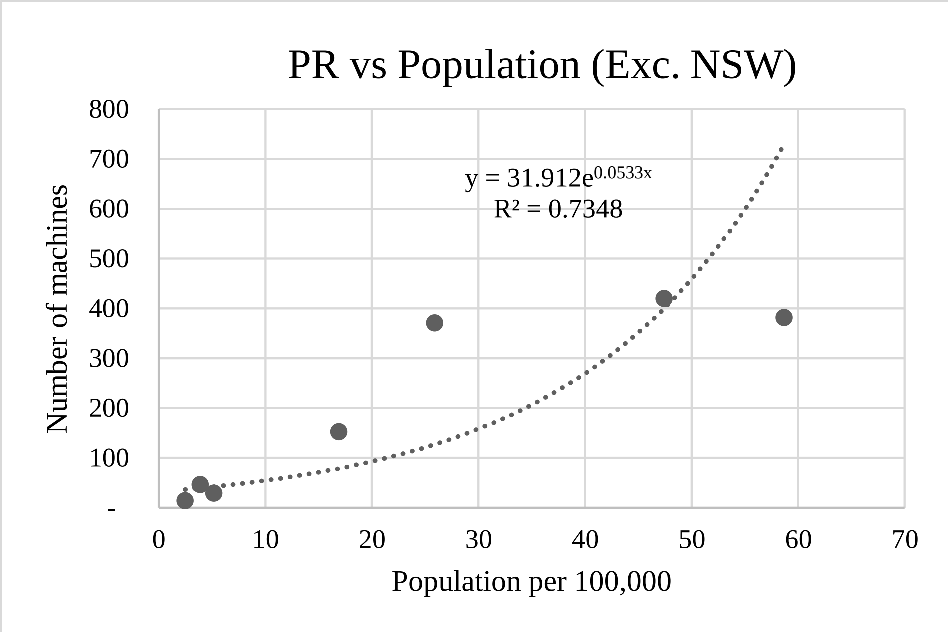
Appendix Figure 1-5. Exponential trendline of panoramic radiography machines (per million population) *vs*. GSP per capita.



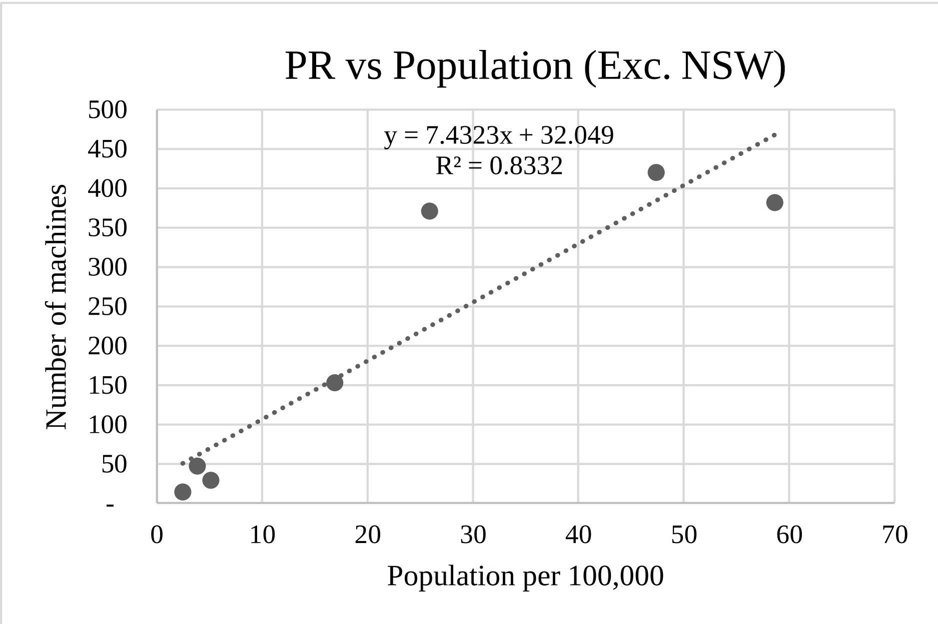
Appendix Figure 1-6. Linear trendline of panoramic radiography machines (per million population) *vs*. GSP per capita.

Appendix Table 1-3. ANOVA analysis of panoramic radiography machines (per million population) *vs*. GSP per capita

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.4065316							
R Square	0.1652679							
Adjusted R Square	0.0261459							
Standard Error	36.274905							
Observations	8							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	1563.16678	1563.167	1.187935	0.317572639			
Residual	6	7895.212367	1315.869					
Total	7	9458.379147						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	46.744731	34.65190633	1.34898	0.226025	-38.04542918	131.5348914	-38.04542918	131.5348914
GSP (per $10,000)	4.3266887	3.969714531	1.089924	0.317573	-5.3868528	14.04023026	-5.3868528	14.04023026



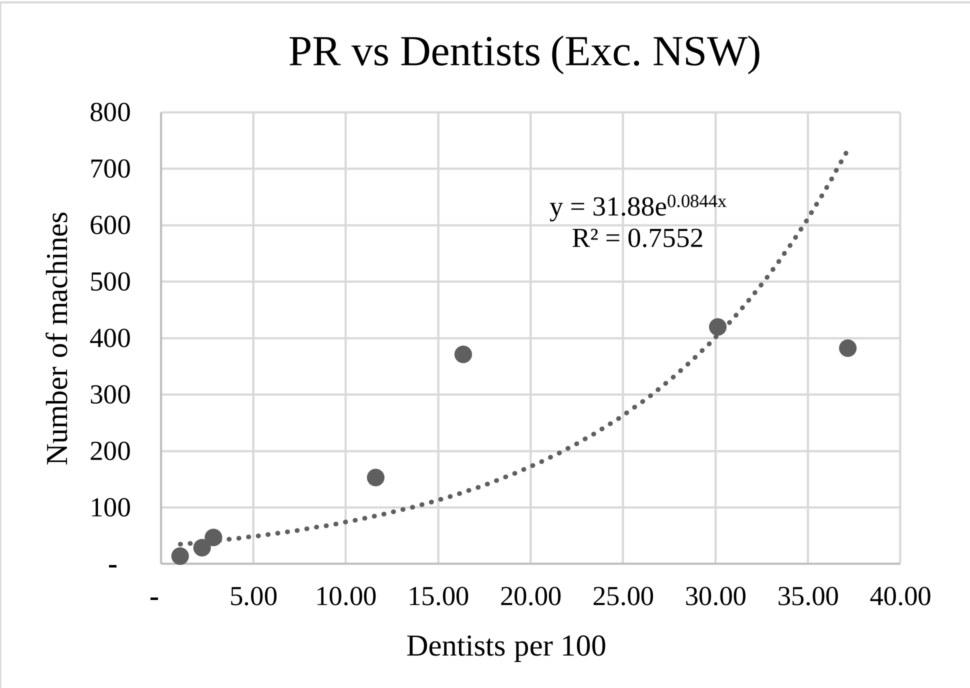
Appendix Figure 1-7. Exponential trendline of panoramic radiography machines *vs*. Australian population (excluding New South Wales).



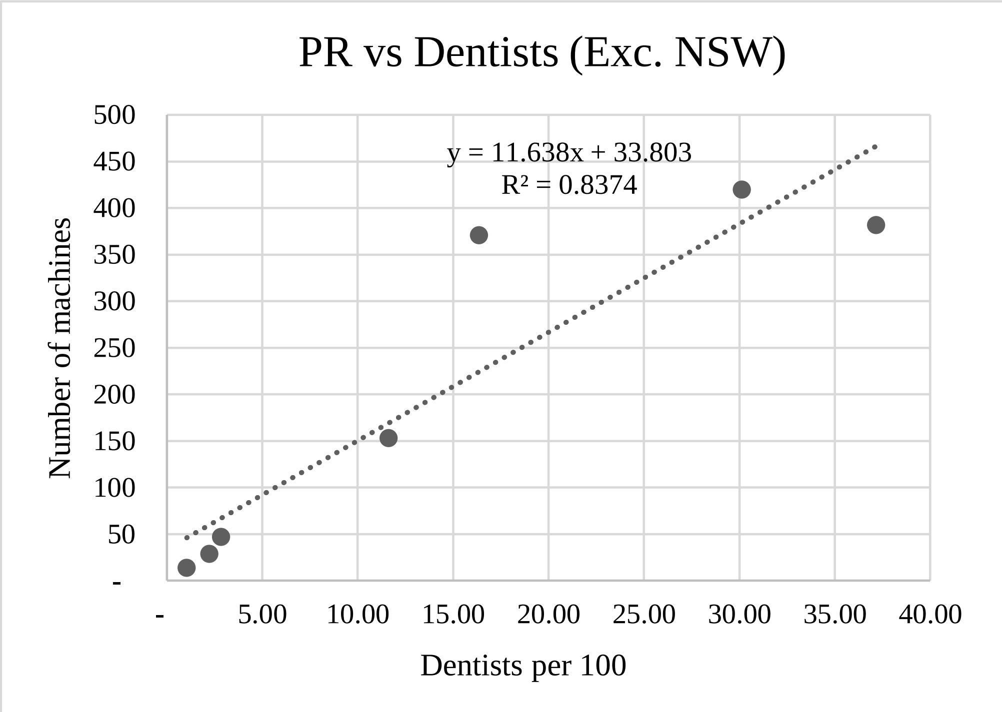
Appendix Figure 1-8. Linear trendline of panoramic radiography machines *vs*. Australian population (excluding New South Wales).

Appendix Table 1-4. ANOVA analysis of panoramic radiography machines *vs*. Australian population (excluding New South Wales)

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.912823669							
R Square	0.83324705							
Adjusted R Square	0.79989646							
Standard Error	81.70823362							
Observations	7							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	166802.2514	166802.3	24.98447708	0.004110177			
Residual	5	33381.17721	6676.235					
Total	6	200183.4286						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	32.0493731	45.97482592	0.697107	0.516810007	-86.13267931	150.2314255	-86.13267931	150.2314255
X Variable 1	7.432324948	1.48692669	4.998447	0.004110177	3.610058208	11.25459169	3.610058208	11.25459169



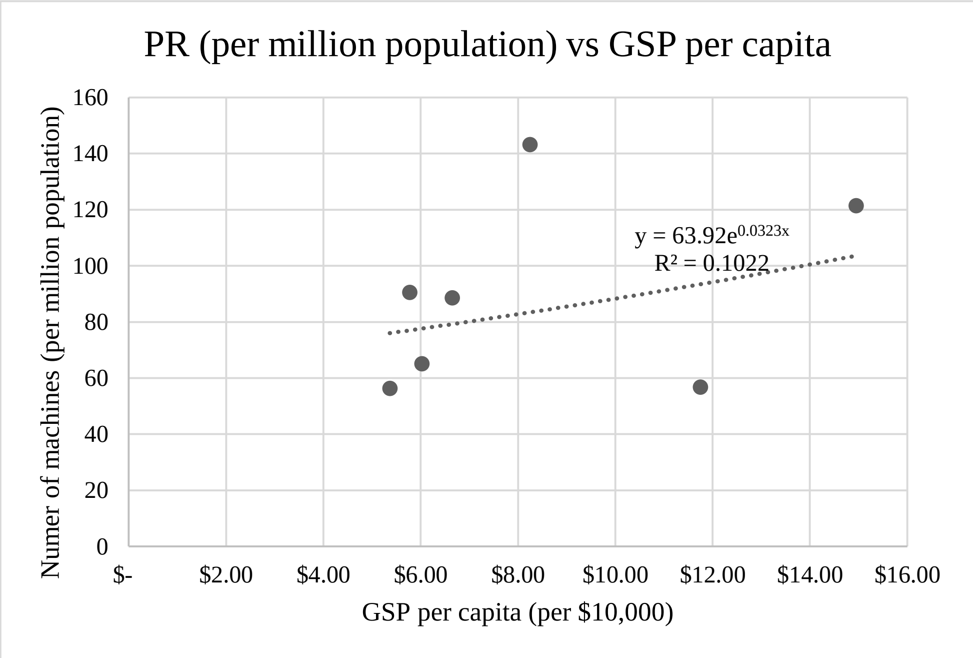
Appendix Figure 1-9. Exponential trendline of panoramic radiography machines *vs*. Australian dentists (excluding New South Wales).



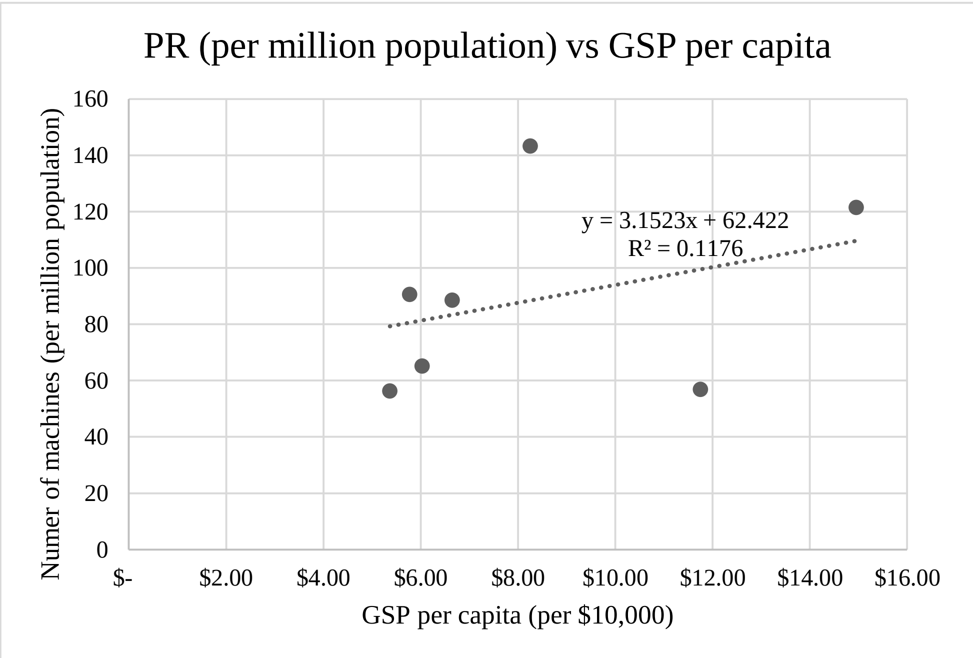
Appendix Figure 1-10. Linear trendline of panoramic radiography machines *vs*. Australian dentists (excluding New South Wales).

Appendix Table 1-5. ANOVA analysis of panoramic radiography machines *vs*. Australian dentists (excluding New South Wales)

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.91509767							
R Square	0.83740374							
Adjusted R Square	0.80488449							
Standard Error	80.6834264							
Observations	7							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	167634.3521	167634.4	25.75102	0.003852194			
Residual	5	32549.07647	6509.815					
Total	6	200183.4286						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	33.8026458	45.0812625	0.749816	0.487126	-82.08242876	149.6877203	-82.08242876	149.6877203
X Variable 1	11.6378674	2.293381087	5.074546	0.003852	5.74254361	17.53319114	5.74254361	17.53319114



Appendix Figure 1-11. Exponential trendline of panoramic radiography machines (per million population) *vs*. GSP per capita (excluding New South Wales).

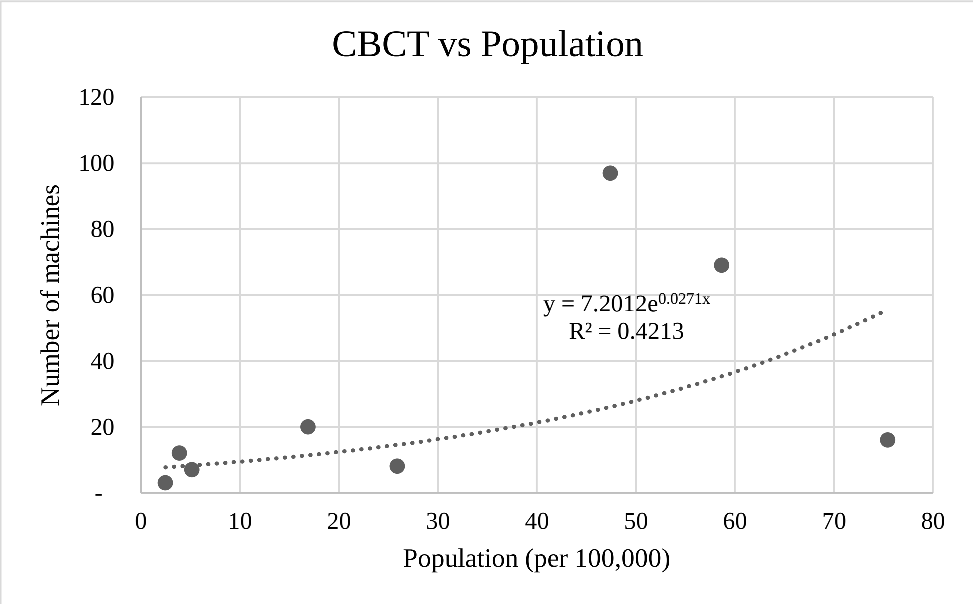


Appendix Figure 1-12. Linear trendline of panoramic radiography machines (per million population) *vs*. GSP per capita (excluding New South Wales).

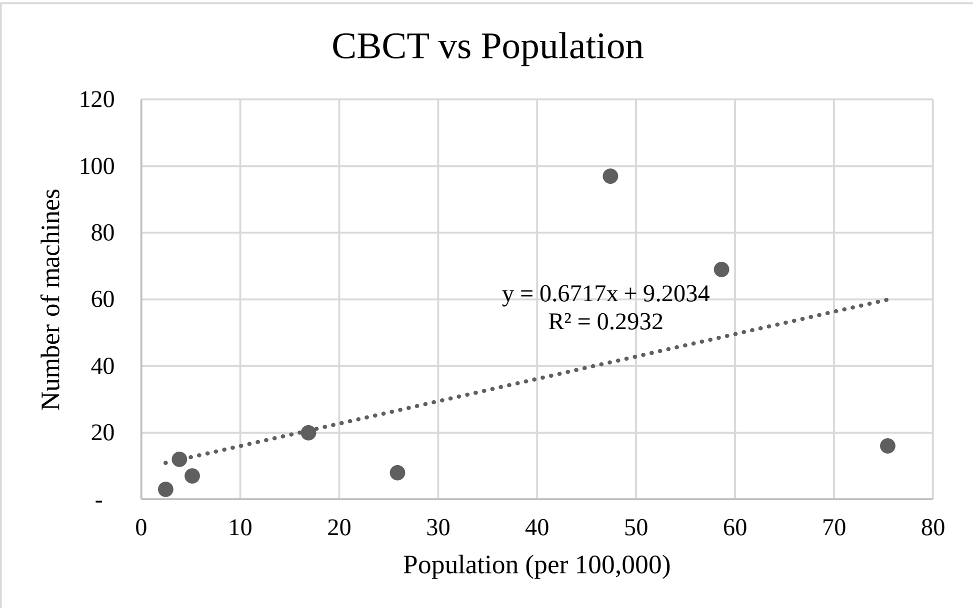
Appendix Table 1-6. ANOVA analysis of panoramic radiography machines (per million population) *vs*. GSP per capita (excluding New South Wales)

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.342885752							
R Square	0.117570639							
Adjusted R Square	-0.058915233							
Standard Error	34.32079761							
Observations	7							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	784.7000465	784.7000465	0.666175925	0.451505834			
Residual	5	5889.585742	1177.917148					
Total	6	6674.285789						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	62.42197182	34.9172874	1.787709656	0.133859218	-27.33577291	152.1797166	-27.33577291	152.1797166
X Variable 1	3.152307433	3.862194127	0.816196009	0.451505834	-6.775778635	13.0803935	-6.775778635	13.0803935

1.2. Cone beam computed tomography machines



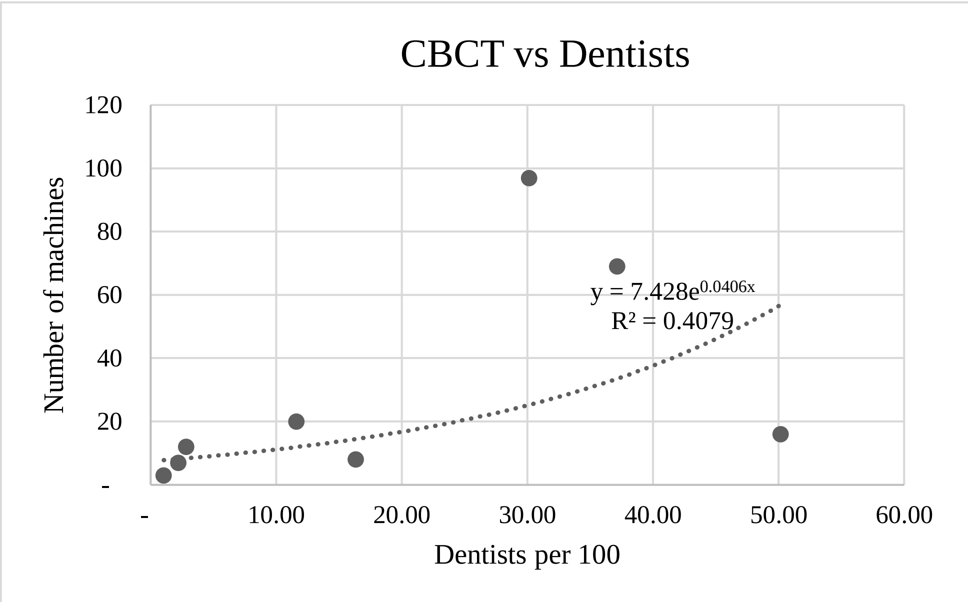
Appendix Figure 1-13. Exponential trendline of cone beam computed tomography machines *vs*. Australian population.



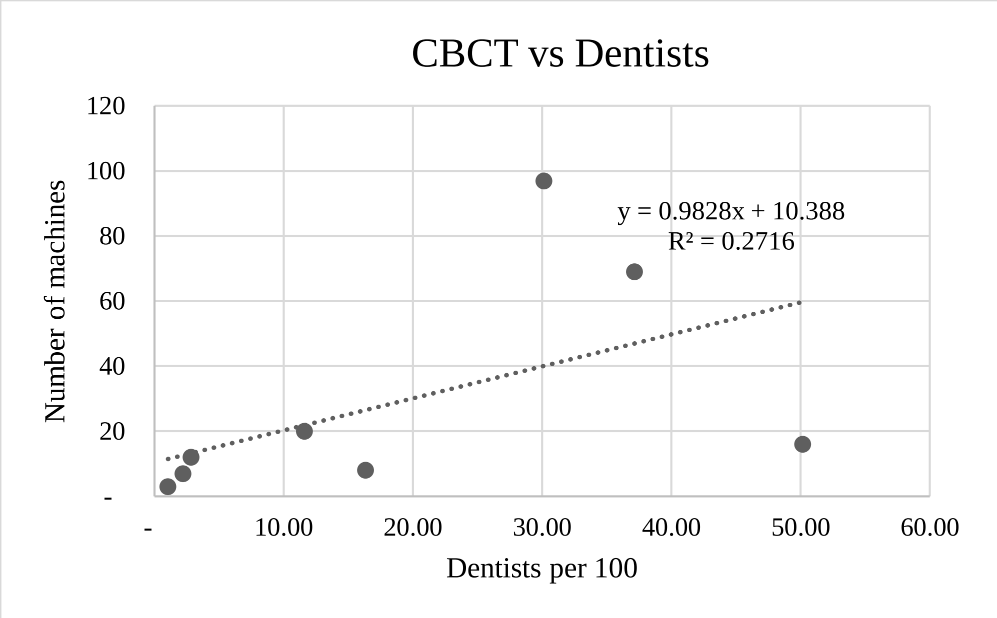
Appendix Figure 1-14. Linear trendline of cone beam computed tomography machines *vs*. Australian population.

Appendix Table 1-7. ANOVA analysis of cone beam computed tomography machines *vs*. Australian population

SUMMARY OUTPUT									
Regression Statistics									
Multiple R	0.5414634								
R Square	0.2931826								
Adjusted R Square	0.1753797								
Standard Error	31.389543								
Observations	8								
ANOVA									
	df	*SS*	*MS*	*F*	*Significance F*				
Regression	1	2452.179486	2452.179	2.488756	0.165737413				
Residual	6	5911.820514	985.3034						
Total	7	8364							
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*	
Intercept	9.2034144	16.75210749	0.549388	0.602571	-31.78751594	50.19434476	-31.78751594	50.19434476	
Population per hundred thousand	0.6716997	0.425778791	1.577579	0.165737	-0.370143466	1.713542876	-0.370143466	1.713542876	



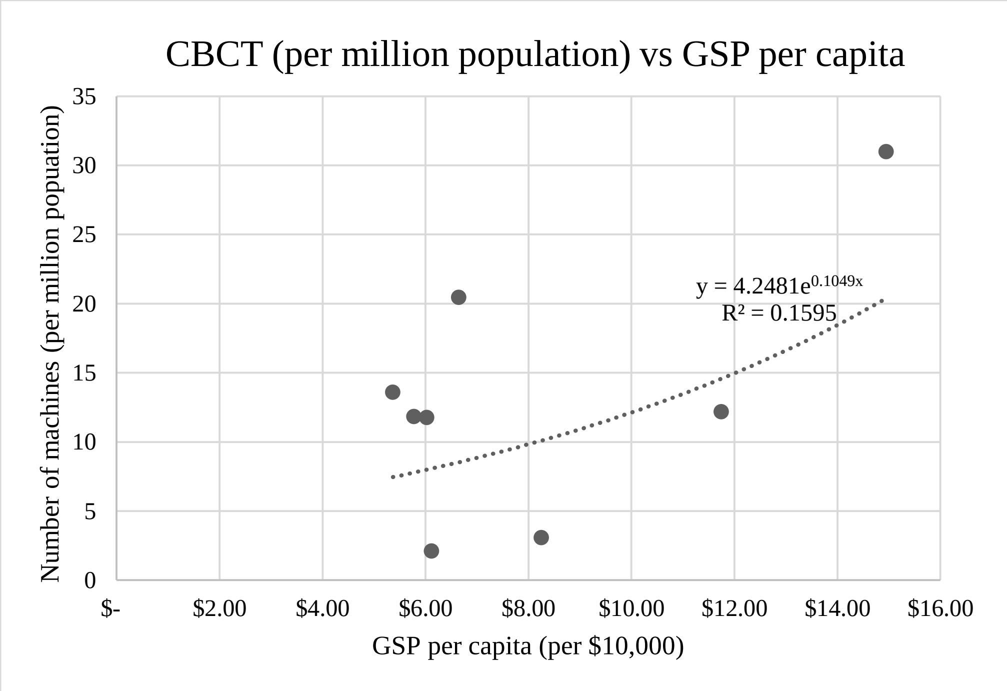
Appendix Figure 1-15. Exponential trendline of cone beam computed tomography machines *vs*. Australian dentists.



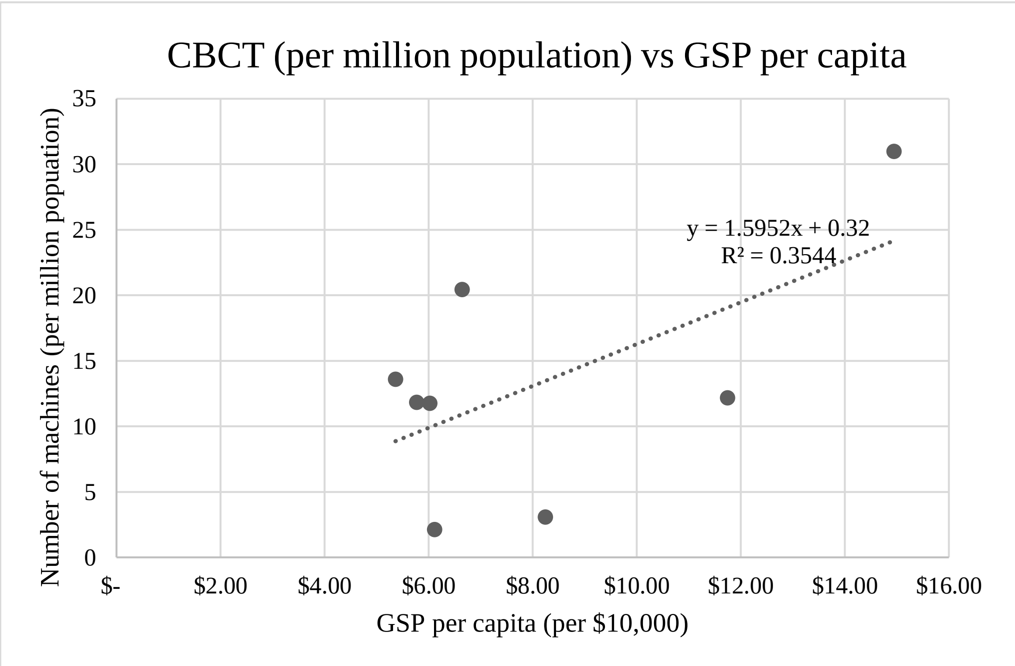
Appendix Figure 1-16. Linear trendline of cone beam computed tomography machines *vs*. Australian dentists.

Appendix Table 1-8. ANOVA analysis of cone beam computed tomography machines *vs*. Australian dentists

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.52113926							
R Square	0.27158613							
Adjusted R Square	0.15018382							
Standard Error	31.8654818							
Observations	8							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	2271.546415	2271.546	2.237075	0.185367104			
Residual	6	6092.453585	1015.409					
Total	7	8364						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	10.3884602	16.785899	0.61888	0.558744	-30.68515498	51.46207543	-30.68515498	51.46207543
Dentists/100	0.98278758	0.657081653	1.495686	0.185367	-0.625033304	2.590608462	-0.625033304	2.590608462



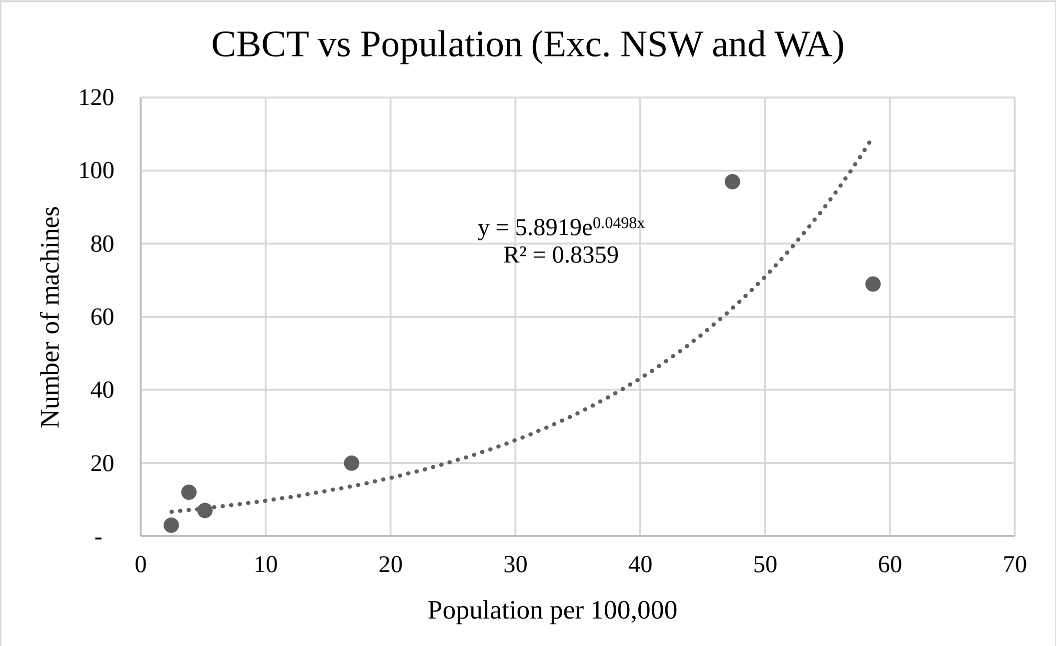
Appendix Figure 1-17. Exponential trendline of cone beam computed tomography machines (per million population) *vs*. GSP per capita.



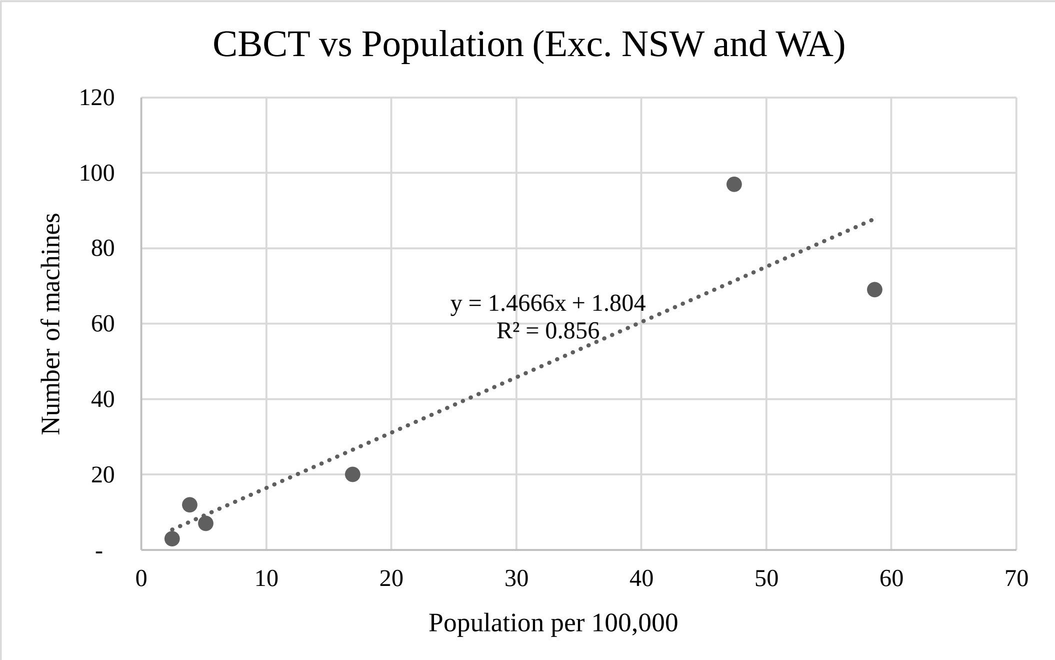
Appendix Figure 1-18. Linear trendline of cone beam computed tomography machines (per million population) *vs*. GSP per capita.

Appendix Table 1-9. ANOVA analysis of cone beam computed tomography machines (per million population) *vs*. GSP per capital

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.59531648							
R Square	0.35440171							
Adjusted R Square	0.24680199							
Standard Error	8.03211909							
Observations	8							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	212.4931622	212.4932	3.293705	0.119468543			
Residual	6	387.0896228	64.51494					
Total	7	599.582785						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.31999566	7.672748943	0.041705	0.968087	-18.45454466	19.09453598	-18.45454466	19.09453598
GSP (per $10,000)	1.59523795	0.878988379	1.814857	0.119469	-0.555569127	3.746045035	-0.555569127	3.746045035



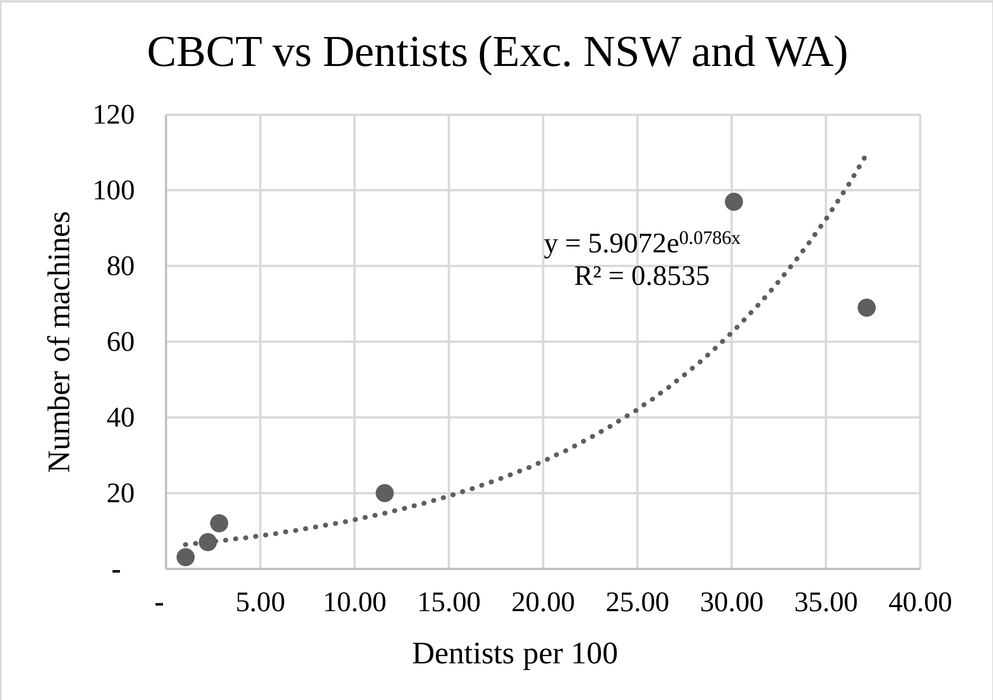
Appendix Figure 1-19. Exponential trendline of cone beam computed tomography machines *vs*. Australian population (excluding New South Wales and Western Australia).



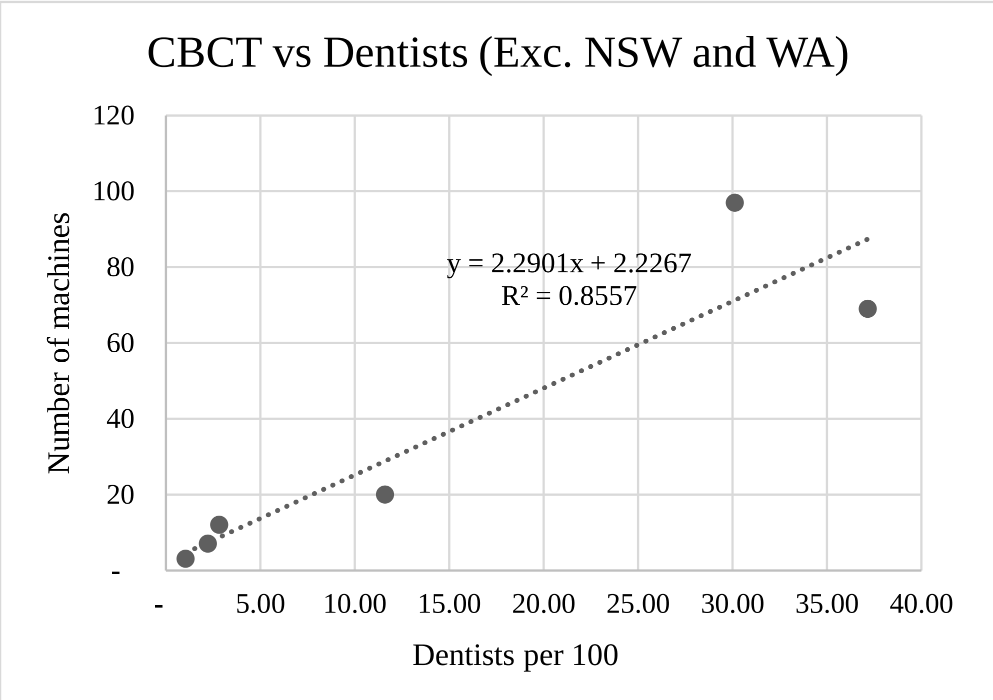
Appendix Figure 1-20. Linear trendline of cone beam computed tomography machines *vs*. Australian population (excluding New South Wales and Western Australia).

Appendix Table 1-10. ANOVA analysis of cone beam computed tomography machines *vs*. Australian population (excluding New South Wales and Western Australia)

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.925216437							
R Square	0.856025455							
Adjusted R Squ	0.820031818							
Standard Error	16.49726892							
Observations	6							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	6472.693805	6472.694	23.78269	0.008179755			
Residual	4	1088.639528	272.1599					
Total	5	7561.333333						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	1.804013738	9.527288479	0.189352	0.859037	-24.64797972	28.2560072	-24.64797972	28.2560072
X Variable 1	1.466613491	0.300735847	4.87675	0.00818	0.631636921	2.301590061	0.631636921	2.301590061



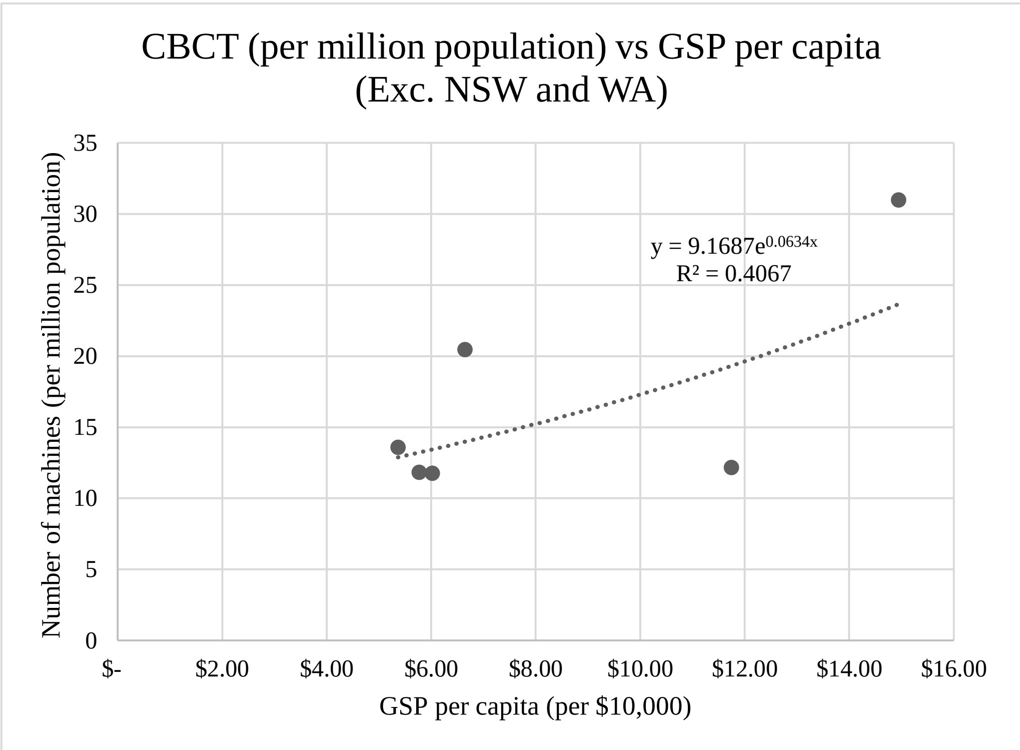
Appendix Figure 1-21. Exponential trendline of cone beam computed tomography machines *vs*. Australian dentists (excluding New South Wales and Western Australia).



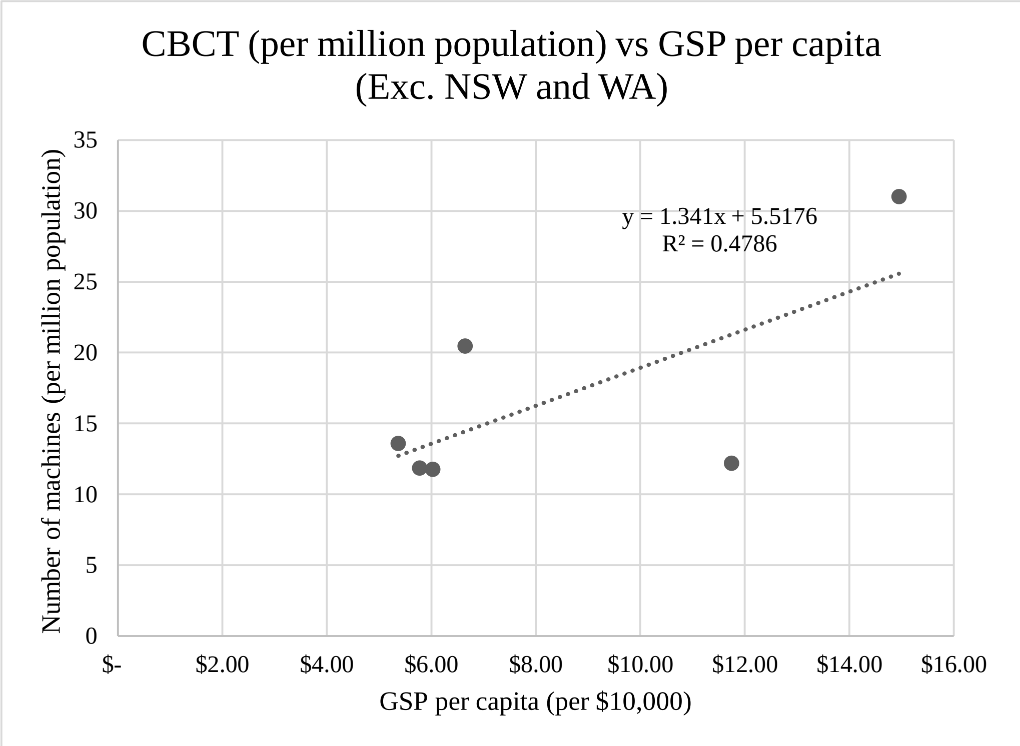
Appendix Figure 1-22. Linear trendline of cone beam computed tomography machines *vs*. Australian dentists (excluding New South Wales and Western Australia).

Appendix Table 1-11. ANOVA analysis of cone beam computed tomography machines *vs*. Australian dentists (excluding New South Wales and Western Australia)

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.92502475							
R Square	0.85567079							
Adjusted R Square	0.81958848							
Standard Error	16.5175762							
Observations	6							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	6470.012039	6470.012	23.71442	0.008221204			
Residual	4	1091.321294	272.8303					
Total	5	7561.333333						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	2.22671815	9.478802182	0.234916	0.82581	-24.09065577	28.54409208	-24.09065577	28.54409208
X Variable 1	2.29014815	0.470280912	4.869745	0.008221	0.984439011	3.595857284	0.984439011	3.595857284



Appendix Figure 1-23. Exponential trendline of cone beam computed tomography machines (per million population) *vs*. GSP per capita (excluding New South Wales and Western Australia).



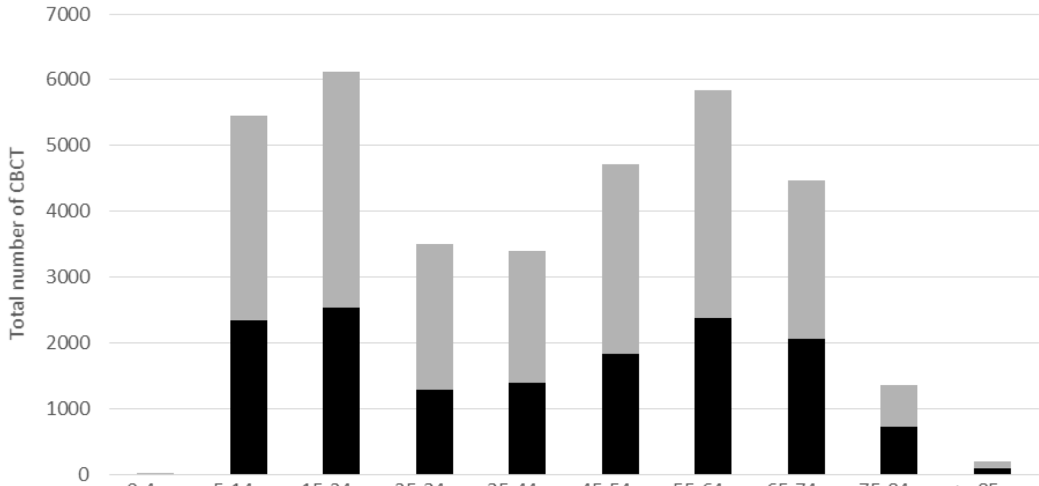
Appendix Figure 1-24. Linear trendline of cone beam computed tomography machines (per million population) *vs*. GSP per capita (excluding New South Wales and Western Australia).

Appendix Table 1-12. ANOVA analysis of cone beam computed tomography machines (per million population) *vs*. GSP per capita (excluding New South Wales and Western Australia)

SUMMARY OUTPUT								
Regression Statistics								
Multiple R	0.691834446							
R Square	0.478634901							
Adjusted R Square	0.348293626							
Standard Error	6.217754516							
Observations	6							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	1	141.9676984	141.9677	3.6721668	0.127816387			
Residual	4	154.6418849	38.660471					
Total	5	296.6095833						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	5.517610792	6.414549723	0.8601712	0.4381958	-12.29203439	23.32725597	-12.29203439	23.32725597
X Variable 1	1.341032008	0.699806456	1.9162898	0.1278164	-0.601942201	3.284006216	-0.601942201	3.284006216

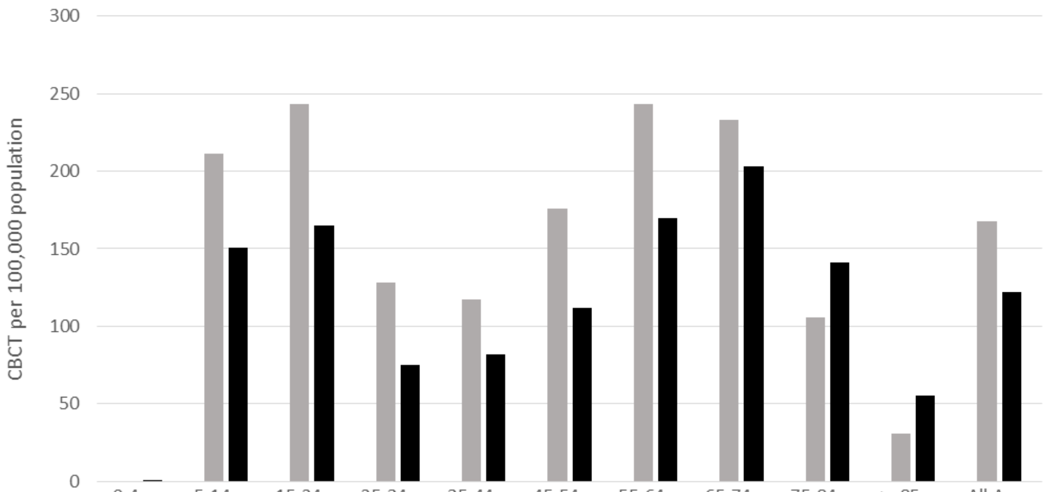
APPENDIX 2

MBS: Rebated cone beam computed tomography and panoramic radiography scans



	0-4 yrs	5-14 yrs	15-24 yrs	25-34 yrs	35-44 yrs	45-54 yrs	55-64 yrs	65-74 yrs	75-84 yrs	>=85 yrs
Female	3	3107	3587	2227	1998	2870	3462	2420	632	95
Male	9	2350	2532	1283	1399	1837	2376	2057	720	98

Appendix Figure 2-1. The number of Medicare rebated CBCT scans related to patient age and gender, for the 12-month period of Dec 2014–Nov 2015 (item codes 57362/57363).



	0-4 yrs	5-14 yrs	15-24 yrs	25-34 yrs	35-44 yrs	45-54 yrs	55-64 yrs	65-74 yrs	75-84 yrs	>=85 yrs	All Ages
Female	0	211	243	128	117	176	243	233	106	31	168
Male	1	151	165	75	82	112	170	203	141	55	122

Appendix Figure 2-2. The number of Medicare rebated CBCT scans per 100,000 population related to patient age and gender, for the 12-month period of Dec 2014–Nov 2015 (item codes 57362/57363).

Appendix Table 2-1. Australian state, territory and national summary for the number of Medicare rebated PR scans over four recent 12-month periods

Codes	Time period	State or territory								National
		NSW	VIC	QLD	SA	WA	TAS	ACT	NT	
SURG:	Nov 2011-Oct 2012	39,427	9,466	12,731	4,667	3,289	801	1,196	598	72,175
57959(NK)	Nov 2012-Oct 2013	36,884	8,254	12,936	6,088	3,310	709	1,024	970	70,175
57960	Nov 2013-Oct 2014	40,275	8,081	12,488	6,463	3,288	973	787	1,192	73,547
	Dec 2014-Nov 2015	37,798	7,271	11,253	7,515	3,984	1,285	658	1,760	71,524
DENT:	Nov 2011-Oct 2012	191,049	231,240	167,011	55,996	53,237	18,332	3,478	3,099	723,442
57962(NK)	Nov 2012-Oct 2013	183,078	218,000	160,204	50,734	52,022	18,619	3,283	2,873	688,813
57963	Nov 2013-Oct 2014	200,410	225,316	171,279	50,404	52,874	17,196	3,092	3,081	723,652
	Dec 2014-Nov 2015	183,120	220,037	169,849	47,859	48,759	17,125	2,866	2,566	692,181
ORTHO:	Nov 2011-Oct 2012	69,348	53,076	22,181	15,629	6,896	5,962	3,250	1,162	177,504
57965(NK)	Nov 2012-Oct 2013	62,659	54,320	22,320	16,617	6,683	5,081	3,367	1,033	172,080
57966	Nov 2013-Oct 2014	63,654	56,042	21,849	17,141	5,715	6,389	3,405	767	174,962
	Dec 2014-Nov 2015	62,984	60,084	20,731	16,864	4,988	5,217	3,298	605	174,771
TMJ:	Nov 2011-Oct 2012	1,554	864	1,703	474	464	304	167	10	5,540
57968(NK)	Nov 2012-Oct 2013	1,313	694	1,547	615	495	236	72	21	4,993
57969	Nov 2013-Oct 2014	1,416	856	1,643	617	553	293	72	52	5,502
	Dec 2014-Nov 2015	1,541	1,033	1,600	865	617	297	51	36	6,040

Appendix Table 2-2. Australian state, territory and national summary for the number of Medicare rebated PR scans per 100,000 population over four recent 12-month periods

Codes	Time period	State or territory (Per 100,000 population)								National
		NSW	VIC	QLD	SA	WA	TAS	ACT	NT	
SURG	Nov 2011-Oct 2012	530	167	275	280	138	153	315	261	315
57959(NK)	Nov 2012-Oct 2013	489	142	274	361	134	135	263	414	300
57960	Nov 2013-Oct 2014	525	137	260	379	131	185	198	503	310
	Dec 2014-Nov 2015	485	121	230	436	154	242	162	736	296
DENT	Nov 2011-Oct 2012	2,569	4,074	3,614	3,363	2,228	3,515	917	1,350	3,156
57962(NK)	Nov 2012-Oct 2013	2,425	3,766	3,394	3,008	2,108	3,556	844	1,227	2,949
57963	Nov 2013-Oct 2014	2,613	3,817	3,567	2,959	2,094	3,274	777	1,300	3,045
	Dec 2014-Nov 2015	2,351	3,656	3,480	2,775	1,886	3,236	706	1,073	2,864
ORTHO	Nov 2011-Oct 2012	932	935	480	939	289	1,143	857	506	775
57965(NK)	Nov 2012-Oct 2013	830	938	473	985	271	970	865	441	737
57966	Nov 2013-Oct 2014	830	950	455	1,006	226	1,216	856	323	736
	Dec 2014-Nov 2015	809	999	425	978	193	986	812	253	723
TMJ	Nov 2011-Oct 2012	21	15	37	28	19	58	44	4	24
57968(NK)	Nov 2012-Oct 2013	17	12	33	36	20	45	18	9	21
57969	Nov 2013-Oct 2014	18	14	34	36	22	56	18	22	23
	Dec 2014-Nov 2015	20	17	33	50	24	56	13	15	25