CHAPTER 1 INTRODUCTION

The effect of screw angle placement on biomechanical stability of mono-cortical plating should evolve from an understanding of mandibular biomechanics as a functional unit.

For the purpose of this specific investigation a mandibular angle fracture model was created[1, 2] using polyurethane human mandible replicas with elastic modules $^{1}/_{10}$ that of bone, to perform a mono-cortical fixation using unique ISI (Inclined Screw Insertion) plates manufactured for this study. The mandibular angle was chosen as the anatomical area of interest as all rigid internal plating systems applied to the lateral aspect of the ramus/angle, according to the second Champy ideal osteosynthesis line[3] [located infero-lateral (caudal) to the external oblique ridge] demand trans-cutaneous approach in order to apply screws at the conventional 90° angle to the plate surface. An angled screw application will allow plating via preferred intra-oral approach. The vast array of fixation devices with fixation positions have been introduced in the management of mandibular angle fractures. Mini-plates, for the past two decades, are widely used according to the principles described by Michelet and co-workers[4] and Champy and co-workers where plates are placed along physiological functional tension lines. There are many experimental studies simulating fractures at the mandibular angle in a model and testing the stability of different osteosynthesis methods.[5 - 7]

The introduction of an unique own-designed and manufactured testing device with a load protocol to investigate compression/tension and torsional load displacement values of the mandible within known clinical relevant parameters, is proposed.[8 - 11]

The complete absence of other studies on the biomechanical behaviour of angled screw-hole plates prompted this investigation in search of a more stable mono-cortical osteo-synthesis with the probability of intra-oral application screw angles can be differently orientated to the long-axis of a plate and this has been described as a quadrant method explaining the concept (Figure 1). Variations to conventional rectangular screw placement depicted by the vertical line through the plate-hole, can be described as a semi-circle diagonal to the long-axis of a plate and sub-divided into quadrants one and two (1 & 2) or the orientation of the screw angle can be in a semi-circle parallel to the long-axis of the plate geometry in quadrants three and four (3 & 4).

Zero degrees (0°) is represented by the plate surface and a vertical line through the centre of a plate-hole represents rectangular (90°).

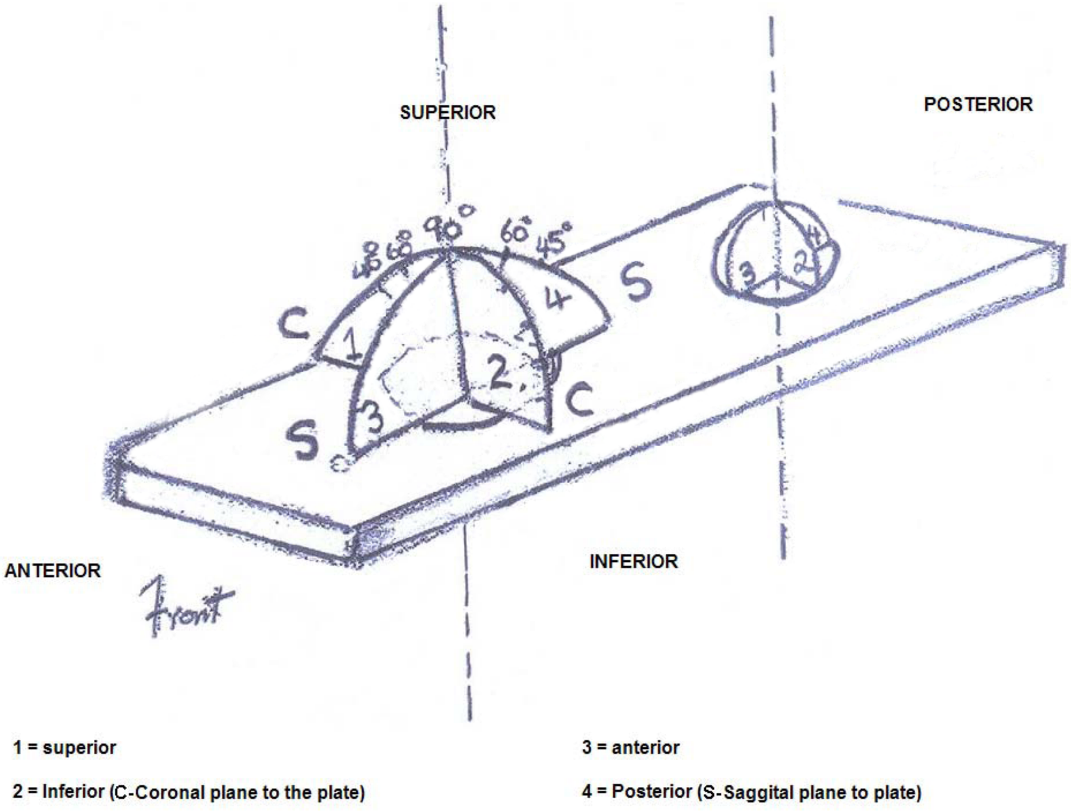


Figure 1: Screw angle-quadrant plate-hole orientation

For the purpose of this investigation all screws were placed in quadrant three at the prescribed angle orientation in the length of the plate for all plate holes in the anterior (distal) fracture-fragment section of the plate and quadrant one for the plate holes in the vertical (proximal) fracture-fragment section of the six hole plates used.

Plating the ventral (lateral) aspect of the external oblique line in a mono-planar, mono-plate fashion with angled screw insertion is unique and is tested according to sound biomechanical principles with proven clinical relevance.

The mono-cortical ISI plates, used in this study, were geometrically identical except for the screw-hole angles. Fracture simulation as an oblique (saw cut) separation at the angle of the mandibular resembled a most unstable fracture situation, clinically relevant to a horizontally and vertically unfavourable fracture. Compression Screw Angle Testing (CSAT) was performed investigating cantilever forces. Tension Screw Angle Testing (TSAT) investigated torsion force stability for angled screw application.

The load point for compression/tension force application was constant without an attempt to discriminate between incisal and / or contra-lateral molar loading. The load/displacement data was kept within the clinical significance of 0 to 200N where torsion would relate to a load point positioned at the contra-lateral molar region. All conventional mono-cortical systems used in rigid fixation of angle fractures with screw angle application of 90°, fail to meet post-operative functional requirements for force values of 200N. The force normally applied under clinical loading of incisal edge and contra-lateral molars, thus inflicting a combination of torsional and vertically deforming forces, are simulated in this investigation by separate compression and torsion testing at 200N load force[12] to create an instability factor. The outcome of this investigation should give clinical significance to a preferred screw application, which facilitates intra-oral application to a fracture line located in any anatomical region of the mandible.

A fixation plate design that demonstrates angled screw holes for fixation of temperomandibular joint prostheses, to facilitate drilling and screw application through a pre-auricular incision, has been previously published.[13]

CHAPTER 2 LITERATURE REVIEW

2.1 Mono-Cortical Plating Strategies and its Biomechanical Problem

Finding clinical relevant parameters for this in vitro study of biomechanical bite forces was a high priority. It is important to relate angled screw application to the controversial aspect of mandibular angle fracture management, which is likely to benefit most from angled screw application.

2.2 The Effect of Plating Techniques and Plate Orientation on Biomechanical Stability

The *in vitro* studies with two-dimensional models described by Champy and co-workers in 1978, show tension effects at the level of the dentition and compression effects at the level of the lower border. With regard to angle fractures three observations can be made in mono-cortical plating of the polyurethane synthetic mandibles.[3]

a) A superior border plate cranial to the external oblique ridge, where intra-oral surgical technique and instrumentation is sufficient to perform a mono-cortical plate-fixation, appears to be less resistant to bending forces during loading.

b) A laterally positioned plate is more resistant to vertical forces but still allows a certain amount of lateral movement.

Clinically this type of oesteosynthesis requires additional trans-buccal instrumentation if conventional rectangular screw placement is performed. A scenario which will change to a more user-friendly intra-oral surgical technique if angled screw insertion is employed.

c) In cases where the fracture line is completely vertical to the massenteric-pterygoid muscle sling, must be expected that the distraction effects during chewing and loading in the fracture region will result in even more displacement at the lower border, which apparently cannot be resisted by a single plate on the tension side.[14] These fractures are both vertically and horizontally

> unfavourable in terms of displacement. Finally, in all mono-cortical plate osteosynthesis cases, fractures are seldom in close apposition on the lingual aspect, regardless of careful adaptation of plates to manually reduced fragments. In the angle region slight gaps at the lower border region in all conditions may be the result of the tension effect of screws in combination with a slight under-bending of the plate. It is generally accepted that during function of the lower jaw, tension will occur at the level of the dentition whereas an effect of compression will be observed along the lower border. In the chin area, symphesis torsional forces produce a combination of tension and compression.[14]

Fixation of mandibular fractures by mini-plates, derived from the system developed by Michelett[4] for treatment of mid-face fractures, was implemented by Champy.[3] The mini plates were applied close to the tension zone of the mandible. Because of the dentition and the alveolar nerve structure, the screws are required to be mono-cortical. Champy[18] claims that this mini-plate system also provides sufficient support and stability to the bone fragments of a lower jaw to allow immediate function. Champy mentions three different zones in the mandible for application of the plates delineating ideal lines of osteosynthesis.[3] Firstly, a neutral zone located sub-apical to the dentition in the lateral portion of the mandible, in this location, one plate is sufficient. Secondly, a two-level zone between the mental foramen in which to plates have to be placed to resist the tensional loads. Finally, the region of the angle in which fixation can be performed with one plate, applied lingually (cranial) or buccally (caudal) of the external oblique line to optimise stability (Figure 2).

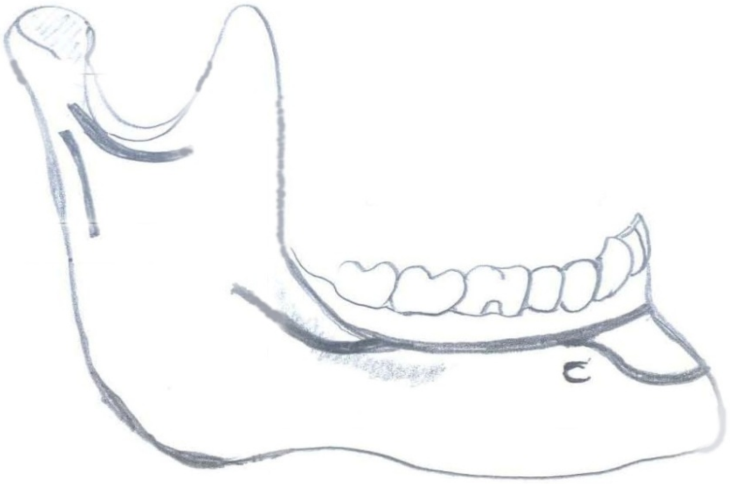


Figure 2: Ideal lines of osteosynthesis, orientated along stress line patterns in the mandible (Condylar neck: Meyer and Corpus: Champy)

Unilateral loading distributed from premolar to molars, will cause increasing distraction at the fracture site at the lower border. This effect is bigger with a secured plate on the superior aspect of the mandibular angle, cranial to the external oblique line as would be with a plate fixed caudal (infero-lateral) of the external oblique ridge as it would be with a fixed caudal (infero-lateral) of the external oblique ridge (the anatomical site chosen for the application of the ISI plate which also corresponds with the strain lines).

All the *in vitro* experimentation regarding mono-cortical fixation of mandible fractures should reveal clinical evidence and relevance to justify plating patterns. In this regard, the treatment of mandibular angle fractures is a very controversial issue with very few prospective studies[15] and, if published, the exclusion criteria are often not well defined, especially in regard to the vertical or horizontally favourable or unfavourable nature of fractures. Currently, popular conventional screw application in most mono-cortical plating systems is rectangular to the plate surface where extra-oral trans-buccal approach is required as in screw fixation of bilateral sagittal split osteotomy fragments or plate fixation on lateral aspect of ramus for mandibular angle fractures. Any plating procedure to the lateral aspect of the ascending ramus and angle of the mandible, demands a stab incision for trans-cutaneous screwdriver trochar and subsequent rectangular screw application (Figure 3). This procedure is associated with possible complications such as scarring, trigeminal and facial nerve damage, bleeding and technical difficulties if it becomes necessary to remove the screws at a later date. Increase in theatre time has cost implications[16] when using a trochar and trans-cutaneous approach.

Maxillo-Facial surgeons have moved away from extra-oral techniques with the superior border mini-plates via intra-oral approach becoming the norm for the treatment of simple mandibular angle fractures. Mandibular angle fractures and the management by either single 2mm mono-cortical superior border plate (mono-plating mono-planar), bi-plating in bi-planar fashion[17 - 19] (one plate on superior border and one on lateral aspect of angle) or bi-plating in a mono-planar fashion[20] superior and inferior on the lateral aspect has become a contentious issue with regard to their inherent biomechanical stability and gapping at the lower border.

Figure 3: Trans-cutaneous surgical approach

2.3 Bite Force and its Clinical Relevance to Mono-Cortical Fixation

As clinicians are using smaller devices with mono-cortical screws, stability of treated fracture segments should at least be in excess of the critical load characteristics for the fracture fragment displacement. Clinically relevant parameters for *in vitro* force application can be deducted from information of the post-surgical population relative to non-operated healthy individuals.

Bite forces in the acute post-operative period are much less than bite forces recorded later in the healing phase and in non-operated individuals.[21] These observations were confirmed when post-operative biting forces were evaluated in 22 patients treated with mini-plate osteosynthesis.

Gerlach and co-workers[22] studied masticatory forces in patients with fractures of the mandibular angle, maximum bite force evaluations demonstrated 31% of normal vertical load one week post-operatively and increased to 58% in the six weeks post-operatively in patients treated with mini-plate osteosynthesis for mandibular angle fractures due to neuromuscular protection. Therefore, the muscle force vectors for the major muscles of mastication can be reduced to 30% (Figure 4).

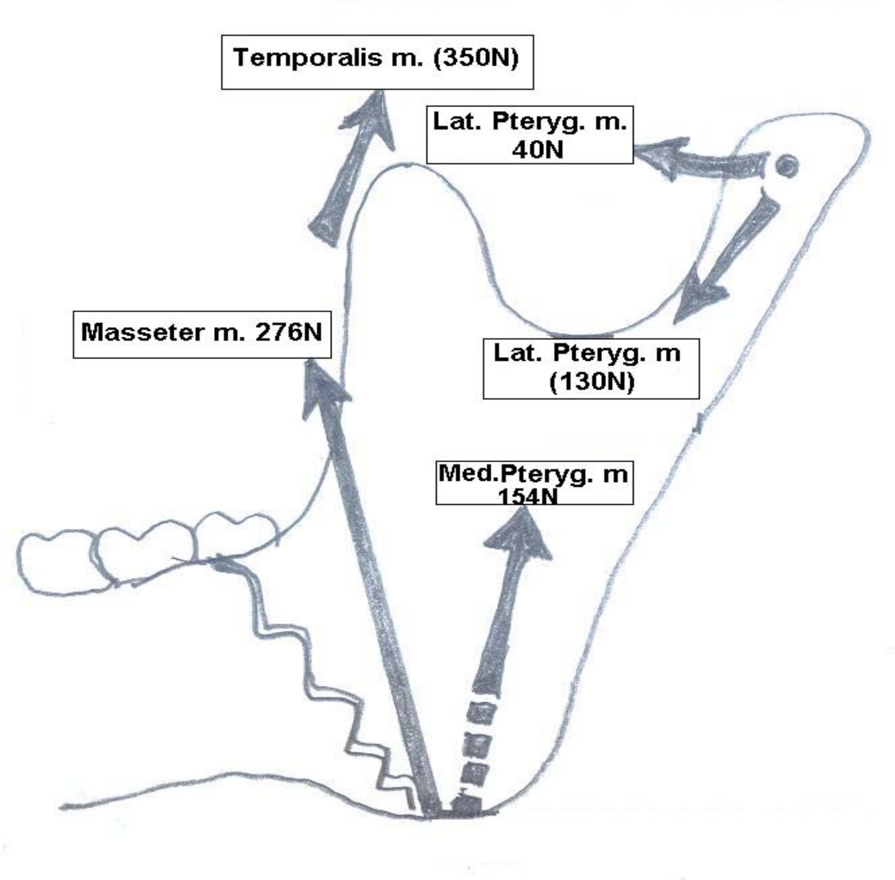


Figure 4: Muscles of mastication (vectors and force values)

Incisal edge loading within 0 to 100 Newton range, and load displacement values for contra-lateral motor loading within 0 to 200N range are considered to be clinically relevant for evaluation of mechanical behaviour of mono-cortical fixation. Masticatory loads following the fixation with mini-plates, exceed 200N three months after osteosynthesis. Several biomechanical stability studies are rendered insignificant as test forces used exceed clinical functional forces.[22] *In vitro* testing within clinically relevant parameters (100 - 200N) should be the norm in comparing the mechanical properties of the different possible fixation philosophies.

In order to adequately investigate the biomechanical behaviour of the various fixation philosophies, an unique testing device was designed and manufactured. The device is located in the Zwick testing machine and allows precise recording of three-dimensional load displacement values of synthetic polyurethane mandibles.

Orthopaedic research has shown better results for torsional load if screws are placed perpendicular to a fracture plane. When bending moments are applied perpendicular to the plane of the screws, screws should be positioned perpendicular to the fracture plane.[23]

Angulated screws in oblique fracture lines, as seen in angle fractures of the mandible, will tend to be more rectangular to the fracture line. Screws placed conventionally through plate holes rectangular to the outer bone cortex, cannot be rectangular to the oblique fracture lines (Figure 5).

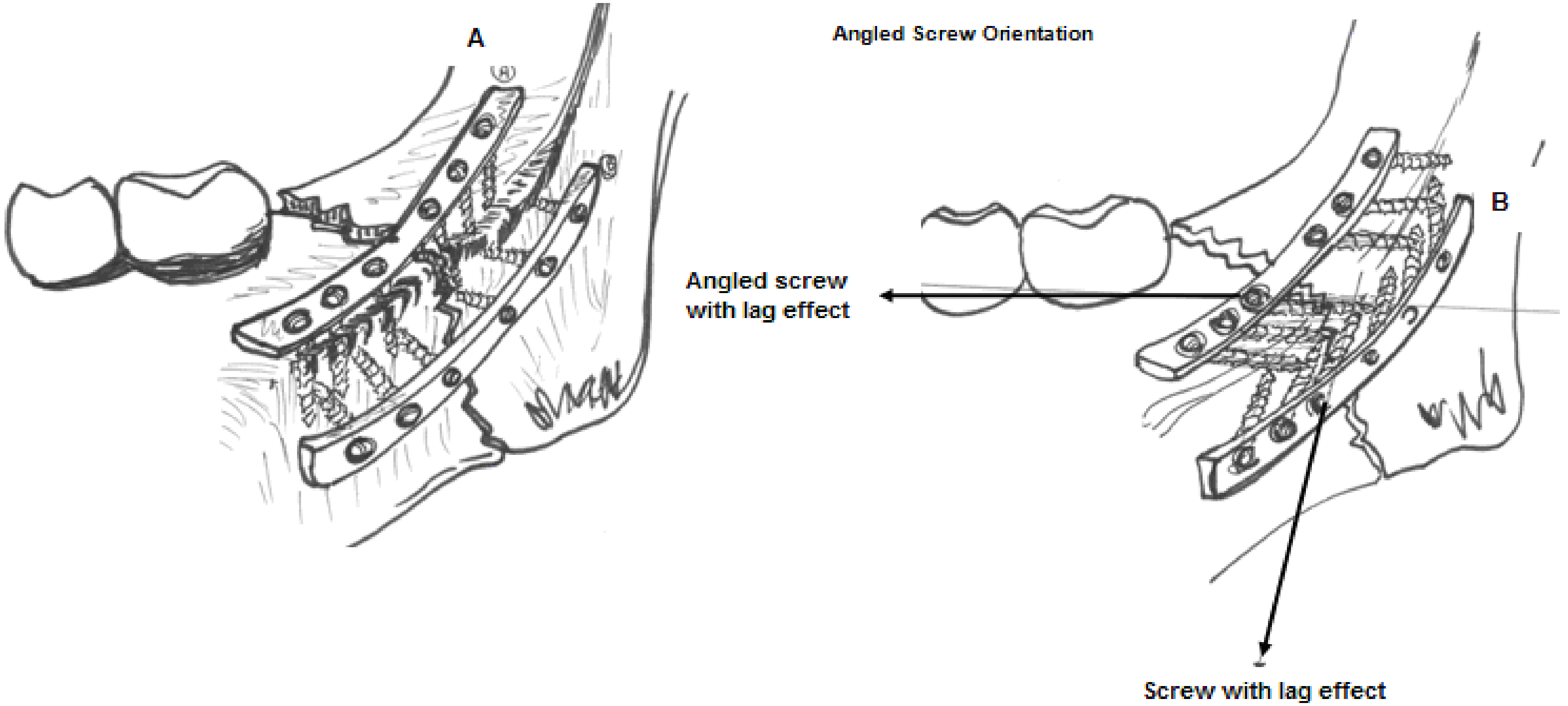
2.3.1 Biomechanical Considerations

In the past three decades, a variety of studies has contributed to the conceptualisation of the biomechanical principles dictating mandibular behaviour during normal function. The two-dimensional models demonstrate tension at the level of the dentition and compression at the lower border of the mandible whereas the three-dimensional approach includes forces of the musculature on the balancing side during mastication. Based on these principles, different methods of plate fixation have evolved to solve the problem of displaced fracture segments.

Currently, controversy continues unabated with regard to the use of one or two mini-plates in mono-cortical plating for the purpose of providing adequate support and stability to facilitate effective immediate function.

In the conventional plating systems, stability is derived from tightening the screw perpendicular to the mini-plate and adjacent bone. Anatomical constraints limit intra-oral access for bi-planar placement of the plate located on the lateral surface of the external oblique ridge. The difficult anatomical access necessitates compensation by drilling and screw application at an angle other than the required right angle. This practice results in an inevitable acute placement angle of screw, screwdriver and screw to bone interface or use of trans-cutaneous surgical approach.

Viewed from a biomechanical perspective, mono-cortical engaging screws inserted at an angle smaller than 90° have a longer surface area of interfacial cortical bone contact and this factor may eliminate the theoretical disadvantage of screw placement at 60°- angle to the bone surface. If this principle is applicable, it can be



A: Superior border plate
Screws at 90° to bone/ plate surface

B: Plate at lateral/ claudal aspect of Linca oblique externa

Figure 5: Screw insertion alignment to the fracture line where (A) angled screw insertion-rectangular to the fracture line and (B) conventional rectangular screw orientation to plate surface and cortex

assumed that the 60° and the 90° configurations should exhibit similar biomechanical characteristics.

If an intra-oral plating system with plate holes at angles <90° were to be designed and placed to coincide with the second more lateral line for ideal osteosynthesis, as described by Champy (Figure 2), its biomechanical properties should be investigated and compared to conventional 90° angle screw placement.[3]

2.4 Angled (Slanted) Screw Application

Krenkel[24] describes principles of the slanted screw plate as follows: “Use of the screw plate is based on the fact that the plate screws can be inserted at angles of between 90° and 30° to the plate surface (*“Comment: the 30° screw angle of insertion has, in this study, been proven to be not clinically viable”)*. The screw head receptacle in the plate is spherical with an oblique insertion groove for the small screw-head which is also rounded on the underside. Four different kinds of slanted screw plates (numbered: A to D) meet most of the requirements arising in maxillofacial surgery. These are made as multi-hole plates in a strip and are cut to suitable length by the surgeon and cannot be contoured to change their shape to be placed along tensile strain lines for all anatomical sites in the mandible.

2.4.1 Type A: Zero degree slanted screw plate

A zero degree slanted screw plate was used by Krenkel as a term in his explanation to describe screw insertion in horizontal plane between 0° - 180°. The screws are inserted from one side along the long axis of the plate. The plate can be used on either the left or right side as an alternative treatment modality for condylar neck fractures. The plate-holes should accommodate screw insertion from 0° to 180° along the long axis of the plate (Figure 6).

The most recent development of the Trapezoidal Condylar Plates (TCP)[25] for functional stable osteosynthesis of fractures in the sub-condylar and condylar region has emphasised the fact that plates should be anatomically specific and geometrically designed along functional tensile strain lines. This *in vitro* study performed on human cadaver mandibles effectively led to optimising the plate design but has plate-holes rectangular to the plate surface. Angled screw–holes in these plates, with the correct angle orientation, would optimise clinical surgical technique favouring either pre-auricular or sub-mandibular surgical approach and be superior in stability compared to rectangular screw insertion.

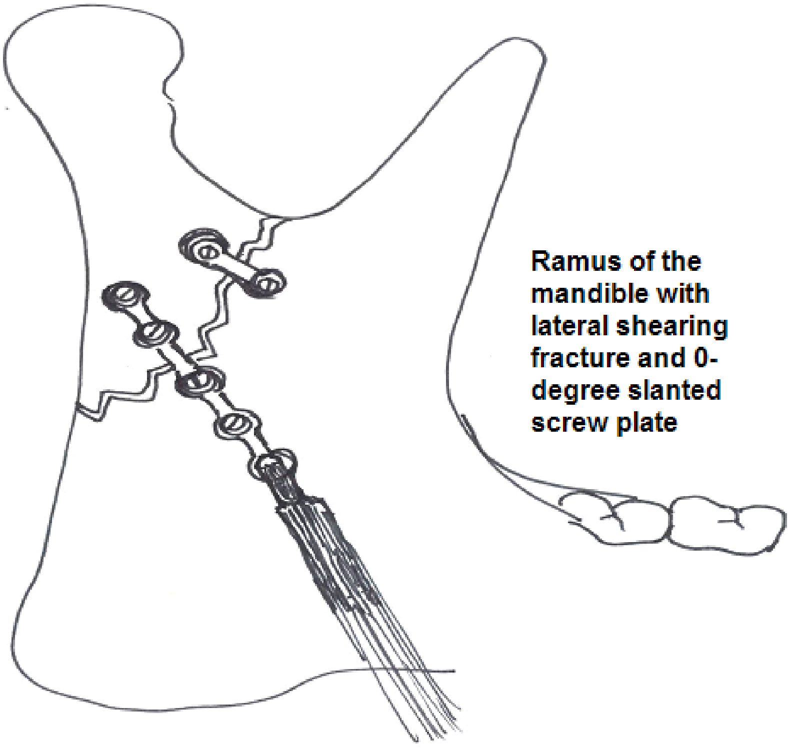


Figure 6: Ramus of the mandible with lateral shearing fractures and 0° slanted screw plate. Screw application between 0° - 180° (0° original description by Krenkel[25] to describe the horizontal plane), no screw can obviously be placed at 0° or 180° to the plate surface

2.4.2 Type B: 45° right side slanted screw plate

The screws are inserted from one side at an angle of 45° from the right of the long axis of the plate. This plate can only be used on the right side (Figure 7).

2.4.3 Type B: 45° left side slanted screw plate

The screws are inserted from one side at an angle of 45° from the left of the long axis of the plate. This plate can only be used on the left side.

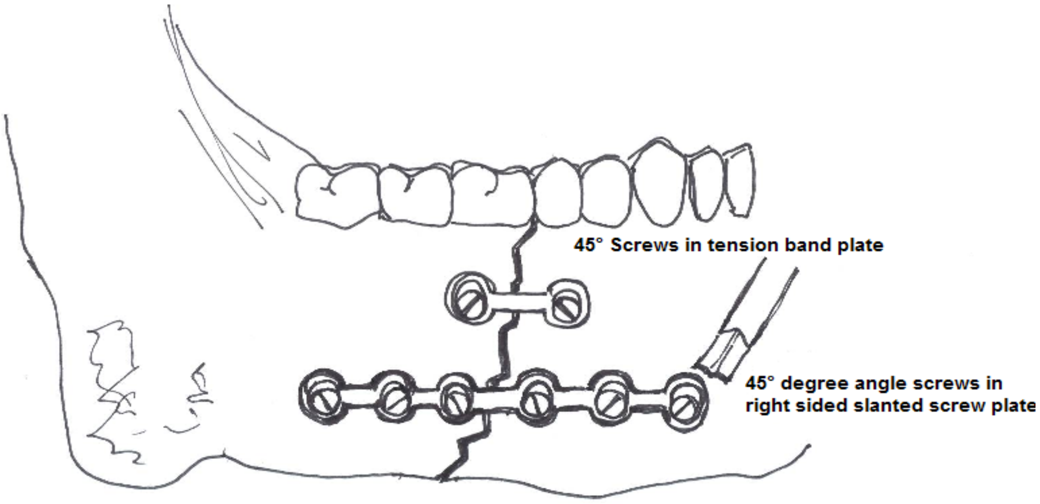


Figure 7: Illustration of right sided, oblique orientation angled 45° (no possible lag effect) screws

2.4.4 Type C: 90° slated screw plate

The screws are inserted from one side at an angle of 45° crosswise to the plate. The plate can be used on either side. The various slanted screw plates are also suitable for other indications; for example, as a primary osteosynthesis plate in the area of the angle of the mandible and in the body of the mandible. Compared to the conventional mini-plate, the slanted screw plate can be easily removed through a small incision because the screw heads are turned toward the oblique surgical access and there are fewer disturbances to the soft tissue. This applies not only to the region of the condylar process but for all intra-oral access for the osteosynthesis of mandibular fractures.

In addition the slanted screw plate may be used as a safety and slanted screw tension plate to add stability to anchor screw osteosynthesis already in place at the upper or lower border of either the body or angle of the mandible.

2.4.5 Type of zero degree slanted screw plate

The screws can be inclined between 0°-180° in the plate holes (0° description by Krenkel[24]) as illustrated (Figure 6).

Angled screw plates: design is complicated by the fact that the screw holes were not cut at a definite angle but rather bevelled to allow variable angle placement (0° and 90° or at slopes allowing 45° placement). This complicated screw-head seating and required washers or oblong holes as shown in Figure 8.

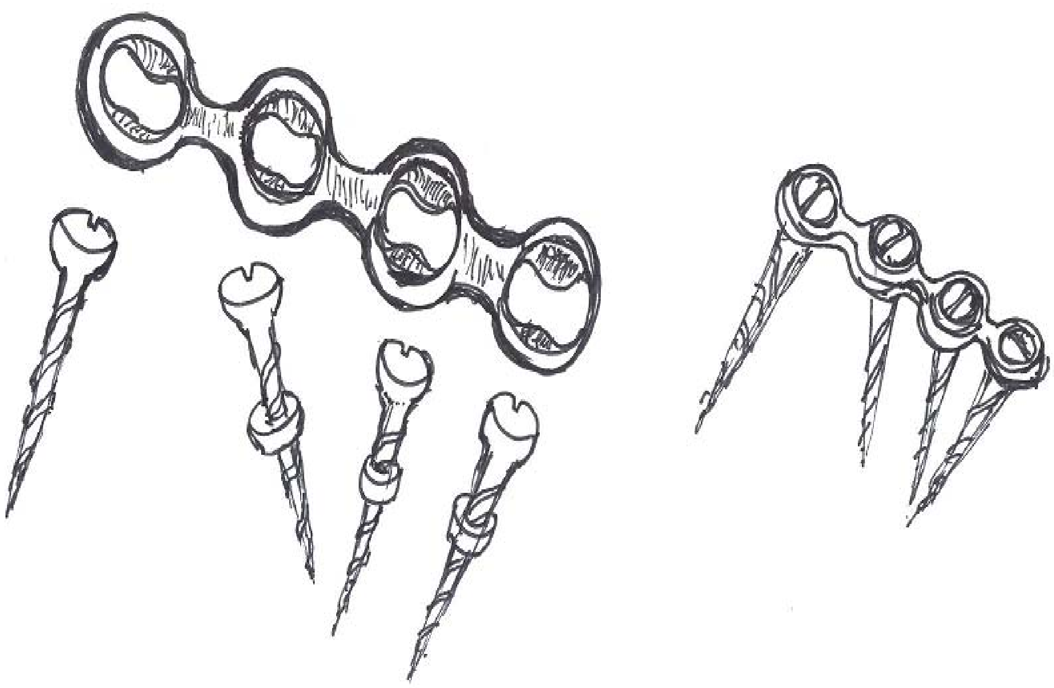


Figure 8: Illustration of screws with washers in multi-angle plate hole (for screw insertion angles 0° - 180°)

These screw plates were used as bi-cortical systems in the ramus and inferior border of the mandible. The plate types A to D are all straight in their design and do not demonstrate plate geometry for placement along specific tensile strain lines which are the basic requirements for functional stable osteosynthesis.

Mono-cortical plating on the lateral aspect of the angle of the mandible using the Inclined Screw Insertion (ISI) mini-plate design, as proposed by the author has been provisionally evaluated.[26] The design concept is illustrated in

Figure 9.

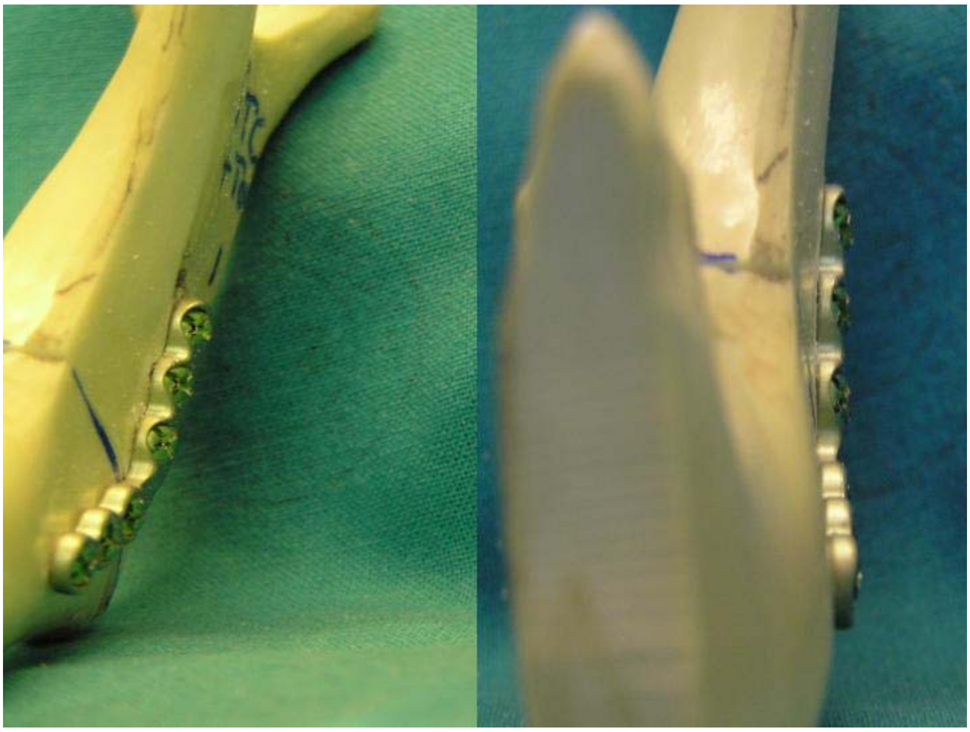


Figure 9: ISI plates applied to lateral aspect of angle of the mandible

2.5 Anatomical Considerations in Angled Screw Application

Viable surgical procedures are dependent on knowledge of the anatomy of the angle of the mandible, including the position of the inferior alveolar neuro-vascular bundle. Furthermore, cortical bone plate thickness varies in the retro-molar area of the mandible which is important when inserting mono-cortical rigid internal plate fixation.

2.5.1 Anatomical consideration for the mandible angle region

2.5.1.1 Cortical thickness in relation to rigid mono-cortical fixation in the mandible angle

Optimum screw length for a mono-cortical screw will engage or transect all the available dense cortical bone for a specific anatomical site if done rectangular to the bone surface 90° at points anthropological interest for screw hole placement. It is known that inferior cortical thickness is very thin at the mandibular angle as opposed to the anterior mandibular region. The cortical plates buccal and lingual at the external oblique ridge of the human mandible are significantly thicker than at the inferior border in terms of cortical thickness, there appears to be mono-cortically at the external oblique ridge over placement. More inferiorly comparative anatomical studies of the mandibular area measured at the external oblique line and 5mm above the inferior border proved that the buccal cortical plate is thicker at the external oblique line (mean: 3.0 to 3.5mm) than at 5mm above the interior border (mean: 2.2mm to 2.5mm) by 0.9 to 1.1mm. This difference was significant ($p < 0.001$) at Sections A, B and C.[27] The thickest cortex is found in the superior-lateral aspect in the third molar area (Figure 10 and 11). Results supported by Heibel and co-workers in a more recent study of autopsy material confirms the above values.[28]

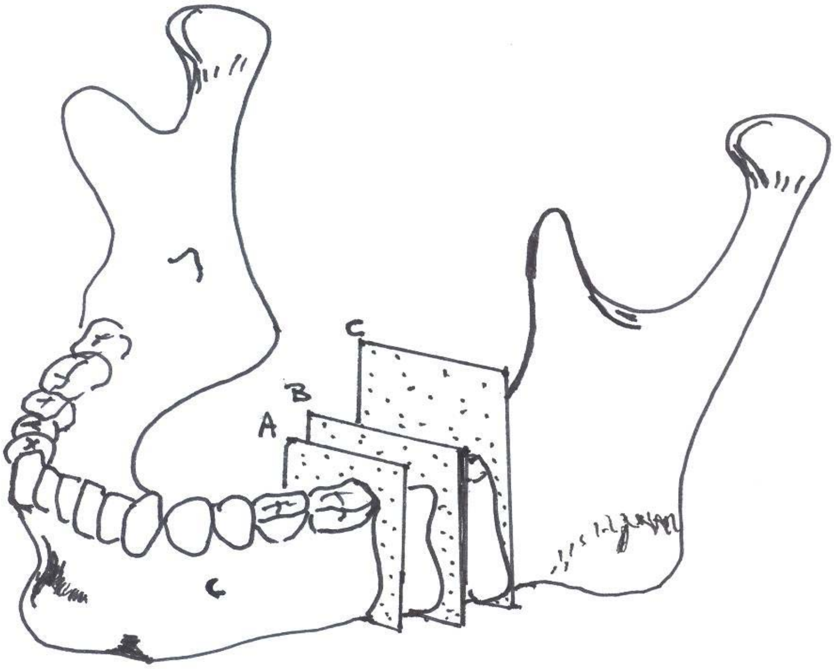


Figure 10: Section A- Distal root of the second molar. Section B- Distal root of 3rd molar. Section C- Just posterior of the third molar tooth and the anterior border of the ramus

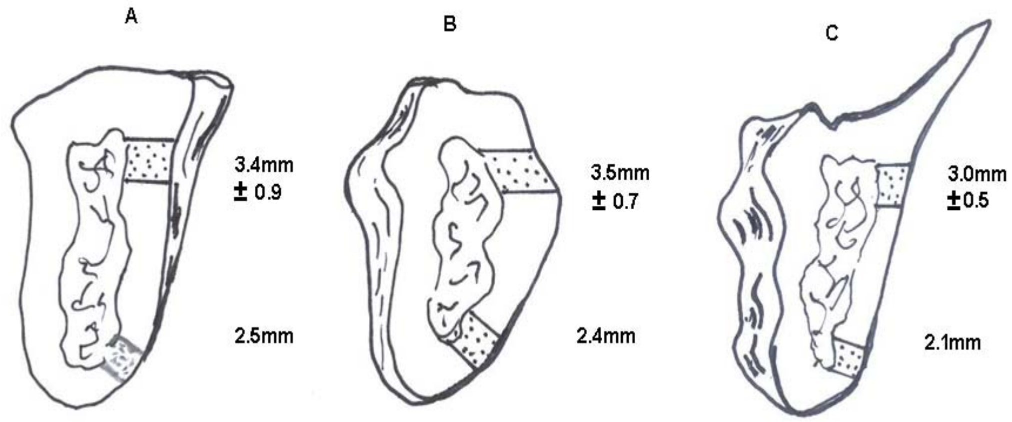


Figure 11: Cortical thickness at different sections A, B and C related to the mandibular angle region

2.5.2 Thickness of the mandible as applicable in a bi-cortical fixation

The total thickness of the mandible at the external oblique ridge and at 5mm above the inferior border is compared in Table 1.

Section	Vertical location	Minimum	Maximum	Mean	S/D P
A	External oblique ridge	70	16.4	13.8	2.0 < .00
	5mm above inferior border	5.4	12.3	9.5	1.2 < .00
B	External oblique ridge	11.6	16.9	14.9	1.4 < .00
	5mm above inferior border	4.0	11.8	8.0	1.5 < .00
C	External oblique ridge	8.0	17.8	13.3	2.0 < .00
	5mm above inferior border	3.3	8.9	6.4	1.3 < .00

The mandible is significantly thicker in the retro-molar region at the external oblique ridge (mean, 13.3 to 14.0mm) than at 5mm above the inferior border (mean, 6.4 to 9.5mm).

2.5.3 Position of the Neuro-Vascular Bundle

Data from anatomical studies indicate that the minimal distance from the inferior aspect of the inferior alveolar canal to the inferior border of the mandible is approximately 5.0mm. The mean distance at the second molar has been found to be 8.3mm and 8.9mm for the third molar region.

If cortical penetration (cutting) is performed just medially to the external oblique ridge, the vertical distance between the most superior aspect of the canal and the cortex will be 6.9mm in the second molar, 10.9mm in the third molar, and 13.9mm in the most anterior symphesis region of the ramus.

2.6 Surgical Approach and Clinical Relevance to Screw Angle Application

2.6.1 Trans-buccal/ per-cutaneous surgical approach for screw systems at 90° to the bone plate surface

A distinct disadvantage of rectangular screw plating in the mandible angle is related to the plate placement on the bucco-lateral aspect. This requires a trans-buccal approach (an approach through the cheek, skin, muscle and periosteum) with the use of a trochar in order to be able to place the screws at right angles (90°) to the plates, as illustrated in Figure 7. Trans-buccal trochar screw placement is required for plates placed buccal or inferior to the external oblique line. Special factors are therefore to be considered according to the fracture site. In certain cases, to ensure avoidance of tooth apices and mental nerve compression by the plate, it may be useful to lower the foramen by making a vertical slot from the inferior dental foramen and set the nerve inferiorly.

In front of the mandibular foramen or, accurately, in front of the canine, two malleable plates, 4.5mm apart, are required to prevent torsion moments. The inferior plate is inserted first, then the sub-apical one. In the horizontal ramus, behind the mental foramen, one sub-apical plate is quite sufficient. The osteosynthesis should be done at higher level the more posterior the fracture is located. For osteosynthesis at the angle, it is known that for several years have used the vestibular osseous flat area located beside the third molar as the osteosynthesis site has been used; that is a genuine ridge made by the external oblique ridge. The plates are located in a frontal plane and the screws positioned in a sagittal direction. When this area cannot be employed (to narrow a ridge, impacted mandibular third molar, alveolar fracture too young a subject) the plate should be applied as high as possible, on the lateral surface of the mandible using the trans-buccal technique. Even in the most difficult cases, a skin incision is unnecessary. After exposure of the angle through the intra-oral approach, the cheek is transfixed with a needle and the osteosynthesis area is determined (as high as possible). The skin is then punctured and penetration of the musculo-aponeurotic tissue is achieved by means of the trochar provided with its guide. The stiletto is now withdrawn from the trochar and the guide is screwed on the retractor with lighting introduced through the buccal approach. The screw-holding screw-driver then enables screw fixation via the transbuccal guide. At the University of Pretoria, the transbuccal method was used in approximately 20% of the cases of osteosynthesis at the angle.

Plates placed in close proximity to these lines produce optimal stability. Note that there are two possible locations for plate placement around the angle within the sympheseal or para-sympheseal areas Champy[3] stressed the need for two plates to counter increased torsional forces.

Studies have shown the possibility of a number of complications. Percutaneous instrumentation can cause a haematoma, false aneurysms, nerve involvement, longer operating time, skin scarring and, furthermore, complicated extended operation time in removing of such plating systems. Higher operating cost due to more time spent has been estimated to add additional operating time of approximately 21 minutes.[16, 29]

Placement of two-plate fixation is more time-consuming and the trans-buccal use of a trochar, which contributes to extended operation time, resulting in longer exposure time of bone to a higher bacterial contamination. Loss of a screw during the surgical procedure, introduced through the trochar, results in extended operating time, as it might have to be retrieved from a tissue plane.

Percutaneous instrumentation is also essential when applying the mono-cortical strut plate system (used to provide increased strength) at the angle of the mandible.[30] The angle of the mandible demonstrates inferior narrowing and the location of a third molar, as an impaction or un-erupted tooth, has a major impact on stabilisation of a fracture. Due to the biomechanics of the mandible, these fractures are associated with the highest incidence of post-surgical complications.

2.7 Screw Angle Comparative Biomechanical Stability Pilot Studies

The biomechanical behaviour of a mono-cortical angled plate hole system has never been compared to conventional rectangular 90° placement for degrees of 75°, 60° and 45°. The plate design for this *in vitro* study has 2mm profile and dedicated screw holes machined at angles of 90°, 75°, 60° and 45°. The plating system can be applied mono-cortically at the infero-lateral aspect of the external oblique line to coincide with the thick cortical area also to be placed with known functional tensile strain lines and according to the second Champy line for ideal osteosynthesis in the angle of the mandible (Figure 12).

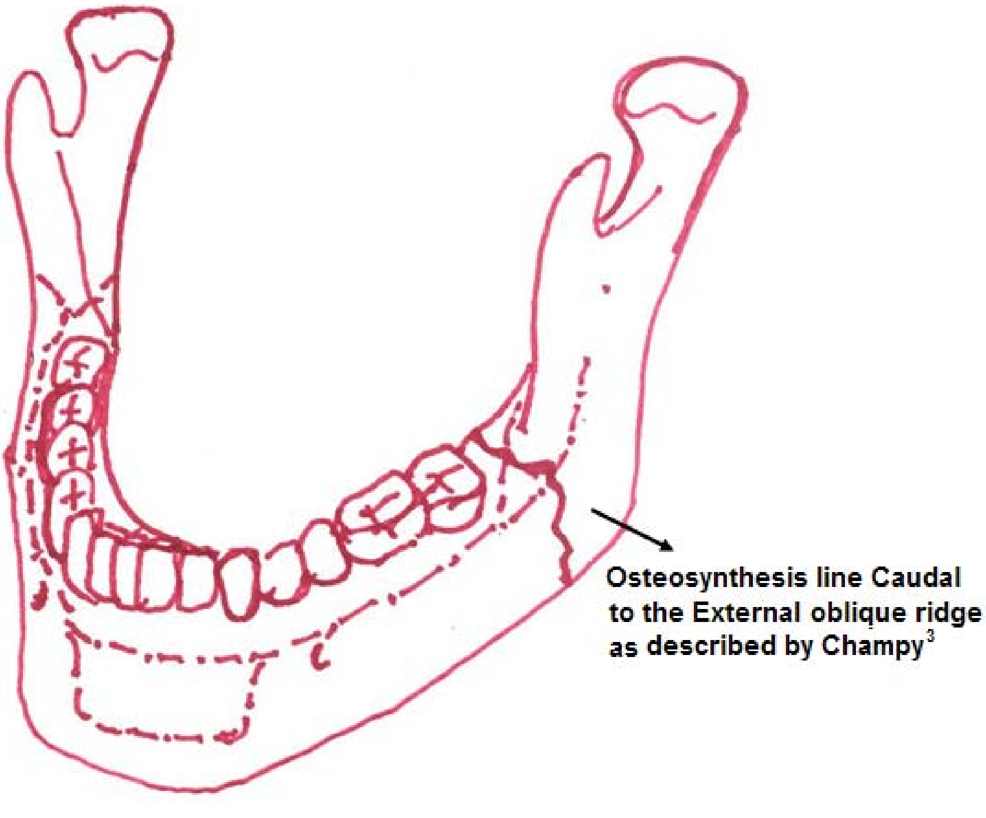


Figure 12: Depiction of Champy's ideal lines of osteosynthesis

Investigating the biomechanical stability behaviour of angled screw application in a mono-cortical fashion would clarify its clinical relevance in view of:

- limited biomechanical stability information available,
- fixation criteria applicable for ISI in mandibular fractures.

The major advantages in its use would be intra-oral minimal invasive application (restricted only by specific anatomical regions with limited access due to tissue tension). A direct line of vision during application simplifies technique for intra- or extra-oral surgical technique.

Bi-cortical angled (60°) intra-oral insertion of screws of 2mm diameter can be used in the rigid fixation of mandibular sagittal split ramus osteotomies[31]. No significant difference on the stability was noticed between screws placed 60° or 90° to the long axis of bone for both *in vitro*[32] and *in vivo* application (Figure 13).

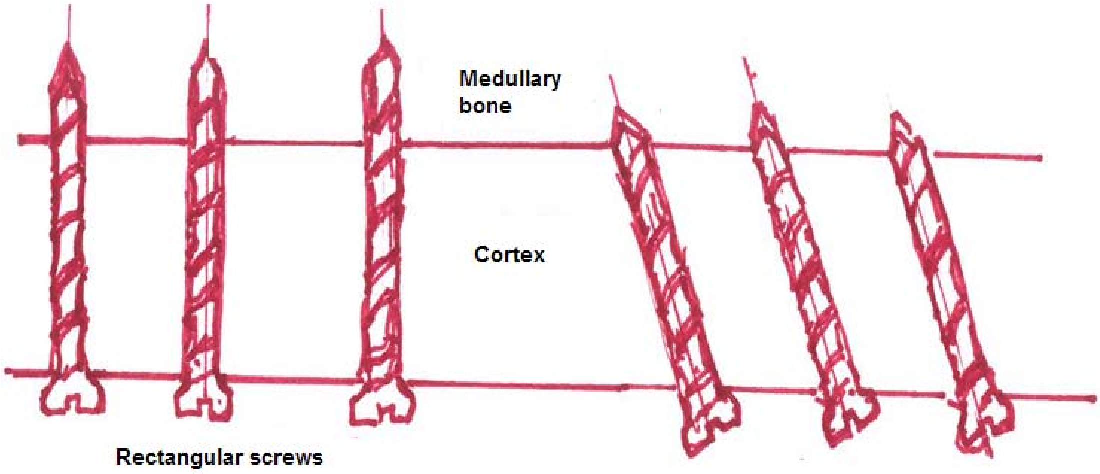


Figure 13: Illustration of cortex transacted with rectangular and inclined screw placement (Also see Figure 40)

It is postulated that screws inserted at 60° have a longer area of contact in the bone cortex. For the same length of screw more cortex can be transacted without having threads in medullary bone – longer screw travel at an angle of <90°, and therefore longer screws, can be used clinically to benefit three-dimensional stability.

For the same length of screw more cortex can be transacted and if angulated, less screw thread is present in medullary bone. Intra-oral screw placement for fixation of the angle of the mandible is the preferred surgical technique. However, 90° screw surgical placement usually requires an extra-oral approach.

The plates for rigid internal mono-cortical fixation of mandibular fractures all have plate holes orientated 90° to the long-axis of the plate. The slanted-screw plate designed by Krenkel[24] with transverse holes would accommodate screws placed at angles 30° to 90° to the long axis of bone to facilitate placement intra-orally to the dorsal border of the mandibular ramus.

In this research investigation of screw angle placements for angles 30° to 90° it was proven that a screw at 30°-angle to the long axis of a plate would perforate cortex and travel parallel to the under surface of a plate. This would result in “lifting” the plate from the bone surface. The screw angle at 30° was confirmed by CAD drawing to be clinically unsound.

Biomechanical stability in vitro pilot studies were conducted to express feasibility and an anatomical cadaver study completed to establish clinical relevance of the angled screw application specifically for the application to the lateral aspect of the external oblique line as illustrated in Figure 14.

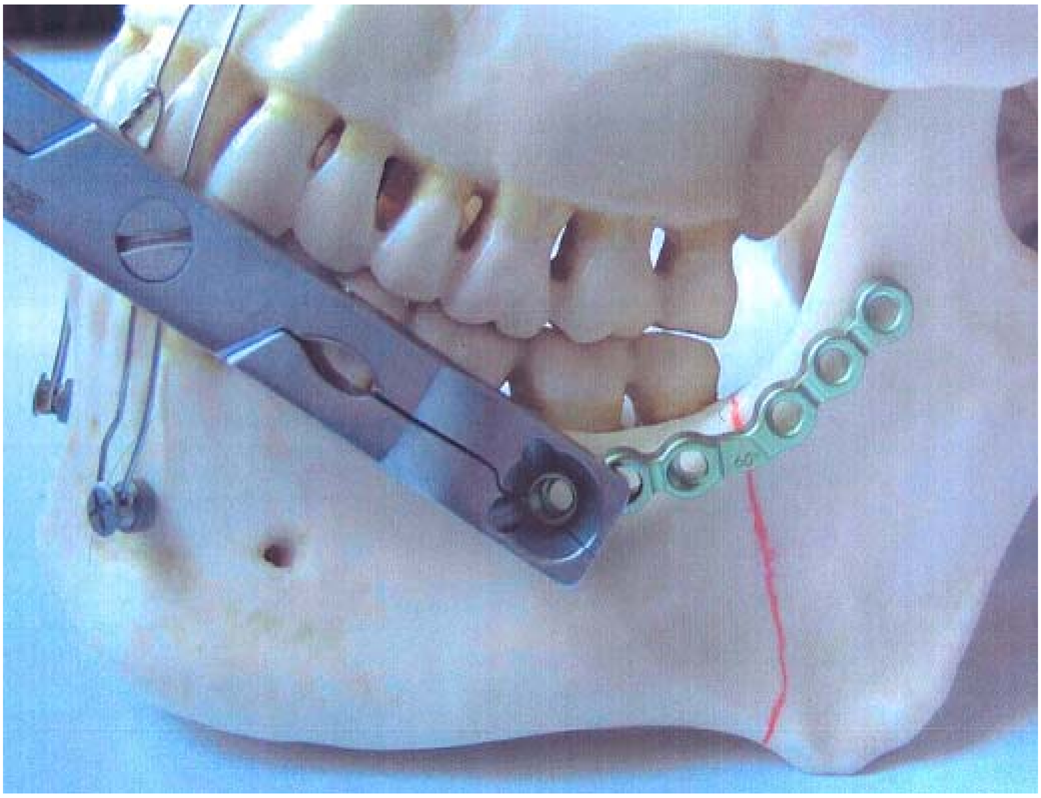


Figure 14: Inclined Screw Insertion (ISI) plate holes

The pilot study was considered for investigation and presented to the Centre for Integrated Sensing Systems as a project proposal: “Pilot study on mono-cortical systems used in mandible fractures” (ISP (2002) IC 036). The CSIR outlined conditions for the proposed project on 01/07/2002, which was unacceptable with regard to the intellectual property claim made by the CSIR (Addendum 1). It was decided to design and manufacture for this research a unique jig and biomechanical testing device for application in the Instron meter at the Centre of Stomatological Studies, School of Dentistry, University of Pretoria: “Protocol entitled – The effect of innovative screw angled mini-plates on biomechanical stability of monocortical fixation – an in vitro model.” (Addendum 2).

This initial study was completed prior to January 2003 and the results indicated no significant difference between rectangular and 60° degree angled screw placement with regard to compression testing – this prompted further investigation to compare the same in a load bearing situation (Figures 1 to 3).

The superior biomechanical stability for load bearing biomechanical stability for the 60°-angled screw system supported further investigation leading to this PhD protocol. The results of this first pilot study were reported at the facial trauma clinic “Where First and Third Worlds Meet” presented by the Division of Maxillo-Facial and Oral Surgery, University of the Witwatersrand, Johannesburg in February 2003. These results were presented during an oral presentation with title: “Mono-cortical management of mandibular fractures”.

An unique 6-hole titanium fracture plate for mono-cortical management of mandibular angle fractures with plate holes at 60° angles was prototyped based on above pilot studies and presented as a paper under the title: “The Minimal Invasive Mono-Cortical Angle System (MIMAS)” at the 16th International Conference on Oral and Maxillofacial Surgery, Athens, Greece in 2003[26]. The distinct advantage being angled screw placement permitting intra-oral application of a plate to the lateral aspect of the external oblique line without trochar transbuccal (cutaneous) application required for conventional rectangular screw application.