GONIAL ANGLE AND ITS ASSOCIATION WITH MANDIBULAR RESIDUAL RIDGE RESORPTION IN IMPLANT-OVERDENTURE PATIENTS.

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2019

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RESEARCH SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF CLINICAL DENTISTRY (RESTORATIVE DENTISTRY IN PROSTHETICS DENTISTRY)

FACULTY OF DENTISTRY
UNIVERSITY OF MALAYA
KUALA LUMPUR

2019

UNIVERSITY OF MALAYA

ORIGINAL LITERARY WORK DECLARATION

Name of Candidate : PL. Ranganayakidevi A/P S. Palaniappan

Matric No : DGS160001

Name of Degree : Master of Clinical Dentistry

(Restorative Dentistry in Prosthetic Dentistry)

Title of Research : Gonial angle and its association with mandibular residual ridge resorption in implant-overdenture patients.

Field of Study : Dentistry

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ABSTRACT

Purpose: This study aimed to investigate various methods of gonial angle measurements and to determine the association between gonial angle and residual bone resorption in edentulous patients provided with implants overdenture.

Materials and method: 23 patients wearing maxillary complete dentures opposing mandibular implant overdenture prosthesis were recruited. The posterior ridge resorption was measured using the proportional area index method, whereby the dentopantomograph (DPT) of pre- and 4 years post- implant placement of these patients were compared. Mandibular gonial angle measurements were done on 5 out of the 23 patients using four measurement methods: (i) Two different vertical line tracing points on DPT (exterior border points and mid-condylar points), (ii) Manual measurement on 3D printed mandibular model using goniometer, (iii) Lateral cephalometric view of CBCT using Mimics software. The results from each measurement methods were then compared.

Results: The results showed a strong association between CBCT measurements and both DPT measurement methods (R^2 = 0.927, 0.829), but weak association between CBCT and to the manual measurement on the 3D printed models (R^2 = 0.098). However, the associations were not significant ($p>0.05$). The mean (SD) for the exterior border points method was 128.76º (7.82), while for the mid-condyle points method was 130.89º (7.06) however, the difference was not significant ($p = 0.185$). The posterior ridge resorption in implant overdenture patients showed no correlation with gonial angle ($r < 0.3$, $p>0.05$) as measured on DPT images.

Conclusion: No significant difference between the different gonial angle measurement methods was observed in this study. No correlation between the mandibular gonial angle and posterior mandibular bone resorption was found.

Keywords: Gonial angle, Residual ridge resorption, Implant overdenture prosthesis, Dentopantomogram.

ABSTRAK

Tujuan: Kajian ini adalah untuk mengkaji pelbagai kaedah pengukuran sudut gonial dan menentukan perhubungan antara sudut gonial dan resorpsi tulang di bahagian posterior mandibel pada pesakit yang dirawat dengan implan overdenture.

Bahan dan kaedah: 23 pesakit yang memakai gigi palsu penuh maxilla dengan prosthesis implant overdenture di mandibel telah direkrut. Resorpsi posterior tulang mandibel diukur dengan menggunakan kaedah indeks kawasan proporsional, di mana dentapantomogram (DPT) pra-dan 4 tahun selepas peletakan implant pesakit-pesakit ini telah dibandingkan. Ukuran pengukuran sudut mandibular telah dilakukan pada 5 daripada 23 pesakit dengan menggunakan empat kaedah pengukuran: (i) Dua garis menegak yang berbeza di DPT (titik sempadan luar dan titik tengah-kondil), (ii) Pengukuran secara manual menggunakan goniometer pada model mandibel cetakan 3D, (iii) Pandangan lateral kefalometrik CBCT menggunakan perisian Mimics. Keputusan dari setiap kaedah pengukuran kemudiannya dibandingkan.

Keputusan: Hasil menunjukkan persamaan yang tinggi antara pengukuran CBCT dan kedua-dua kaedah pengukuran DPT (R^2 = 0.927, 0.829), tetapi hubungan yang lemah antara CBCT dan pengukuran manual pada model bercetak 3D (R^2 = 0.098). Walau bagaimanapun, hubungan tersebut tidak signifikan ($p > 0.05$). Purata (sisihan piawai) untuk kaedah titik sempadan luar adalah 128.76° (7.82), manakala bagi kaedah titik tengah-kondil ialah 130.89° (7.06) namun perbezaannya tidak signifikan ($p = 0.185$). Resorpsi tulang posterior pada pesakit implan tidak menunjukkan korelasi dengan sudut gonial ($r < 0.3$, $p > 0.05$) seperti yang diukur pada imej DPT. Kesimpulan: Dalam batasan kajian ini, tiada perbezaan dalam semua kaedah pengukuran sudut gonial yang

digunakan. Sudut in juga tiada perkaitan dengan resorpsi tulang mandibel di bahagian posterior pada DPT dan perhubungan ini juga tidak signifikan.

Kata kunci: Sudut gonial, Resorpsi tulang di bahagian posterior, implan overdentur, dentopantomograf.

ACKNOWLEDGEMENTS

First and foremost, all praises belong to Almighty God. Secondly, I offer my gratitude and appreciation to my supervisors, Prof. Dr. Norsiah Yunus, Associate Prof. Dr. Norliza Ibrahim and Dr. Siti Fauzza Ahmad for their endless dedication. They were more than generous with their expertise and precious time. Without them I would not have achieved my goals for this research project. I would also like to offer special thanks to all the staff in the Faculty of Dentistry / University of Malaya who provided the assistance and support in the mechanics of producing this thesis. Thirdly, I would like to acknowledge and thank Dr. Tameem Khuder who offered a great help. Last, but not least, thanks to all my friends and family for continuously supporting and encouraging.

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LIST OF SYMBOLS AND ABBREVIATIONS

CBCT	:	Cone Beam Computed Tomography
3D	:	Three-dimensionally
DPT	:	Dentopantomograph
IOD	:	Implant Overdenture
SD	:	Standard Deviation
TMJ	:	Temporomandibular Joint
PLA	:	Polylactic Acid
FDM	:	Fused Deposition Modelling

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CHAPTER 1: INTRODUCTION

The demand to treat edentulous patients who are having problems wearing conventional complete dentures using implant retained overdenture is increasing. Implant-retained overdenture is more favourable among patients because this treatment modality is more cost-effective and applicable (Henry, 2000). However, a 10-year follow-up study by Henry et. al (1995) had reported that the implant-supported fixed prosthesis was more successful than the overdenture in preserving marginal bone height around the implants with individual implant failure. On the other hand, implant overdenture prosthesis had also been shown to minimize mandibular bone loss compared to conventional complete denture prosthesis (Von Wowern & Gotfredsen, 2001) (Khuder at. al, 2017).

The force action in implant overdenture cases can be explained by lever actions. Implant-supported mandibular overdentures with 2 implants presents with two kinds of lever forces acting. The first being the first lever arm which is the distance from crestal bone to the abutment, and the second being the second lever arm which distance from occlusal plane to abutment. When the first order lever is decreased and the second order lever is increased, the stresses on the residual ridge may be decreased which in turn may proportionally preserve bone height. The stress obtained from applying a mastication load both unilaterally and bilaterally is distributed into 2 segments namely: the posterior ridge and the bone around the implants (Ebadian et. al, 2012).

The craniofacial morphology, contributes to the physiologic and morphogenic variables affecting bite force values. Maximum bite force varies with skeletal measures that equates to the ratio between anterior and posterior facial height as well as, mandibular inclination and gonial angle. The geometry of the mandibular lever system mirrors the amounts of bite force. The elevator muscles exhibit greater mechanical advantage when the ramus is more vertical and the gonial angle is more acute (Ingervall & Minder, 1997).

A negative correlation is exhibited between bite force and mandibular inclination. An increase in bite force could result in the transmittal of more stress to the residual alveolar ridge (Mercier & Lafontant, 1979). The long-faced type of the cranio-facial morphology had reported being in association with smaller values of the bite force and vice versa (Farella et. al, 2003). Researchers also suggested that a significant correlation exists between bite force and muscle thicknesses and between masseter-temporal muscle thickness and facial morphology. It has been concluded that masseter muscles are thicker in short-faced subjects than in normal or long-faced subjects. As a result, short-faced people may exhibit stronger bite force.

Facial height may vary in individuals with varying gonial angles. This is because of facial height influences the degree of masseter muscle attachment to the lower border of the mandible. Thus, it can be hypothesized that the gonial angle affects the elevator muscle attachment. This relates to the bite force generated and the amount of residual ridge resorption. Even though implant-supported overdenture patient encounters lesser bone resorption compared to conventional dentures, the event of contraction still occurs. To assess the amount of predictable bone resorption, the gonial angle may serve as a guide in clinical evaluation.

Various researches have been done and presented on the implant overdenture and bone resorption. However, there is insufficient evidence to conclude the involvement of the gonial angle, and residual ridge resorption. The association between mandibular anatomy and bone resorption of implant supported over denture needs to be explored further.

1.1 Aim of the study

This study aimed to investigate various methods of gonial angle measurements and to determine the association between gonial angle and residual bone resorption in edentulous patients provided with implants overdenture.

1.2 Objectives of the research

i) To compare between exterior border points method and mid-condyle points method in the gonial angle measurement based on DPT images.

ii) To determine the association between methods of gonial angle measurement from DPT and 3-dimension (3D) printed models to the measurement based on the lateral cephalometric view of Cone-beam computed tomographic (CBCT) images.

iii) To determine the correlation between the gonial angle and posterior residual ridge resorption in mandibular implant-overdenture patients based on DPT images.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Dentition in a person maybe lost due to dental caries, trauma, erosion, attrition, abrasion or lost through periodontal diseases (Holt et. al, 2000). Following tooth loss, the residual alveolar ridge will continuously reduce because of bone resorption resulting in a decreased denture-bearing area. This resorption is tremendously great during the first few months after the tooth extraction than later (Kovačić et. al, 2012). According to Glossary of Prosthodontic Terms (GPT) (2017) residual alveolar ridge is the portion of the alveolar ridge and its soft tissue covering which remains following the removal of or loss of teeth. Klineberg et. al (2012) mentioned that tooth loss represents a major oral disability which is comparable to an amputation, with severe impairment of oral functions.

The sequelae of tooth loss leading to an edentulous arch causes continuous residual ridge resorption (RRR) both in the horizontal and vertical direction. This is an ongoing loss of hard and soft tissues. Clinically it maybe most noticeable when there is a loss of orofacial support which includes facial esthetics, phonetics, and the collapse of vertical dimension. These changes will give an ageing appearance to the patient due to the lack of lip support and decreased facial height (Vogel, 2008). Concurrent with these changes on facial structures are impaired oral function, pain, insufficient retention, and instability of conventional dentures resulting in nutritional and psychological changes. Brodeur et. al (1993) found that this group of edentulous patients mostly consume less vegetables and fruits which cause poor quality diet.

The rate of bone resorption often varies among different individuals and within the same individual at different times. Atwood in 1962 stated that the factors related to the rate of resorption are divided into anatomic, metabolic, functional, and prosthetic factors. Anatomic factors describe the size, shape, and density of ridges, the thickness and character of the mucosa covering, the ridge relationships, and the number and depth of sockets. Metabolic factors include all of the metabolic factors which control the relative cellular activity of the osteoblasts (bone-forming cells) and the osteoclasts (bone-resorbing cells). Functional factors include the frequency, intensity, duration, and direction of forces applied to the bone which are affecting the cellular activity, resulting in either bone formation or bone resorption. Prosthetic factors consist of the myriad of techniques, materials, concepts, principles, and practices which are incorporated into the prostheses. Age, gender, and general health of the patient are relatively inadequate to describe the bone resorption but do suggest some idea on clinical outcomes.

Treatment of an edentulous patient with conventional complete dentures is a routine management. This classical treatment plan is relatively inexpensive in comparison to fixed implant-supported prostheses. Similarly, to any restorative step or procedure, a complete removable denture requires extensive consideration to detail if an excellent clinical result is to be achieved. If the denture resulted is unstable or inadequately retained, it will leave the patient with dissatisfaction especially during function. These patients usually report with problems such as pain when chewing or reduced efficiency in mastication (Al-Ghafli et. al, 2009). When there is a lack of satisfaction with the present denture, the patient will seek for a new one. Lack of denture satisfaction may also be due to compromised occlusion and esthetics.

Delivery of a complete denture to the patient is not the final step in the treatment of edentulous patients. A conventional complete denture may eventually become an ill-fitting prosthesis. One of the greatest drawbacks of full denture is the misconception on the patient's part, that dental care is no longer needed. Such patients deny themselves of routine maintenance of their prostheses and general oral health. Patient's recall and review visits to the dentist is mandatory and it continues long after that (Zarb et. al, 2004). Patients in this present day, have high expectations for oral health. Thus, implant-supported overdenture is one of the solutions to these problems (Doundoulakis et. al, 2003). Implant-supported overdenture is defined as a removable complete denture that is supported and retained either completely or partially by dental implants (GPT, 2017).

The success of the implant-supported overdenture treatment obviously requires maintenance of healthy peri-implant tissues. Reason being the soft tissue seal around the implants indicates that the surrounding mucosa is not inflamed. Good oral hygiene and regular professional care are essential to maintaining these prosthesis (Humagain et. al, 2008). Periodontal maintenance, periodic clinical assessment of implant fixtures, prostheses and surrounding tissue is vital to clinical success. Professional removal of supragingival and subgingival deposits on a regular basis and counselling on the home care technique is equally critical (Humphrey, 2006).

2.2 Conventional complete denture versus implant supported overdentures

The greatest issue with complete dentures is mostly seen in the mandibular denture. There are treatment options that could assist in increasing retention and stability when conventional denture as management is not optimum. The implant overdenture is a remarkably accepted solution because of its associated simplicity, minimal invasiveness, and cost-effectiveness. The implant overdenture supported by both implant and mucosa for the removable prosthesis compared to that is supported only by implants, but resulted in a greater number of implant placement. The rate of resorption of residual ridges with implant-supported overdenture decreased significantly from the resorption rates seen of ridges with conventional dentures. A combined mucosa–implant-supported overdentures show less bone resorption in contrast, to purely implant-supported or purely mucosa supported prosthesis (Assad et. al, 2004).

Two to four implants may be used for support the implant overdenture; however, it is advantageous to use more than two implants to accommodate the improbable circumstances if one of the implants fail during the patient’s lifetime. Many options are available for the retention of the prosthesis, such as magnets, clips, bars and balls. The resultant implant-supported overdenture had good stability and retention, and patients who have received them have better function and satisfaction. Implant-supported denture makes a very crucial contribution to the patients overall general health because patients can consume a better diet with more nutrition and fibre (Doundoulakis et. al 2003).

Doundoulakis et. al in 2003 also discussed the disadvantages of conventional complete dentures versus the advantages of implant-supported overdentures. Disadvantages of the conventional complete denture is listed as the need for extensive detail specification for proper fabrication, lack of retention and stability (especially in mandible), continued loss of alveolar bone leading to further instability and lack of chewing function if ill-fitting. Advantages of the implant-supported overdenture on the other hand, includes the need of only a few implants to support the prosthesis, good stability, good retention, improved function, improved esthetics, reduced residual ridge resorption and the possibility for the incorporation of existing denture into the new prosthesis.

Burns et. al in 1995 did a prospective clinical evaluation of mandibular implant overdentures for patients’ satisfaction and preference using questionnaires. Through this he found that 2 mandibular implant supported overdenture opposed by a maxillary conventional complete denture is a more satisfactory treatment than conventional complete dentures for edentulous patients. Yunus in 2015 concluded that with both implant-supported mandibular overdenture or fixed prosthesis, the oral health-related quality of life (OHRQoL) may be increased.

2.3 Mini implant as an alternative to standard implants for mandibular overdenture

Mini-implants are an alternative to standard implant fixtures in most edentulous situations. Their reduced diameter (<3.0 mm) enables insertion in narrow ridges. The insertion procedures are also simpler and faster, as they use a reduced series of drills, often with a flapless approach. With this approach augmentation procedures may be avoided, more cost effective, greater comfort and reduces risks of postoperative morbidity (Mazor et. al, 2004).

A review done by Sohrabi et. al (2012) reflects the survival rate of small-diameter implants which appears to be similar to that of regular diameter implants. In this study, the majority of the studies reported to have survival rates between 95–100%, and no study reported survival rates below 89%. It can be concluded that the survival rates of mini-implants are favourable when used for mandibular overdentures. The treatment outcome also praises patient satisfaction (Sohrabi et. al, 2012).

The placement of 4 mini implants when compared to 2 ensures greater survival of the overdenture prosthesis. However, 2 standard implants in the mandible ensure better outcome and OHRQoL in comparison to mini implants. This will compensate for the continuous insertion-removal cycles exhibited at the attachment system. The success of a treatment is usually patient centred and subjective (De Souza et. al, 2015).

Table 2.1: Survival rate of mini implants placed on edentulous mandible for overdenture prosthesis.

Citation	Study design	Implant type	Implant size	Implant length	Number of implants/ Number of patients	Jaw segment	Type of restoration	Follow-up duration	Survival rate
Al-Nawas et. al (2011)	Randomized trial	Straumann	3.3mm	8mm, 10mm, 12mm, 14mm	178 implants, 89 patients	mandible	overdenture	1 year	98.0%
Spiekermann et. al (1995)	Retrospective study	IMZ	3.3mm		127 implants, 61 patients	anterior mandible (between mental foramina’s)	overdenture	10 years	95.0%
Ahn et. al (2004)	Prospective study	IMTEC	1.8 to 2 mm	13mm, 15mm, 18mm	27 implants, 11 patients	mandible	overdenture	6 months	96.3%

2.4 Factors for success of implant treatment

Success and survival of treatment are two words very closely related but different. A surviving dental implant intraorally may not be as successful as a treatment. Success criteria in implant treatment as indexed by Cochran et. al (2002), (a) Absence of persistent subjective complaints, such as pain, foreign body sensation, and/or dysesthesia (b) Absence of a recurrent peri-implant with suppuration (peri-implantitis) (c) Absence of mobility (d) Absence of a continuous radiolucency around implant and no rapid progressive bone loss (e) Possibility of restoration. Any implant with anomalistic symptoms and signs as mentioned will usually be considered as a failure and be explanted (Cochran et. al, 2002).

The success of an implant is mainly determined by, demographic variables, health-status variables, anatomic variables, implant fixture-specific variables and prosthetic variables (Vehemente et. al, 2002). Demographic variables suggest the patient's age at the time of implant placement and gender. When patients age increases, the failure rate tends to accelerate. As people get older, bone density decreases because the amount of bone resorption is greater than the amount of bone production. As the cortical bone is thinner, porosity increases in spongeous bone (Bryant, 1998). General health status was graded using the American Society of Anesthesiology (ASA) system, a preoperative morbidity. Patients were classified as healthy (ASA 1), with mild systemic disease (ASA 2), or with moderate or severe systemic disease (ASA 3). Medical conditions that compromise wound healing, such as immunosuppression or diabetes, and current tobacco use status is vital to be investigated. Preoperative morbidity greatly influences postoperative outcomes. In patients with ASA 2 and above there must be an allowance of adequate time to stabilize preoperative medical status and planning of postoperative monitoring (Leung at. al, 2001).

Surgical technique and approach of the operator also contributes to the success of the treatment. Failure can be diminished if these related factors are selected appropriately to suit the clinical scenario and to achieve primary stability during the procedure. Even in poor quality bone, when operators select the proper length, diameter, shape, surface of the implant and improved surgery methods, they can increase initial stability and the treatment outcome (O'Sullivan et. al, 2000). In the fully edentulous mandible, failure rates of fixed partial denture and overdenture when discussed by Goodacre et. al (2003) were 3% and 4% respectively.

Anatomic variables are a predictable indicator for the success of any treatment. Through this, we can reason out the forces, stress and strain that is acting on the prosthesis. Amongst the indicators are the density of bone as described by Misch (2008): D1 (dense cortical), D2 (porous cortical and dense trabeculae), D3 (porous cortical and fine trabeculae) and D4 (fine trabeculae). Bone density is directly related to the strength of the bone before microfracture. He also noted that the bone density influences the amount of bone contact with the implant surface. The bone-implant contact (BIC) is greater in the cortical done than the trabecular bone. Thus, D2 would be ideal for implant placement as it has 65% to 75% BIC. This type of bone can be seen in the anterior mandible, posterior mandible and anterior maxilla (Misch, C. E, 2008). The qualitative character of bone determines the treatment plan during dental implant management (Misch, 1999).

With a sound knowledge of the anatomy of the bone, the muscle attachments, angulations of bone, blood and nerve supply, a more comprehensive treatment plan may be offered to the patient. Information on these anatomical variations maybe gathered through clinical evaluation and radiographs (Ryu et. al, 2015).

The gonial angles precisely denote the muscle attachments to the bone which determines the forces that act on it. Severe ridge resorption has been reported in association with implant-retained overdentures (IROs) (Atwood, 2001). This phenomenon has been attributed to several factors, namely higher bite force, higher contact deformation exerted by the type of prosthesis, and the concentration of forces induced by the type of prosthesis on the posterior region of the mandible due to the cantilever effect. All these factors contribute to severe compression of the soft tissue mucosa under the overdentures and affect the blood flow that supplies nutrients to and removes metabolites from the bone, potentially leading to increased resorption (Sawada et. al, 2011). The blood supply to the mandible predominantly comes from the sub periosteal plexus of vessels and is vulnerable to reduced circulation under denture pressure. Hydrostatic pressure generated in the soft tissue mucosa during function was a major biomechanical determinant accounting for RRR under the denture (Ahmad et al, 2015).

2.5 Gonial angle

Gonial angle is also called as the angle of the mandible or the mandibular angle. It is denoted as the angle formed by the junction of the posterior and lower borders of the human lower jaw. According to Jensen & Palling (1954) the gonial angle is the angle at which the lower border of the mandibular body meets the posterior border of the ramus. This geometric angle is the point of intersection between these two sides. Xie & Ainamo (2004), studied a Chinese population and found an average value for the gonial angle is 128.25° on the left side and 127.68° on the right side.

The action of masticatory muscle strength and the stiffness of the mandibular bone tissue structure will cause leverage on the malformation of the mandible (Chen et al., 2000). According to Da Costa De Sousa et. al (2019) the muscles involved in mastication include the masseter, the medial pterygoid, the lateral pterygoid and the temporal muscles. In functional terms, other groups of muscles are involved only in the process of mastication, such as the post-cervical group, which acts as a stabilizer of the basis of the cranium, and the infra-hyoid group, which stabilizes the hyoid bone, thus allowing the mylohyoid muscle and the anterior venter of the digastric muscle to control the mandibular bone position. According to Newton's 3rd law, "all ordained movements come from a stable basis, provided by the articulations of the body which act as a support at the moment when the strain acts around them, resisting the movements with a strain equal or opposed to the movement strain”. The temporomandibular joint (TMJ) is an operational unit formed by the right and left joint complexes, and since the mandible is a single bone the joints on each side are coordinated so it acts in all movements (Da Costa De Sousa et. al, 2019).

Individuals with low gonial angles have been shown to have higher bite force and larger masseter muscles. The angulations of the masseter have been reported to be more anteriorly inclined relative to the occlusal plane in individuals with high gonial angles, and more vertical in individuals with low gonial angles. Consequently, the force from the masseter was found to be inversely related to the gonial angle (Takada et al, 1984).

2.6 Measuring the gonial angle

In the past there have been many methods that have been employed to measure the gonial angle. The lateral cephalogram was to use a mathematical protractor directly on the radiograph to obtain the value as suggested by Moipolai et. al (2003). Hasegawa et. al (2013) used the lateral cephalograms to trace the ramus plane. Where he describes the ramus plane as a plane that is tangential to the posterior border of the mandible. Later he marked point M as the most inferior part of the symphysis. A line that passes the point M and which is parallel to the occlusal plane is described as the mandibular plane. The intersect between the ramus plane and the mandibular plane makes up the gonial angle. Conventional cephalometric tracings were also used to calculate the gonial angle value. In this, the skeletal landmarks and anatomical planes were used to measure the angle value (Madachi et. al, 2017).

Ahmad et al (2015) used 3D reconstructed model from the Mimics software. A line was drawn tangential to the posterior borders of the ramus and the condyle, and another line tangential to the most inferior points at the lower border of the mandible. The intersection of these two lines formed the gonial angle. As Mimics only allow lines to be drawn from selected points on the model, the line tangential to the most inferior points at the gonial angle and lower border of mandible was drawn on the mandible rather than on its lower border.

A more traditional way to measure the gonial angle was discussed by Helmy et. al (2003). In this study, a conventional radiograph was taken after the sheep mandible was hemisected. The mandibular plane and the ramus plane were drawn. The angle where it intersected was recorded. This method was more practical as it was similar to clinical scenarios of taking a dentopantomogram to do measurements and diagnosis. The gonial angle maybe altered by means of distraction osteogenesis. Distraction osteogenesis is a way to make a longer bone out of a shorter one. After a bone is cut during surgery, a device called a distractor pulls the 2 pieces of bone apart slowly. The result of this research shows that the majority of sheep specimens had a decreased gonial angle after distraction (Helmy et. al, 2003).

Landmark identification with dried mandible can be considered equal in clinical reliability to standard 2D cephalometric analyses according to Catić et al (1998) and Vandenberghe et. al (2015). They also mentioned that, the dentopantomogram is used mostly for the linear measurement of a vertical, horizontal, or oblique variable. Dimensions of structures on the radiographic images are similar to the actual dimensions of the filmed structures as long as the distances measured do not traverse the midline of the mandible. All characteristic distortion effects seen in 2D imaging techniques are due to the different magnification factors that are valid for the vertical and horizontal dimensions outside the centre of the sharply depicted layer. The focal trough on the dentopantamogram is narrow in the anterior region and flares laterally in the posterior region. The reliability of panoramic radiograph is influenced by the head position during imaging (Catić et. al, 1998) (Vandenberghe et. al, 2015).

It is important to evaluate the similarity of the gonial angles of patients both on panoramic radiographs and lateral cephalometric. The first has several advantages over the latter, including the ability to evaluate mandibular asymmetry and mandibular growth direction, the separate and clear measurement of both the right and left sides, with relatively low radiation exposure, and the possibility of greater clinical versatility. It has been reported that the gonial angle is wider for edentulous persons than for dentate individuals. This could perhaps be because of morphological changes secondary to tooth loss and its sequelae (Araki et. al, 2015).

Panoramic radiography has been reported to assist in measuring mandibular inclination and gonial angle. By virtue, dentists routinely request panoramic radiographs during dental examination, for customary treatment planning. Furthermore, in panoramic radiography, the right and left gonial angle scan is measured easily without superimpositions or interference of anatomic landmarks, which may occur frequently in a lateral cephalogram (Katti et. al, 2016).

2.7 Posterior Residual Ridge Resorption

In a study conducted by Wilding et al (1987), mandibular bone resorption was determined by using the proportional area index method. In this, a comparison was made between measurements made directly from dry mandibles, and measurements made from panoramic radiographs of the same mandibles. A method was developed to demarcate two areas of the radiograph, one of which was defined by the crest of the residual alveolar ridge and the other independent of the alveolar ridge. This proportional value was referred to as the Area Index.

2.8 Age and gender

Ageing itself does not cause tooth loss. However, the prevalence of dental and general diseases and functional disabilities increase with age, which may incline the number of older people to become edentulous (Henriksen et. al, 2003). In 2018, the Malaysian Statistical Department had divided our population into 3 classes; (i) young age (aged below 14 years old), (ii) working age (aged 15–64 years old), and (iii) old age (65 years and over). In this study, the mean age of patients is 66.22 years, which shows that patients are mostly of old age class mostly.

In Western countries, older females lose teeth more frequently than males (Pajukoski et. al, 1999), while Japanese men are more often edentulous than women in elderly age group (Shimazaki et. al, 2003). In this study, the number of edentulous females is more than the number of males. The difference in gender might be contributed by other factors such as culture. This includes general health and smoking (Dietrich et. al, 2007). In Malaysia, the prevalence of tobacco use is higher in men (24.8%) than women (3.5%) (Parkinson et. Al, 2009). Apart from that, poor dental attendance has been regarded as an independent separate risk factor for edentulousness (Norlén et. al, 1996). Cardiovascular diseases have also been shown to be associated with poor dental health, tooth loss, and especially with severe periodontal disease (Geerts, 2004). Socio-economic factors, such as income and educational level, have been shown to be associated with edentulousness. This association may be related to the financial status or cultural differences amongst social classes (Palmqvist et. al, 2000).

2.9 Type of implant attachment

Patients in this study were treated with either telescopic attachment (34.8%) or locator attachment (65.2%) for their implants to receive the implant-supported overdenture. Prasad et. al (2014) had concluded that the criteria for selection of implant attachment include, available bone, patient's prosthetic expectation and economical status, the clinical expertise of a specialist and the availability of skilled technician. For example, the required inter-arch space for telescopic attachment is larger in comparison to the locator attachment. Even though the telescopic attachment type may be regarded as a first choice, it may not be feasible in every case. Any type of attachment if properly selected will give positive treatment outcome. However, in this study, it is documented that not only attachment type but also the position of implants in the jaw influences the retention and stability of the prosthesis.

In a 3-year prospective clinical study on maxillary implant overdentures by Zou et. al (2013), locator attachment produced superior clinical results compared to the telescopic attachment in terms of peri-implant hygiene, prosthodontic maintenance measures, and removable prosthesis rehabilitation. However patient satisfaction may be independent of the attachment system even though it may affect the success of treatment (Kim et. al, 2012).

CHAPTER 3: MATERIALS AND METHOD

3.1 Study design

This is a retrospective study done on complete denture patient who had received maxillary complete denture opposing mandibular implant overdenture prosthesis in the Department of Restorative Dentistry, Faculty of Dentistry, University of Malaya. Ethical approval for this study was obtained from the Faculty of Dentistry Medical Ethics Committee with reference number DPRG/20/17.

3.2 Sample size calculation

Residual ridge resorption

The sample size was calculated using G*Power (Version 3.0.10, 2008) for correlation of bivariate normal models. It is to test the association between mandibular residual ridge resorption to gonial angle. The expected correlation was set at 0.3 (to obtain moderate correlation) and power set at 0.8, to give an estimate sample size of 67.

However, in this study, only 23 patient's data were available and all were included. The power calculated was 0.3 with $\dot{\alpha}$= 0.05.

Gonial angle measurements

A minimum sample of 9 gonial angle values are required to fulfil the G*power testing for 23 patients to compare 4 methods of the gonial angle measurements. Thus, 5 printed mandibles are used to give a minimum of 10 angle values.

3.3 Instrument

3.3.1 Dentopantomogram (DPT)

Selection of radiographic images

The DPT of edentulous patients who had 2 mandibular inter-foramina implants were obtained from the Unit of Oral Radiology, Faculty of Dentistry, University of Malaya. The DPT used was (i) before mandibular implant placement (baseline) (ii) at 4 years review (follow-up). The selection criteria for the radiographs were (i) no overlap between the maxillary and mandibular jaw bones, (ii) visible gonion and sigmoid notches of the mandible, (iii) visible exterior border of the condyle.

All DPTs were performed in a standard manner using a panoramic unit (Veraviewepocs 2D / J. Morita, Japan), operated at 62/7.5: kV/mA with an exposure time of 14.9 seconds.

3.3.2 Cone Beam Computer Tomography (CBCT)

3.3.2.1 Lateral cephalometric view of CBCT

Lateral cephalic view is used to measure the gonial angle and the data obtained from this measurement method is used as a gold standard for comparison to other methods.

3.3.2.2 3D mandibular printed models

5 CBCT data were selected randomly. The DICOM CBCT data was converted to STL file prior to printing. The mandibular models were printed with polylactic acid (PLA) material (thermoplastic aliphatic polyester) with a slice thickness of 0.10mm. Printing was done using Fused Deposition Modelling (FDM) printer (3D printer model: Ultimaker 2 Extended). This printer uses a material extrusion method for fabrication. In

FDM, an object is built by selectively depositing the melted material layer-by-layer in a pre-determined path.

3.4 Data collection procedure

3.4.1 Gonial angle measurements using DPT

Two (2) different vertical lines were used for measurement using DPT (i) Exterior border points method, (ii) Mid condyle point method. The horizontal line for both methods is the same which is the inferior border of the mandible. The vertical and horizontal lines were drawn of the DPT. The intersection of these lines forms an angle. This angle is measured as the gonial angle and is measured on both right and left sides. The angle measurements were determined by using the Image J software version 1.49. (Wayne Rasband, National Institutes of Health, USA). Measurements were done 3 times under the same viewing conditions.

3.4.1.1 Exterior border points method

The vertical line was drawn from the external border of the mandible which includes the condyle margin until the angle of the mandible. (Figure 3.1). This technique has been advocated in the study conducted by M. Helmy et. al (2013).

3.4.1.2 Mid-condyle points method

This is a newly proposed method for measuring the gonial angle. The vertical line is marked from midpoint of the condyle until the gonion at the inferior border of the mandible. This line was be translated to the posterior border of the mandible as a parallel line (Figure 3.2).

3.4.2 Gonial angle measured from CBCT

Vertical line was drawn from the posterior border of the mandible which includes the condyle margin until the angle of the mandible, inferior border of the mandible forms the horizontal line. Mimics software (Version 20.0) was used to measure the angle digitally. (Figure 3.3)

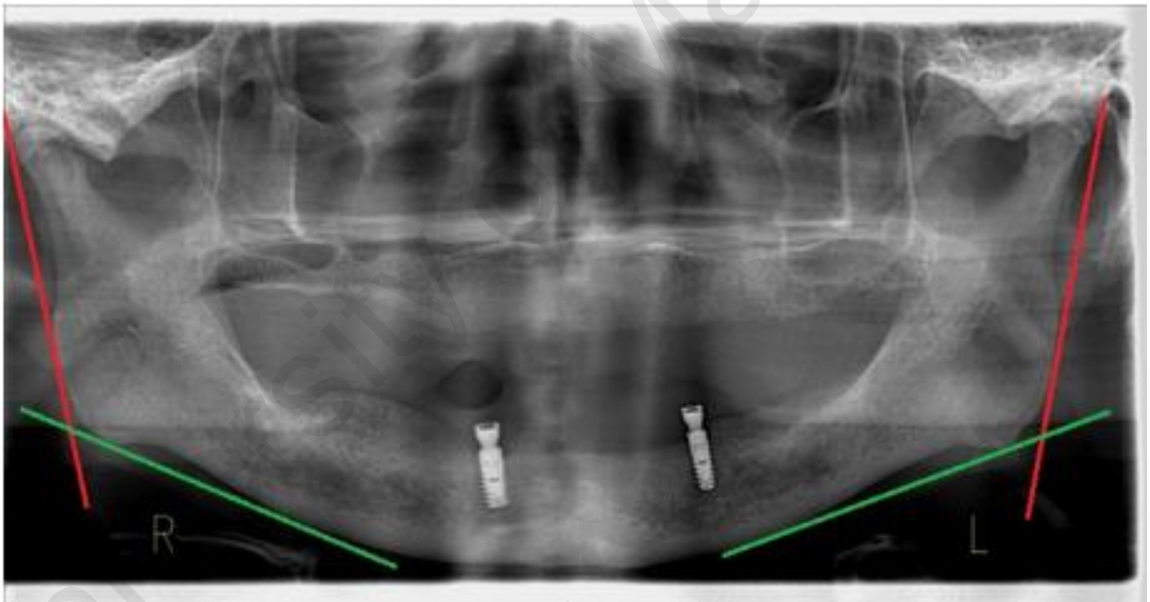

Figure 3.1: Exterior border points method. (red line- vertical line, green line-horizontal line)

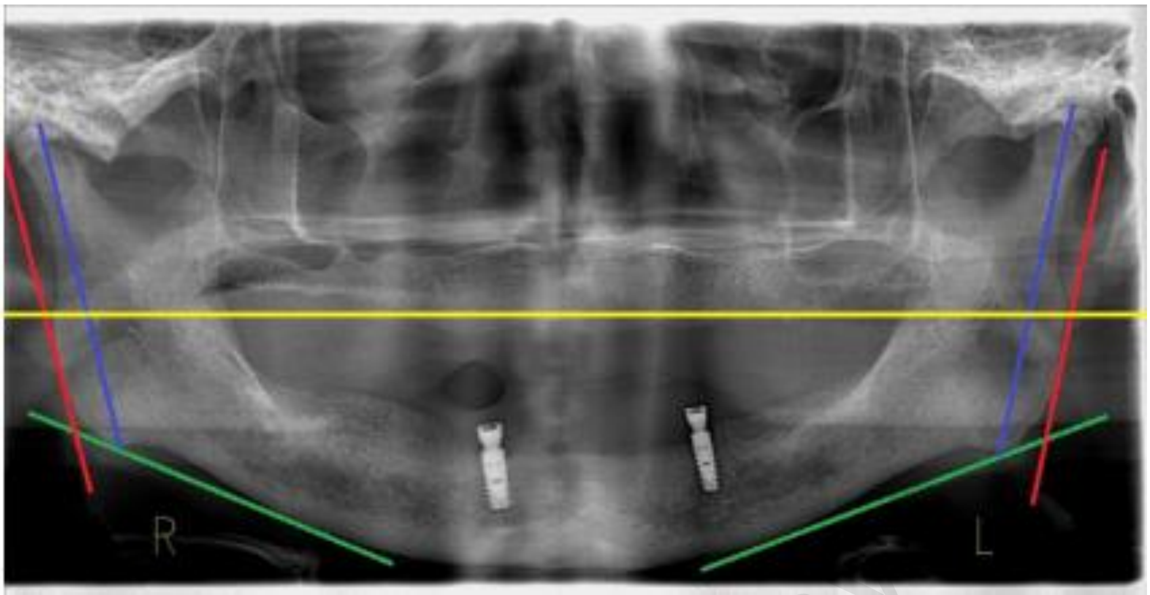

Figure 3.2: Mid-condyle points method. (blue line- mid condyle to gonion, red line- vertical line translated from blue line, green line- horizontal line, yellow line- mid line of image)

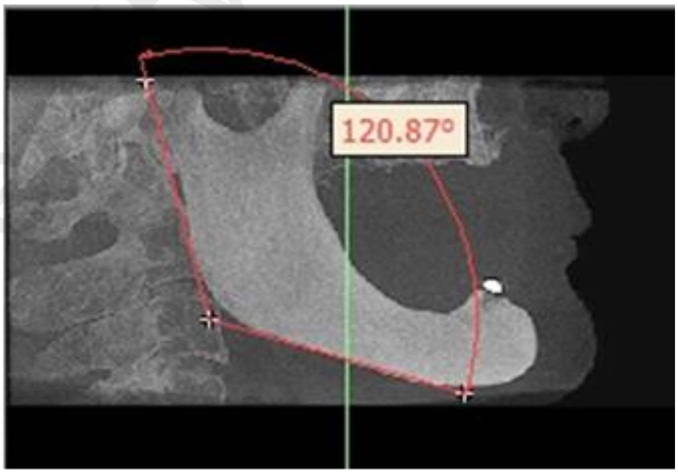

Figure 3.3: Measurement of gonial angle from CBCT images using Mimics software.

3.4.3 3D gonial angle measurement

Figure 3.4: Manual measurement of the gonial angle with a goniometer on patients' 3D printed mandible.

The gonial angle of the 3D model was manually measured using a goniometer (Baseline advantage medical equipment, stainless-steel goniometer). The ruler was placed on the exterior and inferior borders of the mandible. The angle produced at the intersection of these 2 lines is the gonial angle (Figure 3.4).

3.5 Intra examiner agreement

To ensure intra-observer agreement, all measurements were taken by one researcher and repeated after a lapse of 1 week on 3 different days for every method used.

3.6 Secondary data collection

3.6.1 Posterior residual ridge resorption measurement

Measurements for posterior residual ridge resorption for this study were taken at baseline and in a 4-years mean follow-up observation period. This is a secondary data from Khuder. et al, 2017. Reference points and landmarks were digitally traced using Corel draw X6 software version (16.0.0.707, 2012 Corel Corporation). In the mandibular arch, the most inferior point of mental canal M, sigmoid notch S and gonion G (on the left and right sides), used to construct a triangle M-S-G with point N centre. A-M line was drawn perpendicular to G-M line, then G-F line was drawn through N. A and F represents intersection points with the alveolar crest. The G-F line extended to meet S-M line at Q and L-M line was determined on A-M line by the same distance of N-F on G-F line. Posterior mandibular X and Y areas were outlined by AFNM and LQNM respectively.

The ratio for each of these segments was calculated by dividing (X/Y) at each side and the RRR result by subtracting the ratio at the baseline from the ratio at follow-up (Negative value indicates bone resorption) (Figure 3.5). Data was summed up for the left and right sides. The surface area measurements were determined for each X and Y areas using the Image J software version 1.49. (Wayne Rasband, National Institutes of Health, USA).

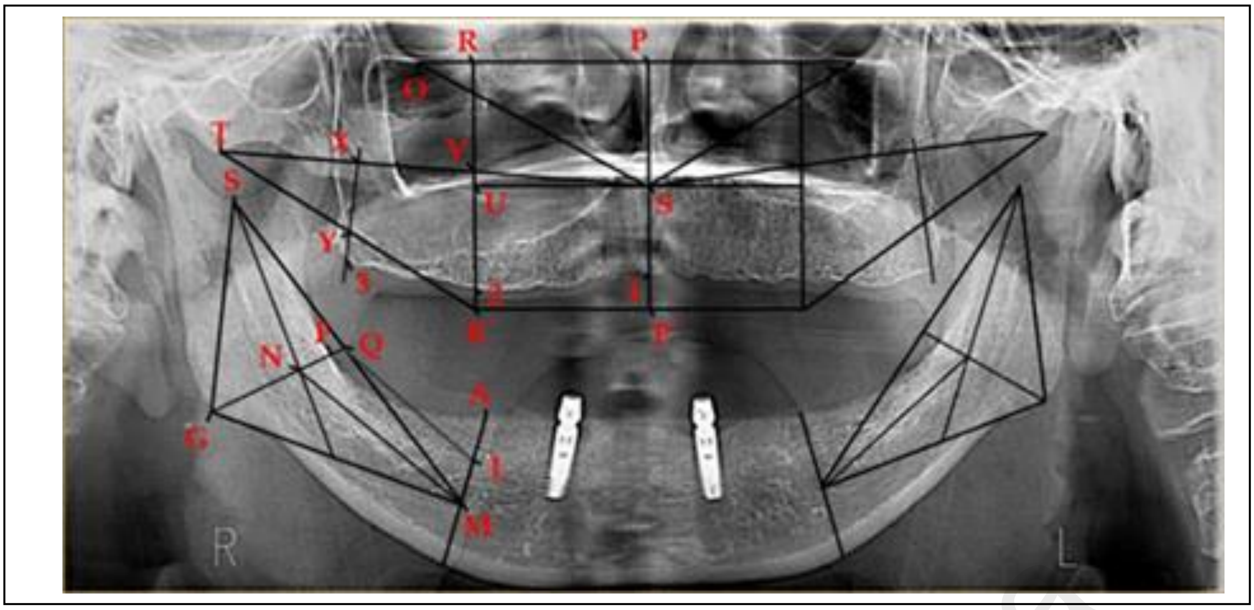

Figure 3.5: Reference points and landmarks for mandibular residual ridge measurement on a DPT.

3.7 Statistical analysis

All the results were analyzed based on the research objectives. Data were analyzed by using SPSS (version 20 SPSS Inc.) with a statistically significant value set at p=0.05. Paired t-test was used to compare means between right and left sides for gonial angle measurement done on DPT. Comparison of the 2 gonial angle measurement methods based on DPT images using exterior border points and mid-condyle points as the vertical line tracing was tested with independent t-test. Levene's Test for Equality of Variances was also performed and equal variances were assumed.

In order to determine the association between methods of gonial angle measurement from DPT and 3-dimension (3D) printed models to the measurement based on the lateral cephalometric view of CBCT images, linear regression was used to obtain the coefficient strength (R^2). The R^2 with the 1 is highest (100%) association and 0 is the lowest (0%). ANOVA with Bonferroni post-hoc analysis was used to compare mean values of measurement methods.

The correlation between gonial angle and posterior residual ridge resorption in mandibular implant-overdenture patients (bone change index) is determined from the Pearson Correlation test.

CHAPTER 4: RESULTS

4.1 Demographic data, types of implant attachment and shape of the mandibular arch

A total of 23 edentulous patients who received mandibular implant-supported prosthesis were included in this study. All patients were treated in 2014 and are annually followed-up. Mean values and distribution of demographic data such as age, gender, type of implant attachment and the mandibular arch form are as shown in Table 4.1.

Table 4.1: Demographic distribution for age, gender, type of implant attachment and mandibular arch forms (n=23).

Variable		**Mean (SD)**	**n (%)**
Patients age		66.22years (8.48)	
Gender	Male		6 (26.1%)
	Female		17 (73.9%)
Type of implant attachment	Telescopic		8 (34.8%)
	Locator		15 (65.2%)
Mandibular Arch forms	Tapered		12 (52.17%)
	Ovoid		4 (17.39%)
	Missing		7 (30.44%)

The age range of the patients was between 53 years and 84 years (mean = 66.22 years, SD = 8.48). Of 23 patients, 6 were males (26.1%) and 17 were females (73.9%).

The attachment between the implant and the overdenture used includes the telescopic attachments for 8 patients (34.8%) and locator attachments for 15 patients (65.2%). The mandibular arch forms of the selected patients were mainly tapered (12 patients) and 4 patients with ovoid arch forms.

4.2 Comparison between exterior border point method and mid-condyle point method as the vertical line tracing on DPT images

Comparison between right and left gonial angles were done for each method using paired t-test. The results showed that there is no significant difference between right and left gonial angles for both methods ($p>0.05$). The p-value for mid-condyle measurement method is 0.744, while for the exterior border method is 0.881 (appendix A).

To compare between two different measurement methods, both left and right side gonial angle of each mid-condyle point and exterior border point were combined to get a larger sample size for comparison ($n = 46$) (Table 4.2). The mean (SD) gonial angle of these 2 measurement methods were compared by independent t-test ($t(90) = 1.335$, $p = 0.185$). Since $p > 0.05$, both measurement methods do not show a significant difference. The Pearson correlation between the tested methods is strong ($r = 0.951$, $p= 0.000$).

Table 4.2: Comparison between 2 measurement methods of gonial angles on DPT (n = 46).

Measurement n = 46	Gonial angle (degree) Mean (SD)	p-value *
Exterior border points	128.76 (7.82)	0.185*
Mid-condyle points	130.89 (7.06)	

*Independent t-test.

4.3 Association between gonial angles measurement between CBCT methods to 3D printed models, and two methods in DPT images

The mean (SD) of gonial angle from CBCT measurement method is 122.45°, SD = 6.82, and the highest mean among all methods is the mid-condyle points method (127.69°, SD = 5.14). However, when all the mean was compared using ANOVA with Bonferroni post-hoc test, the difference was not significant (F (3, 36) = 1.360, p = 0.271).

Association of gonial angles from CBCT measurements to 3 different methods were analysed using linear regression as shown in Table 4.3. Both left and right side gonial angle of each measurement methods were combined to get a larger sample size for analysis.

Table 4.3: Association of gonial angles with CBCT measurements to 3 different methods (n=10).

<table>
<tr><th colspan="2" rowspan="2">Measurement methods</th><th>Gonial angle (degree)</th><th colspan="3" rowspan="2">R^2, p-value*</th></tr>
<tr><td>Mean (SD)</td></tr>
<tr><td colspan="2">CBCT</td><td>122.45 (6.82)</td><td rowspan="2">0.098
0.377*</td><td rowspan="3">0.927
0.918*</td><td rowspan="4">0.829
0.235*</td></tr>
<tr><td colspan="2">3D printed mandible</td><td>126.00 (5.34)</td></tr>
<tr><td rowspan="2">DPT</td><td>Exterior border points</td><td>124.45 (6.74)</td><td rowspan="2"></td></tr>
<tr><td>Mid-condyle point</td><td>127.69 (5.14)</td><td></td></tr>
</table>

R^2=strength of correlation by linear regression

*p-value >0.05 is not significant

A weak association was found between gonial angle measured by CBCT and 3D printed mandible however, this association was not significant (R^2 = 0.098, p = 0.377). Even though high association was found between gonial angle measured between CBCT and both DPT methods, however both associations are not significant. The R^2 for mid-condyle points method is 0.829 (p = 0.235) while R^2 for exterior border points method is 0.927 (p = 0.918) (Table 4.3).

4.4 Correlation between gonial angle and posterior residual ridge resorption in mandibular implant-overdenture patients based on DPT images

The mean (SD) for the right posterior residual ridge resorption is -0.078 (0.081) while on the left posterior mandible is -0.086 (0.095). There is no significant correlation ($r < 0.3$, $p > 0.05$) between both methods and the posterior residual ridge resorption in mandibular implant-overdenture patients.

Table 4.4: Bone change index and gonial angle (degree) by the two methods for each patient with mean values (n=23).

n	Bone change index	Gonial angle (degree)	
		Mid- condyle method	Exterior border method
1	-0.184	130.83	133.01
2	-0.051	138.71	136.38
3	-0.068	124.67	123.19
4	-0.135	117.39	117.35
5	-0.204	123.97	120.15
6	-0.063	141.48	137.90
7	-0.110	117.95	113.36
8	-0.085	141.02	138.42
9	0.071	132.13	131.75
10	-0.106	138.57	138.20
11	-0.037	128.17	124.76
12	-0.039	131.80	126.64
13	-0.027	135.65	136.55
14	-0.006	135.83	133.17
15	-0.055	139.45	140.11
16	-0.129	132.55	128.57
17	0.007	121.56	116.31
18	-0.004	126.55	126.68
19	-0.131	124.17	118.66
20	-0.182	128.66	127.43
21	-0.085	132.22	132.44
22	-0.197	130.33	127.76
23	-0.072	136.75	132.66
Mean (SD)	-.082 (.071)	130.89 (7.06)	128.76 (7.82)
**r-value*	1	0.225	0.204
p-value		0.303	0.349

*(r- value) Pearson correlation for bone change index vs gonial angle (2 tailed) at $p<0.05$

CHAPTER 5: DISCUSSION

5.1 Comparison between 2 gonial angle measurement methods based on DPT images

In determining the gonial angle using DPT, the vertical line and horizontal line has to be clearly defined to measure the angle at the intersection. The vertical line at times on the DPT is not clear as the exterior border of the condyle was blurred out or not clear. Due to this problem, the new vertical line to include mid-condyle points as an alternative is proposed to overcome this issue. This proposed method of using mid-condyle points and exterior border points needed to be correlated to justify the use clinically.

The sample size was 67 when calculated for correlation of bivariate normal models, with an expected correlation set at 0.3 (moderate correlation), with power of 0.8. However, the sample size was small (n = 23), thus the correlation obtained cannot be generalized.

The right and left gonial angles within the same DPT measurement method showed p = 0.744 for mid- condyle method and p = 0.881 for exterior border methods. This shows that the difference between the right and left side were not significant within the same measurement method. When the correlation between the methods were analyzed (n = 46), the correlation was very strong (r = 0.951, p = 0.185). The different methods also show no significant difference in measurement value. From this outcome, both the mid-condyle point method and exterior border point method for measuring the gonial angle on DPT images will give similar degree readings.

5.2 Determination of gonial angles using 3D printed models, CBCT and DPT images

CBCT imaging has become a standard of practice in implant dentistry in comparison to other modalities (Benavides et. al, 2012). Serrant et. al (2014) had proved that CBCT is more accurate as a diagnostic tool than conventional radiographs. Errors on panoramic radiographs are often reported in relation to the position of the patients' head and the focal trough. This leads to unwanted magnification or distortion that reduced the diagnostic value of the radiograph (Yeo, 2002).This 3 dimensional (3D) radiographic modality provides multiplanar reconstructions, significantly less radiation compared with other 3D advanced imaging modalities (such as: medical Computed tomography), fast, efficient, in-office modality, interactive treatment planning, adequate for bone grafting assessment, and compatible for computer-aided surgery.

Since the CBCT is used by most clinician during implant treatment planning, the gonial angle measurements using CBCT is compared to two measurement methods (external border points and mid-condyle point) using DPT and 3D printed models were compared in this study. This shows that there is a strong correlation between CBCT measurements to both DPT measurement methods, but a weak correlation to the manual measurement on 3D printed mandible with a goniometer. However, p-value signifies that there is no significant difference between the methods.

According to Xinhua et. al (2015) there is a large amount of distortion in PLA printed 3D models especially in the margins of the object. In this study, the gonial angles measured are at the margins of the object, the correlation coefficient value was weak maybe due to the distortion during printing. The printing will exhibit contraction forces between layers and may sometimes lead to voids or irregularities of the surface of the printed object (Wang et. al, 2017). This causes small discrepancies at time of measurements and leads to inaccurate readings.

5.3 Posterior residual ridge resorption

The residual ridge resorption on the right and left sides at the posterior mandible is independent of each other. The changes on the right side do not influence the changes on the left side. This shows that the right and left sides are not dependent on variables. Reis & Zaidel (2001), concluded that there is a functional asymmetry on the left and right sides on the face. This paper states that the asymmetry is merely an anatomical variant, not a pathology but may affect the functional component. Thus, this asymmetry cannot be used as a determinant of health.

5.4 Association between gonial angle and posterior residual ridge resorption in mandibular implant-overdenture patients using DPT images

There is no significant correlation between the gonial angle and the posterior mandibular bone resorption ratio (correlation coefficient, $r < 0.3$, $p>0.05$). Previous studies on bone resorption and gonial angle, it showed a negative correlation (Takada et al, 1984) (Ahmad et. al, 2015). The studies done had a large sample size of $n = 55$ on dentate patients (Takada et al, 1984) and used data from CBCT (Ahmad et. al, 2015).

Changes in mandibular gonial angle were studied within the same patient in the dentate and edentulous regions. Ceylan et. al (1998) performed this study using DPT and found no significant differences between the mandibular angles when comparing partially edentulous and totally edentulous subjects. Later Joo et. al (2013) measured the gonial angle of dentate and edentulous patients on 240 DPT's. In this study, it was found that the edentulous patients had larger gonial angles than the dentate. The size of the gonial angle was found to be inversely correlated to the mandibular alveolar bone height.

5.5 Limitations of the study

This study included patients only based on only radiographic selection criteria. Medical records, edentulism period and social history could have influenced the outcome of the results included. Financial constraints made it impossible to recruit many patients for bigger sample size and limited the treatment for a longer overall observation period.

CHAPTER 6: CONCLUSION

Within the limitations of this study, the following conclusions were made:

1. A very strong correlation between the exterior border points method and mid-condyle points method when both points were used as the vertical line during measurement on DPT. Both methods do not show a significant difference.
2. There was a strong association between gonial angle measurement method using the lateral cephalography view of Cone-beam computed tomographic (CBCT) image and dentopantomogram (DPT), but a weak association to the 3D (3-dimensionally) printed models angle measurement. No significant difference between methods was found.
3. There is no correlation between both DPT measurement methods and the posterior residual ridge resorption in the mandibular bone of implant-overdenture patients.

CHAPTER 7: RECOMMENDATIONS

1. To have a larger sample size in the future to establish a more significant result.

2. To have a longer follow-up time from base line to investigate long term effects on posterior mandibular bone resorption.

3. To conduct Finite Element Analysis to study the forces acting on the mandible to understand bone resorption better.

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