A comparative study of the effect of one-suture and suture-less techniques on post-operative complications following third molar surgery

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Declaration

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Summary

Objective

Lower third molar surgery remains one of the most common surgical procedure in oral and maxillofacial surgery. It has its own risks, and post-operative complications, that influence the recovery period, and affect a patient's quality of life. It has been suggested that wound closure technique is an operative factor that influences early post-operative complications, after lower third molar surgery. This is a comparative study that investigates two secondary closure techniques; partial closure using one suture and the suture-less technique, after using a modified buccal envelope flap for lower third molar surgery. This study aims to determine which of the two secondary closure techniques assessed is superior in improving wound healing, and reducing post-operative complications, following lower third molar surgery.

Materials and methods

We carried out a prospective, randomised, double-blind, split-mouth controlled trial, to investigate the effect of closure technique on post-operative complications and wound healing following lower third molar surgery. Thirty-seven patients, who had bilateral impacted third molars of similar surgical difficulty, were recruited, with thirty-four successfully completing the study. We compared partial closure using one suture to the suture-less technique. Surgical sites were divided into two groups, Group A: one suture, and Group B: suture-less. Each patient received both treatments at the same time. During the first post-operative week, all patients were asked to daily assess pain, facial swelling, and bleeding, using subjective self-assessment scales. All patients attended follow-up appointment at one week, to objectively assess facial swelling and wound healing, and at one month, to assess wound healing.

Results

The results showed a statistically significant difference between the two techniques in the following outcomes: a) less post-operative pain in one suture technique at day five ($p = 0.046$), and six ($p = 0.034$), b) better socket healing at one week ($p = 0.002$), and one month ($p = 0.014$) in one suture technique, and c) better soft tissue healing at one week ($p = 0.016$) in one suture technique.

The results showed no statistical significant difference between the two techniques in a) post-operative pain during the first four days, b) post-operative swelling, c) post-operative bleeding, d) food impaction within surgical site and e) periodontal health of the buccal site for the adjacent lower second molar at one month (all $p > 0.05$).

Conclusion

The one-suture technique for lower third molar surgery is superior to the suture-less technique in reduction of post-operative pain at day five and day six, and improving wound healing at one week and at one month post-operatively. There is no difference between the two techniques in reduction of post-operative swelling.

To

My lovely parents

Tahsin & Mariam

My beautiful wife

Areej

My little princess

Noor

My beloved brothers and sisters

Ahmad & Amro *Roba & Rasha*

My beloved father-in-law and Mother-in-law

Uncle Yousif & Aunt Mona

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List of Abbreviations

AAOMS	American Association of Oral and Maxillofacial Surgeons
AB	Antibiotic
A&E	Accident and Emergency Department
ANOVA	Analysis of Variance
ASA	American Society of Anaesthesiologists
BIPP	Bismuth Iodoform Paraffin Paste
CAL	Clinical attachment level
CBCT	Cone Beam Computed Tomography
CHX	Chlorhexidine
cpd	Cigarettes per day
GA	General anaesthesia
GTR	Guided Tissue Regeneration
IAN	Inferior Alveolar Nerve
ID	Inferior dental
IV	Intravenous
LA	Local anaesthetic / local anaesthesia
LN	Lingual nerve
MO	Mouth opening
MRI	Magnetic Resonance Imaging
N/R	Not reported
NICE	National Institute for Health and Care Excellence
NRS	Numerical rating scale
NSAIDs	Nonsteroidal anti-inflammatory drugs
OCP	Oral contraceptive pill
OPG	Orthopantogram
PD	Pocket depth
PRF	Platelet-rich-fibrin
PRP	Platelet-rich-plasma
TMD	Temporomandibular Joint Disorders
TMJ	Temporomandibular Joint
UK	United Kingdom
USA	United States of America
VAS	Visual analogue scale

1. INTRODUCTION

Third molars generally erupt between the ages of seventeen and twenty-one years (Bouloux et al., 2007), they may erupt as early as fourteen years among Nigerians (Odusanya and Abayomi, 1991), and up to age of twenty-six years in Europe (Pahkala et al., 1991).

Agenesis of third molar differs between populations and ranged from 0 % in Tasmania to nearly 100% in Mexican Indians (Rozkovcova et al., 1999). Mutation in PAX9 gene is thought to be the cause for missing third molars (Pereira et al., 2006).

The impaction of lower third molar occurs in up to 73% of young adults in Europe (Elsey and Rock, 2000). This impaction happens due to the inadequate space to accommodate the lower third molar teeth, which results from insufficient development of retro-molar space (Bjork, 1969; Bishara and Andreasen, 1983; Grover and Lorton, 1985), or insufficient mesial movement of the modern human dentition, due to lack of interproximal attrition (Lytle, 1995). Additionally, the medial angulation of the third molar bud at the early calcification and root development stages could lead to an unfavourable path of eruption (Grover and Lorton, 1985; Richardson, 1981).

Impacted lower third molar could lead to a variety of pathological consequences, that include a decayed tooth (Bouloux et al., 2015), distal caries in the second molar (Allen et al., 2009), pericoronitis, and acute dental diseases (Yamalik and Bozkaya, 2008; Venta et al., 1993). A higher incidence of periodontal diseases related to the impacted lower third molar may have an impact on systemic health (Elter et al., 2004; Elter et al., 2005; White et al., 2006; Blakey et al., 2002; Offenbacher et al., 2012).

While a few studies have investigated the effect of lower third molar impaction on lower incisors crowding (Harradine et al., 1998; Ades et al., 1990), the accumulating evidence has not been able to establish this causal relationship (Zawawi and Melis, 2014).

Although there is no evidence to support, or refute removal of asymptomatic impacted third molar teeth (Ghaeminia et al., 2016; Mettes et al., 2012), the American Association of Oral and Maxillofacial Surgeons (AAOMS) fully supports the elective prophylactic removal of asymptomatic impacted third molar teeth that are unlikely to erupt into a disease-free position (Lieblich et al., 2012). The concept of prophylactic removal of asymptomatic third molar teeth is no longer accepted in the most recent National Institute for Health and Care Excellence (NICE) guidelines, which advise that the removal of impacted third molars, should be carried out for teeth with evidence of pathology (NICE, 2000).

Lower third molar surgery remains one of the most common surgical procedure in oral and maxillofacial surgery (Jerjes et al., 2010). As any other surgical procedure, lower third molar surgery has its own risks, and post-operative complications, that influence the recovery period, and affect a patient's quality of life (Colorado-Bonnin et al., 2006; White et al., 2003). A lot of research has been directed toward investigating these post-operative complications, to predict the patient at risk, and to find the ideal, and most cost-effective way to prevent, or at least minimize theses complications, in order to improve post-operative quality of life.

We carried out this prospective, randomised, double-blind, split-mouth controlled study, in order to investigate the effect of wound closure technique, through using different number of sutures, on the post-operative complications, following lower third molar surgery.

The following literature review discusses the post-operative complications following lower third molar surgery, and the factors that may influence their incidence. It also examines in detail the literature published on different closure techniques, and their effect on the post-operative complications.

2. NULL HYPOTHESIS, AIMS AND OBJECTIVES

2.1 Null hypothesis

There is no difference between using one suture after lower third molar surgery and suture-less lower third molar surgery, in terms of degree of wound healing, post-operative pain, post-operative bleeding, post-operative swelling, and the post-surgical periodontal status of the adjacent lower second molar.

2.2 Alternative hypothesis

There is a difference between using one suture after lower third molar surgery and suture-less lower third molar surgery, in terms of degree of wound healing, post-operative pain, post-operative bleeding, post-operative swelling, and the post-surgical periodontal status of the adjacent lower second molar.

2.3 Aims

The aim of this study is to determine which wound closure technique, for lower third molar surgery, results in better wound healing, and fewer post-operative complications.

2.4 Objectives

Data will be collected, and analysed, to determine if there is any clinically significant, and /or statistically significant difference, in the following outcomes, following lower third molar surgery:

1) Post-operative pain during the first week
2) Post-operative facial swelling during the first week
3) Wound healing at one week and at one month post-surgery
4) Periodontal condition of the adjacent lower second molar at one month
5) Post-operative bleeding during the first week
6) Post-operative infection and dry socket during the first week

We will determine which of the two secondary closure techniques assessed is superior in improving wound healing, and reducing post-operative complications, following lower third molar surgery.

3. LITERATURE REVIEW

3.1 Post-operative complications following lower third molar surgery

3.1.1 Pain

Pain is a relatively constant consequence of lower third molar surgery, and is due to surgical trauma, which leads to the production and release, of different chemical mediators, in particular, histamine, bradykinin, and prostaglandins (Seymour and Walton, 1984; Garcia Garcia et al., 1997). Pain perception differs between individuals, and is influenced by many factors, such as the patient's age, cultural background, educational level, previous experience of pain, pain threshold, and tolerance (Olmedo-Gaya et al., 2002). Surgical technique, trauma, difficulty in tooth removal, duration of surgery, number of sutures, and type of wound healing are all factors, that are closely linked to the intensity of post-operative pain, following lower third molar surgery (Grossi et al., 2007; Bui et al., 2003a; Dubois et al., 1982; Pasqualini et al., 2005; Coulthard et al., 2014; Olmedo-Gaya et al., 2002; Lago-Mendez et al., 2007; Korkmaz et al., 2015). Seymour et al reported that pain after lower third molar surgery reaches its maximum intensity in the first twelve hours (Seymour et al., 1985). Other clinical trials have shown a maximum intensity of pain, reported at twenty-four hours following the surgery, then it diminishes gradually to reach a zero, or low level on the seventh post-operative day (Conrad et al., 1999; Bello et al., 2011; Cerqueira et al., 2004; Chukwuneke et al., 2008; Anighoro et al., 2013; White et al., 2003).

Different analgesic regimens have been used to alleviate post-operative pain, following lower third molar surgery. Paracetamol at the dose of 1g given every six hours has a

good analgesic effect, following lower third molar surgery (Weil et al., 2007). Recent Cochrane and qualitative reviews have reported that NSAIDs, especially ibuprofen, have a better outcomes than paracetamol on pain relief following lower third molar surgery (Bailey et al., 2013; Bailey et al., 2014; Hyllested et al., 2002), while others reported no difference between the two medications (Bjornsson et al., 2003). However, the combination of ibuprofen and paracetamol has shown better pain relief than giving each one of them alone (Mehlisch et al., 2010). This synergistic effect on pain relief has been also reported when paracetamol is combined with opioids, like codeine (Macleod et al., 2002) and tramadol (Fricke et al., 2004).

In 2013, Yamaguchi and Sano reviewed the concept of pre-emptive analgesia for lower third molar surgery, they conclude that central sensitization, that happens during third molar surgery because of tissue damage can be inhibited by the pre-surgical administration of analgesics, NSAIDs or acetaminophen, and this analgesia should be administered again post-operatively in order to prevent postsurgical peripheral sensitization (Yamaguchi and Sano, 2013). However, the benefit of pre-emptive analgesia, using NSAIDs or opioids, has been found to be non-significant in relieving pain following lower third molar surgery (Bauer et al., 2013; Zacharias et al., 1996; Costa et al., 2015; Jung et al., 2005).

When compared to short acting local anaesthetics, the use of long-acting local anaesthetics, bupivicaine or ropivicaine, for lower third molar surgery, has been associated with better post-operative pain control, during the first few hours of the post-operative period (Markovic and Todorovic, 2006; Crincoli et al., 2015; Christensen et al., 2013; Sancho-Puchades et al., 2012; Bouloux and Punnia-Moorthy, 1999). Other

studies have found no significant difference in post-operative pain between using long or short acting local anaesthetics (Pellicer-Chover et al., 2013; Gregorio et al., 2008). The immediate post-operative infiltration of bupivacaine 0.5% with epinephrine 1: 200,000 has shown to be associated with a prolonged reduction in post-operative pain, following lower third molar surgery (O'Neil and Stassen, 2014).

3.1.2 Swelling

Facial swelling following lower third molar surgery is an acute reversible inflammatory reaction, that has an impact on patient quality of life during the early post-operative period (Obimakinde et al., 2010; White et al., 2003; Colorado-Bonnin et al., 2006). Tissue injury triggers the release of inflammatory cytokines, these inflammatory cytokines, especially histamine, cause localised increase in capillary permeability, hyperaemia, and vasodilation, that eventually lead to inflammatory cells migration, and fluid accumulation in the interstitial space (Hupp et al., 2013; Sortino and Cicciu, 2011). The severity of the swelling is positively correlated to pain intensity, and the swelling is also affected by the extension (length) of the incision, surgical technique, degree of ostectomy, tooth sectioning, surgical time, type of wound healing, and number of sutures used to close the wound (Olmedo-Gaya et al., 2002; Sortino and Cicciu, 2011; Maria et al., 2012; Dubois et al., 1982; Pasqualini et al., 2005; Hashemi et al., 2012; Refo'a et al., 2011; Coulthard et al., 2014; Korkmaz et al., 2015). The post-operative swelling reaches its maximum at forty-eight hours after surgery, and subsides gradually to a low level or no swelling at one week post-operatively (Osunde et al., 2011; Bamgbose et al., 2005; van der Westhuijzen et al., 2005; Troullos et al., 1990; Chukwuneke et al., 2008; Sanchis Bielsa et al., 2008; Anighoro et al., 2013). However, some studies have reported that swelling peaked at seventy-two hours following the procedure (White et al., 2003; Pasqualini et al., 2005; Kazemian et al., 2016). This difference in the swelling peak time

could be a result of inflammatory response variation between individuals (Osunde et al., 2011; Anighoro et al., 2013).

3.1.3 Infection

Early or late post-operative infection is a complication that may occur following lower third molar surgery. The reported incidence ranges from 0.8% to 4.2% (Bouloux et al., 2007). Incidence of infection following lower third molar surgery is influenced by age, surgical time, presence of oral infection, exposure of the inferior dental canal, degree of impaction, and amount of bone removal (Chuang et al., 2008; Clauser et al., 2009; Bouloux et al., 2007; Benediktsdottir et al., 2004; Figueiredo et al., 2005). Antibiotic administration before, and after lower third molar surgery has proven to decrease risk of post-operative infection up to 70% (Arteagoitia et al., 2016; Marcussen et al., 2016; Lodi et al., 2012; Ramos et al., 2016; Ren and Malmstrom, 2007). Because of the low prevalence of infection, and the potential side effects of antibiotics, their routine prescription for lower third molar surgery is not justified (Arteagoitia et al., 2016). However, antibiotic use should be considered for patients with known risk factors for post-operative complications, such as smoking, poor oral hygiene, and older age (Ren and Malmstrom, 2007).

3.1.4 Bleeding

The reported incidence of prolonged excessive post-operative bleeding following lower third molar surgery has ranged from 0.1% to 0.6 % (Haug et al., 2005; Bui et al., 2003a; Chiapasco et al., 1993). A higher incidence of post-operative bleeding was reported in older patients, and for third molars with deep, and distoangular impaction (Chiapasco et al., 1993; Baensch et al., 2016). In patients with normal coagulation, injury to blood vessels within soft tissues or bone is considered the most common cause of post-

operative bleeding, which usually can be managed effectively using local measures (Bouloux et al., 2007; Susarla et al., 2003).

3.1.5 Dry socket

Dry socket, also known as alveolar osteitis, is a common post-operative complication following lower third molar surgery (Bowe et al., 2011; Blum, 2002). Its incidence ranges from 1% to 45% (Blum, 2002), and the incidence peaks at age forty to forty-five years (Rud, 1970; Rood and Danford, 1981). Different definitions and diagnostic criteria for dry socket have been reported in the literature. It is described by Blum as "a post-operative pain in and around the extraction site, which increases in severity at any time between day one and day three after the extraction, accompanied by a partially or totally disintegrated blood clot within the alveolar socket, with or without halitosis, and excluding any other cause of pain on the same side of the face" (Torres-Lagares et al., 2005; Blum, 2002). It arises due to an increased local fibrinolytic activity in the extraction socket, leading to disintegration of the clot (Birn, 1970). Multiple factors have been implicated in the increased risk of dry socket following lower third molar surgery , these reported factors include: difficult extraction and surgical trauma (Blum, 2002; Torres-Lagares et al., 2005; Nusair and Younis, 2007; Bortoluzzi et al., 2010; Abu Younis and Abu Hantash, 2011; Eshghpour and Nejat, 2013; Alexander, 2000), inexperienced surgeon (Alexander, 2000; Oginni et al., 2003), female gender (Alexander, 2000; Bienek and Filliben, 2016; Noroozi and Philbert, 2009; Kolokythas et al., 2010), the oral contraceptive (Blum, 2002; Bienek and Filliben, 2016; Kolokythas et al., 2010; Almeida et al., 2016), smoking (Sweet and Butler, 1979; Blum, 2002; Nusair and Younis, 2007; Abu Younis and Abu Hantash, 2011; Cardoso et al., 2010; Noroozi and Philbert, 2009), flap design (Goldsmith et al., 2012; Kirk et al., 2007; Haraji et al., 2010; Coulthard et al., 2014), closure technique (Elo et al., 2016), type of analgesic (Al-

Sukhun and Penttila, 2011), poor oral hygiene, pericoronitis, and previous history of a dry socket (Blum, 2002; Noroozi and Philbert, 2009).

Various pharmacological methods and techniques have been proposed to reduce the incidence of dry socket (Blum, 2002). These pharmacological methods include: systemic antibiotics use (Kolokythas et al., 2010; Lodi et al., 2012; Marcussen et al., 2016; Ramos et al., 2016; Ren and Malmstrom, 2007), topical antibiotic dressing (Sorensen and Preisch, 1987; Davis et al., 1981; Akota et al., 1998; Trieger and Schlagel, 1991; Wisniewska et al., 2009), chlorhexidine mouthwash and gel (Daly et al., 2012; Zhou et al., 2016), systemic tranexamic acid (Anand et al., 2015), and topical application of platelet-rich-plasma (PRP) or platelet-rich-fibrin (PRF) (Haraji et al., 2012; Rutkowski et al., 2007; Eshghpour et al., 2014).

3.1.6 Periodontal complications

Deterioration of the periodontal condition on the distal aspect of the lower second molar has been recognized as a complication related to lower third molar surgery (Quee et al., 1985; Pogrel, 2012; Lee et al., 2016; Richardson and Dodson, 2005). This complication has a higher incidence and severity in patients older than twenty-five-year-old (Kugelberg, 1990; Kugelberg et al., 1991; Dodson and Richardson, 2007).

Operative factors have been also reported to affect the extent and severity of periodontal complications, such as suture technique (Cetinkaya et al., 2009), flap design (Briguglio et al., 2011; Kirtiloglu et al., 2007; Baqain et al., 2012; Monaco et al., 2009; Korkmaz et al., 2015; Chen et al., 2016), and ostectomy method (Chen et al., 2016). The amount of remaining bone distal to the lower second molar, on completion of lower third molar removal, is an important predictor of the final bone level at that site (Meister et al., 1986).

In order to minimize periodontal complications, and optimize the periodontal status of lower second molar, many researchers have suggested different methods for treating the surgical site following lower third molar removal (Lee et al., 2016; Barbato et al., 2016). These methods range from simple scaling and root planning on the distal surface of the second molar (Osborne et al., 1982; Ferreira et al., 1997; Leung et al., 2005), to complex regenerative periodontal therapies such as Guided Tissue Regeneration (GTR) alone (Aimetti et al., 2007; Aimetti and Romano, 2007; Corinaldesi et al., 2011; Pecora et al., 1993), GTR with osseous grafting (Throndson and Sexton, 2002; Hassan et al., 2012), and application of growth factors in form of PRP or PRF (Sammartino et al., 2009; Sammartino et al., 2005; Doiphode et al., 2016).

3.1.7 Neuropathy

Injury to branches of the trigeminal nerve is one of the possible complications associated with lower third molar surgery. It has a significant effect on the affected patient's quality of life (Leung et al., 2013a; Leung et al., 2013b). The reported incidence of temporary injury to the Inferior Alveolar Nerve (IAN), and Lingual Nerve (LN) following lower third molar surgery in the literature varies from 0.26% to 8.4%, and 0.1% to 22%, respectively (Cheung et al., 2010; Mahon, 2014). Whereas the incidence of permanent neurosensory deficit ranges from 0.12% to 0.7% for IAN (Cheung et al., 2010; Smith, 2013; Mahon, 2014), and between 0% and 8% for LN injuries (Boffano et al., 2012).

The risk of IAN injury is influenced by demographic, anatomical, and operative factors. These factors comprise age (Black, 1997; Valmaseda-Castellon et al., 2001; Gulicher and Gerlach, 2001; Tay and Go, 2004), gender (Howe, 1960; Blondeau and Daniel, 2007; Tay and Go, 2004), depth of impaction (Gulicher and Gerlach, 2001; Cheung et al., 2010;

Blondeau and Daniel, 2007), duration of the procedure (Jain et al., 2016; Valmaseda-Castellon et al., 2001), root development and morphology (Gulicher and Gerlach, 2001; Tay and Go, 2004). The intra-operative exposure of the inferior dental (ID) canal has a significant high risk of post-operative paraesthesia (Gulicher and Gerlach, 2001; Tay and Go, 2004; Leung and Cheung, 2011).

Surgical technique has been linked to IAN injury, with increased risk of this injury in lingual split technique (Leung and Cheung, 2011), the risk decreases with tooth sectioning and reduced ostectomy (Jain et al., 2016; Valmaseda-Castellon et al., 2001).

The experience of the surgeon is another operative factor that influences the risk of IAN injury. A number of researchers have demonstrated that the less experienced the operator, the more likely the risk of IAN injury will be (Bataineh, 2001; Hasegawa et al., 2013; Jerjes et al., 2006).

Several studies have highlighted some radiographic signs on OPG, that thought to be associated with a higher risk of IAN injury, these high-risk signs include: darkening of roots, deflection of roots and diversion of the ID canal (Rood and Shehab, 1990; Leung and Cheung, 2011; Howe, 1960; Bell, 2004; Gallesio et al., 2010). However, because of the high specificity and low sensitivity of these radiographic signs, an OPG is more reliable in excluding the close relationship, than confirming the true relationship between the IAN and lower third molar roots (Atieh, 2010). A Cone Beam Computed Tomography (CBCT), is recommended when the OPG is suggestive of an intimate relationship between the tooth and the canal (Hasegawa et al., 2013).

Exposing the IAN to pressure, and chemical irritation from some intra-socket medicaments, could lead to nerve injury and irreversible neuropathy (Renton, 2013).

Factors thought to influence lingual nerve injury during lower third molar surgery have been explored in several studies. Leung and Cheung in 2011 reported, that un-erupted lower third molar teeth are at higher risk of LN deficit, compared with erupted, or partially erupted teeth (Leung and Cheung, 2011). The risk was also reported to be higher in distoangular impaction (Cheung et al., 2010). Some studies have shown a high incidence of post-operative LN deficit when a lingual flap is raised in lower third molar surgery (Bataineh, 2001; Gomes et al., 2005; Robinson and Smith, 1996). The type of retractor used for raising, and protecting lingual flap, has been found to have an impact on the incidence of LN deficit , with a few authors reporting higher incidence when using narrow retractors like Howarths periosteal elevator (Walters, 1995; Greenwood et al., 1994; Rood, 1992), while others blamed broad retractor for causing LN injury (Blackburn and Bramley, 1989). The LN injury in the lingual split technique has been reported to be four times more likely to happen than when using the buccal approach (Leung and Cheung, 2011).

Interestingly, Gullisher and Gerlach in 2001 reported a higher incidence of LN deficit in cases where lower third molar surgeries were carried out under general anaesthesia (GA), this significant association was attributed to the compression of the tongue, caused by a tongue depressor being used in patients treated under GA (Gulicher and Gerlach, 2001). Furthermore, the incidence of LN injury has been reported to be higher when lower third molar surgery was carried out by less experienced surgeons (Jerjes et al., 2006; Valmaseda-Castellon et al., 2001).

Additionally, neuropathy following lower third molar surgery could be a result of nerve insult caused by local anaesthesia (LA), either through mechanical trauma to the nerve from the needle, or the chemical irritation of the local anaesthetic (Renton, 2013; Smith and Lung, 2006). Different types of local anaesthetics, including articaine, priclocaine, and lidocaine, have been reported to have a neurotoxic effect, and result in LN and IAN injuries (Haas and Lennon, 1995; Hillerup and Jensen, 2006; Pogrel and Thamby, 2000; Pogrel, 2007). Thankfully, the vast majority of local anaesthetic-induced nerve injuries resolve within two weeks following the injection (Haas and Lennon, 1995).

3.1.8 TMJ complications

Lower third molar surgery can cause or exacerbate TMJ disorders (TMDs) (Lieblich et al., 2012). This could be an indirect relationship, as lower third molars are often removed in an age group of patients with a high incidence of TMD, especially internal derangements (Pogrel, 2012). Opening the mouth for long period of time, overloading the TMJ without supporting the mandible during tooth removal, or exceeding the opening protective mechanism for the patient under GA, can all cause direct injury to TMJ during lower third molar surgery (Bouloux et al., 2007).

While a few studies were able to establish a significant relationship between lower third molar surgery and TMD (Huang and Rue, 2006; Huang et al., 2014; Huang et al., 2002), another study found, that this significant causal relationship was not present (Huang et al., 2008).

3.1.9 Trismus

Trismus is one of the post-operative complications, that is often associated with lower third molar surgery, as a manifestation of pain, swelling or both (Shugars et al., 2006; Ngeow and Lim, 2016). Trismus can result from the accumulation of inflammatory exudates, and fluid in the fascia of the masticatory muscles (Moraschini et al., 2016), or from the inhibitory effect of muscle pain involving masseters, and lateral pterygoids, which protects the painful muscle, by preventing further movement at the site of injury (Ngeow and Lim, 2016). Accidental injection of LA into the medial pterygoid muscle, could also result in post-operative trismus, following lower third molar surgery (Ngeow and Lim, 2016).

3.2 Factors influencing post-operative complications following lower third molar surgery

The incidence and severity of post-operative complications following lower third molar surgery are affected by non-operative and operative factors. The non-operative factors that influence these complications are related to the patient him/herself. Some of these factors are modifiable, while others are constant.

3.2.1 Non-operative factors influencing post-operative complications following lower third molar surgery

3.2.1.1 Age

Lower third molar surgery in younger patients is associated with a lower incidence of post-operative complications, minimal morbidity, and a shorter recovery period (Baqain et al., 2008; Hupp et al., 2013; Capuzzi et al., 1994; Bruce et al., 1980; Bui et al., 2003a). The higher incidence of post-operative complications in older patients is related to the

increase of the surgical time and the difficulty of extraction (Renton et al., 2001; Gbotolorun et al., 2007; Benediktsdottir et al., 2004; Akadiri and Obiechina, 2009), the slower healing process (Amler, 1977), and the higher incidence of co-morbidities in this age group (Bruce et al., 1980).

As a part of the AAOMS Age-related Third Molar Study, Chuang *et al* in 2007 investigated the risk of increasing age on the frequency of post-operative complications. Patients over the age of twenty-five years were found to be more likely to develop post-operative complications following lower third molar surgery (Chuang et al., 2007). This is in agreement with later study by Clausre *et al* in 2009, who reported more frequent post-operative complications in patients older than twenty-five years of age (Clauser et al., 2009).

A prospective study by Renton *et al* in 2001, showed that lower third molar surgery, in patients over thirty years of age, is significantly more difficult, than in younger patients, and the difficulty increases further for those over fifty years (Renton et al., 2001).
This increase in difficulty of surgery with age is attributed to the increased bone density (Hupp et al., 2013; Hinds and Frey, 1980; Bui et al., 2003a), complete roots formation with higher incidence of hypercementosis, and a greater possibility of the roots being closer to the IAN (Black, 1997).

3.2.1.2 Gender

Gender is another patient characteristic that affects short-term outcomes following lower third molar surgery (Yuasa and Sugiura, 2004). Although some authors reported no effect of gender on post-operative pain after lower third molar surgery (Hansson et al., 1989), most of the studies have shown more severe post-operative pain in females than

males (Seymour et al., 1985; Fisher et al., 1988; Conrad et al., 1999; Phillips et al., 2003). Conversely, Cappuzi et al in 1994 found that males experience more severe pain than females in the first three post-operative days (Capuzzi et al., 1994). This difference in pain perception between the two sexes is attributable to the differences in sensitivity to noxious stimuli, and the difference in analgesic response to pain medications, between males and females (Wiesenfeld-Hallin, 2005). While several studies have concluded that females have greater post-operative morbidity, and longer recovery period following lower third molar surgery (Conrad et al., 1999; Phillips et al., 2003; Benediktsdottir et al., 2004; Blondeau and Daniel, 2007; de Santana-Santos et al., 2013), others have shown no effect of gender on post-operative morbidity, and recovery period (Barbosa-Rebellato et al., 2011; Carvalho and do Egito Vasconcelos, 2011). Interestingly, Renton *et al* in 2001 reported, that male gender is associated with longer procedure time (Renton et al., 2001).

Female gender as a risk factor for dry socket has been established in some studies (Alexander, 2000; Bienek and Filliben, 2016; Noroozi and Philbert, 2009; Kolokythas et al., 2010)

Some authors have reported a higher risk of IAN deficit in females because of the smaller and thinner cortical mandible, and the shorter distance between the tooth, and the mandibular canal (Howe, 1960; Blondeau and Daniel, 2007; Nakagawa et al., 2007). Contrary to those findings, Tay and Go in 2004 reported, that females have a lower risk of developing paraesthesia, following lower third molar surgery (Tay and Go, 2004).

3.2.1.3 Ethnicity

In a four-year prospective study by Renton *et al* in 2001, patients of black African, or black Caribbean ethnicity were shown to require more difficult lower third molar surgery, and a longer operative time, when compared to a white cohort (Renton et al., 2001). This increase in difficulty of lower third molar surgery in these ethnic groups is attributed to the higher incidence of bony impaction, horizontal angulation, unfavourable root formation, and increased crown width (Renton et al., 2001; Otuyemi and Noar, 1996). This may be also explained by the fact of a higher bone density in black African patients when compared to white people as was shown in femoral head test (Harris et al., 1997). In retrospective study by Mahdey *et al* in 2015, Chinese patients undergoing lower third molar surgery, exhibited a higher difficulty score, and a longer operative time, when compared to patients from Indian and Malay origins (Mahdey et al., 2015).

3.2.1.4 Smoking

Smoking is one of the modifiable factors that may influence post-operative complications in lower third molar surgery (Osunde et al., 2014). Larrazábal *et al* in 2010 reported greater pain at twenty-four hours after lower third molar surgery, in patients, who smoked during the first post-operative week, while smoking before surgery showed no significant effect on pain or swelling (Larrazábal et al., 2010). This negative influence of smoking on post-operative pain might be related to the reduced blood supply at the surgical site, due to the vasoconstrictor effect of nicotine (Meechan et al., 1988).

Grossi *et al* in 2007 found, that patients, who smoke were at higher risk for perceiving more severe discomfort, and trismus, following lower third molar surgery (Grossi et al., 2007). However, in contrast to the above findings, Capuzzi *et al* in 1994 reported no

significant influence of smoking on pain and swelling, after lower third molar surgery (Capuzzi et al., 1994).

Dry socket following lower third molar surgery is more likely to occur if a patient smokes (Sweet and Butler, 1978; Larsen, 1992; Osunde et al., 2014). This likelihood increases with the number of cigarettes smoked per day. In a prospective study involving four hundred lower third molar surgeries, Sweet& Butler in 1979 reported, that tobacco smoking patients are at fivefold higher risk to develop dry socket compared to non-smokers, and this risk increases in heavy smoker (> 20 cpd), and those, who smoke on the day of surgery, or on the first post-operative day (Sweet and Butler, 1979). This effect of smoking on dry socket may occur due to the effect of nicotine and carbon monoxide in tobacco, both decrease the blood supply, and oxygen, to the surgical site (Cardoso et al., 2010). Nicotine restrains the proliferation of fibroblasts and macrophages, which leads to disintegration of the blood clot formed inside the extraction socket (Kolokythas et al., 2010; Cardoso et al., 2010). Foreign substances in smoking could act as contaminators, to the surgical site, and lead to dry socket (Blum, 2002). While the effect of heat generated by smoking does not seem to be a significant factor in the aetiology of dry socket (Cardoso et al., 2010), suction, and negative pressure during smoking, could dislodge the formed clot, and result in a dry socket (Noroozi and Philbert, 2009).

3.2.1.5 Contraceptive pill

The effect of the contraceptive pill on post-operative complications following lower third molar surgery is controversial. Some studies showed that post-operative complications are not influenced by the use of the contraceptive pill (Bui et al., 2003b; Heasman and Jacobs, 1984; Larsen, 1992; Capuzzi et al., 1994; Blondeau and Daniel, 2007), while others report a higher incidence of dry socket, following lower third molar surgery in

females taking oral contraceptive pill (OCP) (Sweet and Butler, 1977; Garcia et al., 2003; Chapnick and Diamond, 1992; Catellani et al., 1980; Osunde et al., 2014). This higher incidence of dry socket among females taking the oral contraceptive, has been attributed to the fibrinolytic activity of oestrogen, which contributes to the possible occurrence of a dry socket by increasing lysis of the blood clot (Blum, 2002). Some studies have shown that this effect of the OCP on the incidence of dry socket is dependent on the oestrogen dose in the OCP (Catellani et al., 1980; Blondeau and Daniel, 2007).
Interestingly, Garcia *et al* in 2003 reported more post-operative pain, and analgesic consumption, following lower third molar surgery, in females taking the OCP (Garcia et al., 2003).

3.2.1.6 Oral hygiene

Only a few studies have assessed the effect of oral hygiene on post-operative complications following lower third molar surgery. Sáez Cuesta *et al* in 1999 found, that patients with pre-operative poor oral hygiene, experienced more severe pain during the first six hours after surgery (Sáez-Coem, 1999). Peñarrocha *et al* in 2001 reported, that poor oral hygiene is associated with higher pain levels, and more analgesic consumption, following lower third molar surgery (Penarrocha et al., 2001).
Larrazábal *et al* in 2010 have demonstrated that lower brushing frequency, before lower third molar surgery, and during the first post-operative week is associated with greater post-operative pain (Larrazábal et al., 2010).

This effect of oral hygiene on post-operative pain could be explained by the fact of an increased bacterial plaque, adhered to the teeth in patients with poor oral hygiene, and subsequent increase in the number of bacteria and macrophages releasing toxins, and chemical mediators, which trigger post-operative pain (Penarrocha et al., 2001).

However, poor oral hygiene has no influence on swelling, trismus, and inflammation, following lower third molar surgery (Penarrocha et al., 2001; Larrazábal et al., 2010).

3.2.2 Operative factors influencing post-operative complications following lower third molar surgery

3.2.2.1 Surgical difficulty

Several studies have linked the "difficulty level" of lower third molar surgery to post-operative complications, such as pain (Lago-Mendez et al., 2007; Oikarinen and Rasanen, 1991; Phillips et al., 2003; Yuasa and Sugiura, 2004), swelling (Osunde and Saheeb, 2015), dry socket (Eshghpour and Nejat, 2013), and delayed recovery period (Phillips et al., 2003). Other studies found that the level of difficulty, has no impact on the severity of pain, and trismus, after lower third molar surgery (Osunde and Saheeb, 2015; Garcia Garcia et al., 1997).

Different difficulty scales and indices have been proposed, and used in the literature in order to evaluate the level of difficulty for lower third molar surgery. Most of these indices are dependent on radiographic assessment of the lower third molar and its surrounding structures. Winter in 1926, used three imaginary lines to describe the axial inclination of lower third molar, depth of impaction, and the amount of alveolar bone enclosing the tooth (Winter, 1926).

In 1933, Pell and Gregory radiographically classified the impaction of the lower third molar into nine groups, based on the depth of impaction in relation to the mandibular ramus, and the occlusal plane (Pell and Gregory, 1933). Although this index has been

widely used in literature, its sensitivity has been proven to be low, in predicting lower third molar surgery difficulty (García et al., 2000).

MacGregor in 1985 developed the WHARFE classification to predict surgical difficulty pre-operatively (MacGregor, 1985). The difficulty score in this classification depends on Winter's lines, height of the mandible, angulation of third molar, roots morphology, follicle development, and exit pathway. Edwards *et al* in 1998 demonstrated a poor correlation, between the WHARFE index, and the difficulty anticipated by the surgeon (Edwards et al., 1998).

A difficulty index was developed by Pederson in 1988, this index used lower third molar angulation, and the Pell and Gregory classification, to stratify lower third molar removal into three difficulty levels: slight, moderate, and very difficult (Pedersen, 1988). Pederson's index has been found to be an unreliable tool to predict the actual difficulty of lower third molar surgery (Bali et al., 2013; Akadiri and Obiechina, 2009; Diniz-Freitas et al., 2007).

In addition to the radiographic variables, certain clinical and demographic variables have proven to be important factors, that influence surgical difficulty (Akadiri and Obiechina, 2009). In many clinical trials, age was an important factor in predicting difficulty of lower third molar surgery (Renton et al., 2001; Benediktsdottir et al., 2004; Gbotolorun et al., 2007; Obimakinde et al., 2013; Aznar-Arasa et al., 2014; Park, 2016). The increase in body mass index (BMI) has been linked to a more difficult lower third molar surgery (Renton et al., 2001; Gbotolorun et al., 2007; Alvira-Gonzalez et al., 2017). This is probably because of the reduced cheek flexibility, and decreased visibility of the surgical area, in overweight patients (Renton et al., 2001; Gbotolorun et al., 2007; Alvira-

Gonzalez et al., 2017). However, Susarla and Dodson in 2004 reported that demographic factors, have little influence on surgical difficulty of lower third molar surgery (Susarla and Dodson, 2004).

Interestingly, Aznar *et al* in 2014, reported more difficult lower third molar surgery, in patients with high level of pre-operative anxiety (Aznar-Arasa et al., 2014).

Recently, a "New Index" to assess surgical difficulty of lower third molar surgery has been developed, and tested by Roy *et al* in 2015 (Roy et al., 2015). The authors claim that this index is more reliable in predicting surgical difficulty, when compared to the Pederson index. The New index showed better kappa agreement with operative time than Pederson index did. In addition to Pederson's index criteria, roots width, and their curvature, the difficulty score in the New Index depends on some clinical parameters that include: mouth opening, tongue size, angulation of the external oblique ridge, and cheek flexibility (Roy et al., 2015).

3.2.2.2 Operative time

The duration of lower third molar surgery indirectly reflects the surgical difficulty (Jain et al., 2016; Valmaseda-Castellon et al., 2001). It has been used in several studies as a tool, to measure the difficulty of surgery (Diniz-Freitas et al., 2007; Benediktsdottir et al., 2004; Alvira-Gonzalez et al., 2017; White et al., 2003; Renton et al., 2001).

The average reported operative time for lower third molar surgery has ranged in the literature from 7.5 to 105 minutes (Renton et al., 2001). This wide variation in duration of procedure is attributable to many factors including surgical difficulty, tooth position,

severity of impaction, surgical technique, experience of the surgeon, and the method used to measure the duration of surgery (Renton et al., 2001; Benediktsdottir et al., 2004).

The longer the procedure time, the more prolonged the recovery period (Conrad et al., 1999), the longer the duration of tissue injury during the surgical procedure, the more inflammatory mediators released, which might result eventually in more post-operative complications (Bello et al., 2011).

While the majority of studies reported increased pain severity, and discomfort, when lower third molar surgery takes a longer time (Pedersen, 1985; Berge and Gilhuus-Moe, 1993; Oikarinen and Rasanen, 1991; Hellem and Nordenram, 1973; Bello et al., 2011; de Brabander and Cattaneo, 1988), others have reported no effect of operative time on the severity of post-operative pain (Fisher et al., 1988; Seymour et al., 1985; Seymour, 1983).

Cappuzi *et al* in 1994 have shown that the increase in surgical time causes more post-operative swelling (Capuzzi et al., 1994). This is in agreement with an earlier study by Van Gool *et al* in 1977, who reported more swelling and trismus associated with longer operative time (van Gool et al., 1977). Other studies found no effect of the operative time on swelling and trismus (Berge and Gilhuus-Moe, 1993; Pedersen, 1985). An increase in surgical time has been considered a risk factor for IAN deficit following lower third molar surgery (Valmaseda-Castellon et al., 2001; Jain et al., 2016).

3.2.2.3 Use of corticosteroids

The effect of short-term use of corticosteroid in reducing post-operative complications following lower third molar surgery has been widely reported in the literature (Dan et al., 2010; Herrera-Briones et al., 2013). Different types of corticosteroids with different degree of potency have been investigated for this purpose, including dexamethasone, prednisolone, methylprednisolone, betamethasone, and recently trimicinolone acetonide (Ngeow and Lim, 2016). Injection routes varied as systemic, oral, intravenous, and intramuscular or local, submucosal and endo-alveolar (Ngeow and Lim, 2016). Although the oral route is the most convenient and most acceptable to patient, the local administration of steroids was associated with less side effects (Moraschini et al., 2016). The pre-operatively administration of corticosteroids has shown a better outcome than the post-operative one (Alexander and Throndson, 2000; Herrera-Briones et al., 2013).

The co-therapy of steroids and NSAIDs has shown a synergistic effect in decreasing pain, swelling, and trismus following lower third molar surgery, when compared to corticosteroids or NSAIDs alone (Buyukkurt et al., 2006; Lin et al., 1996; Bamgbose et al., 2005).

3.2.2.4 Surgical techniques

Different surgical techniques for lower third molar surgery have been investigated in order to reduce post-operative complications (Coulthard et al., 2014). These techniques have utilised different flap designs, bone removal methods, irrigation methods, and wound closure techniques.

3.2.2.4.1 Flap design

Flap design for lower third molar surgery is one of the operative factors that affect post-operative recovery (Baqain et al., 2012). Flap designs can be broadly categorized into triangular, and envelope types (Nageshwar, 2002). Modifications that have been added to these two flaps have evolved into new flap designs that have been tested to improve surgical access, improve healing, and minimize post-operative complications (Roode and Butow, 2010; Sandhu et al., 2010; Goldsmith et al., 2012; Nageshwar, 2002; Yolcu and Acar, 2015; Bataineh and Batarseh, 2016; Elo et al., 2016; Briguglio et al., 2011; Arta et al., 2011; Chaves et al., 2008; Kirtiloglu et al., 2007; Korkmaz et al., 2015; Dolanmaz et al., 2013; Kirk et al., 2007).

Some authors found that triangular, and modified triangular flaps are associated with more swelling than other flap designs (Kirk et al., 2007; Baqain et al., 2012; Erdogan et al., 2011; Korkmaz et al., 2015; Roode and Butow, 2010). Higher incidence of dry socket has been reported when envelope flaps are used (Goldsmith et al., 2012; Kirk et al., 2007; Haraji et al., 2010). Erdogan *et al* in 2001, and Korkmaz *et al* in 2015, found less post-operative pain in envelope flaps, when compared to triangular and lateral rotated triangular flaps (Erdogan et al., 2011; Korkmaz et al., 2015). Sandhu *et al* in 2010 found less post-operative pain in bayonet triangular flap compared to the envelope flap (Sandhu et al., 2010). Some investigators report a better wound healing in triangular flaps than in the envelope flaps (Haraji et al., 2010; Sandhu et al., 2010). Unlike previous studies, several other studies reported no difference in post-operative complications between envelope and triangular flaps (Monaco et al., 2009; Dolanmaz et al., 2013; Briguglio et al., 2011).

A recent Cochrane review has reported a moderate quality evidence, that triangular flaps, for lower third molar surgery, have less incidence of dry socket at one week, and

less pain at twenty-four hours, compared to envelope flaps , however, there is some low-quality evidence of more post-operative swelling, related to triangular flaps at one week, compared to envelope flaps, and no difference between the two flap designs regarding infection rate and trismus (Coulthard et al., 2014).

Flaps that leave the gingiva intact around the second molar have better primary periodontal healing (Kirtiloglu et al., 2007). A few studies have reported more pocket depth (PD) reduction and clinical attachment level (CAL) gain around the lower second molar, when a triangular flap is used (Baqain et al., 2012; Briguglio et al., 2011; Korkmaz et al., 2015). However, a recent meta-analysis review concludes that flap design has no significant impact on the periodontal outcomes, following lower third molar surgery (Chen et al., 2016).

3.2.2.4.2 Bone removal and tooth sectioning

The method of bone removal during lower third molar surgery influences the extent of post-operative complications, and the recovery period. Mocan *et al* in 1996 reported that the lingual split technique using chisel produces less trismus, compared to the buccal approach using a surgical bur (Mocan et al., 1996). This is in contrary to the results from Absi and Shepherd in 1993, who found no difference in post-operative complications between the two techniques (Absi and Shepherd, 1993). Praveen *et al* in 2007 compared three methods for bone removal during lower third molar surgery, and more pain was associated with the lingual split technique. Whilst the surgical bur technique has had the highest swelling scores amongst the three methods, the lowest swelling scores were reported in the simplified split bone technique using the chisel (Praveen et al., 2007).

Compared to the buccal approach, lingual split technique has a significantly 2.3 and 4.1 times higher risk of IAN and LN deficit , respectively (Leung and Cheung, 2011).

Several studies have investigated the difference in post-operative complications between using piezosurgery and the traditional surgical bur technique. Although piezosurgery was associated with longer operative time (Sortino et al., 2008; Mantovani et al., 2014; Sivolella et al., 2011; Basheer et al., 2017; Rullo et al., 2013), it was associated with less swelling (Sortino et al., 2008; Barone et al., 2010; Troedhan et al., 2011; Goyal et al., 2012; Piersanti et al., 2014; Mantovani et al., 2014; Basheer et al., 2017; Arakji et al., 2016), less pain (Troedhan et al., 2011; Goyal et al., 2012; Piersanti et al., 2014; Mantovani et al., 2014; Basheer et al., 2017; Arakji et al., 2016), and less trismus (Sortino et al., 2008; Barone et al., 2010; Basheer et al., 2017; Arakji et al., 2016), following lower third molar surgery. Interestingly, when compared to conventional rotary instruments, piezosurgery has shown an increased bone density, and amount of remaining bone distal to the second molar, following lower third molar surgery (Arakji et al., 2016). This minimal morbidity associated with piezosurgery is linked to the favourable bone healing process, and better haemostasis (Rullo et al., 2013; Vercellotti, 2004; Sortino et al., 2008).

Greater damage to the IAN can occur without sectioning the tooth (Valmaseda-Castellon et al., 2001; Jain et al., 2016). Valmaseda-Castellon *et al* in 2001 stated that tooth sectioning reduces ostectomy, and subsequently results in lesser risk of IAN damage (Valmaseda-Castellon et al., 2001). Bataineh *et al* in 2001, and Genu et al. in 2008, did not find any statistically significant association between nerve damage and tooth sectioning (Bataineh, 2001; Genu and Vasconcelos, 2008). Interestingly, in one clinical trial, tooth sectioning was found to increase trismus during the first two post-operative days (de Brabander and Cattaneo, 1988).

3.2.2.4.3 Irrigation and curettage

Birn in 1973 postulated that energetic repeated irrigation of the alveolus might interfere with clot formation, and gives rise to infection, Birn also reported that violent curettage might injure the alveolar bone (Birn, 1973).

Butler & Sweet in 1977 compared high volume saline (175 ml) irrigation with low volume (25 ml), and found irrigation using high volume saline significantly reduces incidence of dry socket to approximately 50%, compared to the low volume (Butler and Sweet, 1977).

Sweet *et al* in 1976 compared mechanical irrigation with manual irrigation, with both groups receiving high volume (350ml), they found no statistically significant difference between the two techniques (Sweet et al., 1976).

Tolstunov in 2012 has reported that the traditional protocol of socket irrigation with a 5 ml normal saline solution, after surgical removal of impacted lower third molar, is associated with more incidence of dry socket compared to a no-irrigation protocol (Tolstunov, 2012).

The use of povidone iodine as an irrigant and coolant in lower third molar surgery was compared to the traditional irrigant, normal saline, in two prospective randomized control trials. Due to its anti-inflammatory, and haemostatic properties, the use of low-concentration povidone iodine has proven to be associated with less post-operative oedema, swelling, and trismus following lower third molar surgery (Arakeri and Brennan, 2011; Hashemi et al., 2015).

3.2.2.4.4 Wound healing

The type of healing of the surgical wound is one of the factors most closely linked to post-operative complication, following lower third molar surgery (Pasqualini et al., 2005).

There are two mechanisms for healing in the surgical site that can take place, primary or secondary. In primary healing, within twenty-four hours, the fibrin clot fills the narrow space between the approximated edges of the incision, and neutrophils present at the incision margins start migrating toward the clot. In forty-eight hours, the migrating epithelial cells from both incision edges, which started depositing basement membrane components, will form a thin but continuous epithelial layer bridging the gap beneath the incision surface. By day three, macrophages start invading the incision space and the fibrin clot is progressively replaced by granulation tissue. In day five to ten, multiple layers of new epithelium are formed, the fibroblast in the underlying tissue start to grow and produce collagen fibrils that begin to bridge the incision (Stricker et al., 2007; Sheffield, 1996).

Similar to primary healing, in secondary healing, the epithelium bridges the gap and grow over the surface of granulation tissue, however, there is a more intense inflammatory reaction and marked proliferation of granulation tissue, than that seen in primary healing (Stricker et al., 2007; Sheffield, 1996).

The type of wound healing is determined by the closure technique utilised, and the number of sutures used by the surgeon. In secondary healing, a communication between the socket and the oral cavity is maintained by using no suture (Waite and Cherala, 2006; Osunde et al., 2012; Quadri et al., 2016; Kazemian et al., 2016; Hashemi et al., 2012;

Damodar et al., 2013), or by closing the flap partially using a small number of sutures (Bello et al., 2011; Osunde et al., 2011; Xavier et al., 2008; Anighoro et al., 2013; Refo'a et al., 2011; Gay-Escoda et al., 2015; Sanchis Bielsa et al., 2008). This secondary healing could also be achieved by removing a wedge of mucosa over the extraction socket (Danda et al., 2010; Pasqualini et al., 2005; Dubois et al., 1982; Maria et al., 2012; Kakadia et al., 2013; Khande et al., 2011; Chaudhary et al., 2012). In primary healing, the socket is closed completely, with the overlying mucosal flap hermetically sealed, to achieve primary healing of the socket. The surgeon usually uses two to three sutures, and sometimes, a modification to the flap design is necessary to facilitate advancing the flap over the extraction socket (Bello et al., 2011; Xavier et al., 2008; Dubois et al., 1982; Danda et al., 2010). Placement of a dressing (Holland and Hindle, 1984; Egbor and Saheeb, 2014), or insertion of a drain into the lower third molar surgical wound (Rakprasitkul and Pairuchvej, 1997; Chukwuneke et al., 2008) have been used to modify wound healing, and alleviate post-operative complications.

3.2.2.4.5 Closure technique

Old oral surgery textbooks mentioned different techniques of wound closure, and authors have different preferences (Dubois et al., 1982). A primary closure technique, which is derived from basic surgical principles, is preferred by Howe (1971), Archer (1975), Guralnick (1968), Kruger (1974), Thoma (1969), Killey and Kay (1975) and Waite (1987) (Dubois et al., 1982). On the other hand, other authors prefer secondary healing of the wound, Bourgoyne (1957), Blair and Ivy (1923), Padgett (1938), and Mead (1954). However, both closure techniques were acceptable by Clark (1965) and Winter and Rovenstine (1947) (Clark, 1965; Winter and Rovenstine, 1947; Dubois et al., 1982). Surgeons in favour of primary closure claim that it decreases the risk of post-operative infection, while those who are supporting secondary closure suggest that this approach

allows for better drainage of inflammatory exudates, which results in reduced pain, and less swelling (Carrasco-Labra et al., 2012). Accordingly, these on-going conflicting opinions have evolved into a wide variety of partial closure techniques, that have been tested, and compared to the traditional complete closure technique in several recent clinical trials (Carrasco-Labra et al., 2012).

a) Partial closure using fewer sutures (see Table 3.1)

In a cross-over trial, included twenty patients, who underwent surgical removal of both lower third molar teeth, Xavier *et al* in 2008 observed less pain at forty eight hours, and less trismus, when the triangular flap is closed partially, than if closed completely. The authors observed no statistically significant difference between the two techniques in relation to swelling, which diminished gradually in both techniques. Interestingly, the probing depth, three months post-operatively, was found to be greater in the complete closure group, and the difference was statistical significance at the vestibular distal region of the adjacent second molar.

The authors conclude that " the strategy of not suturing the mesial relieving incision after extraction of impacted lower third molars leads to the diminution of immediate painful symptomatology, but has no influence on the swelling"(Xavier et al., 2008).

Twenty-five healthy women underwent surgical removal of both lower third molars in a cross-over study by Sanchis Bielsa *et al* in 2008. The authors have conclusively shown that secondary intention healing, after surgical removal of a semi-impacted third molar, is associated with lesser pain, swelling, and trismus than healing taking place by primary intention (Sanchis Bielsa et al., 2008).

Bello *et al* in 2011 carried out a randomized, parallel-group, controlled clinical trial, consisting of eighty-two patients required surgical removal of one or both lower third molars, to compare the effect of partial and total wound closure techniques on post-operative morbidity, after lower third molar surgery. The results demonstrated no significant difference between the two closure techniques in terms of pain, trismus and the incidence of dry socket. There was a significantly higher incidence of reactionary bleeding in partial closure group, and greater swelling in the total closure group. The authors attributed the lack of a positive influence of the partial closure technique on pain perception, to a lack of the effect on the amount of chemical mediators and their stimulation of the peripheral and central nervous system. Overall, the authors conclude that both wound closure techniques have their strong and weak points, but the partial wound closure technique is associated with more morbidity due to the distressing nature of reactionary bleeding (Bello et al., 2011).

Osunde *et al* in 2011 compared the effect of single and multiple suture techniques, on inflammatory complications, after lower third molar surgery, in fifty patients. The authors found statistically significant lower pain, swelling and trismus during the first three days, when the wound was closed partially using one suture, compared to complete closure using multiple sutures. The investigators reported no significant difference between the two closure techniques at the fifth, and seventh post-operative day (Osunde et al., 2011).

In 2011, Refo'a *et al* compared primary closure to the partial closure technique. Thirty-two patients underwent surgical removal of lower third molars in this study. Patients on whom the partial closure technique was used, showed significant less pain, swelling, and more mouth opening, during the first week after surgery (Refo'a et al., 2011).

Unlike Refo'a et al, a recent cross-over study by Gay-Escoda *et al* in 2015, that involved forty patients, was unable to demonstrate any significant difference for pain, trismus, and swelling, between the partial closure technique and the total closure technique, during the first week, after surgical removal of impacted lower third molars (Gay-Escoda et al., 2015).

A clinical study by Anighoro *et al* in 2013, investigated the difference between complete closure and partial closure of the wound, after surgical removal of lower third molar, in one hundred and twenty patients. Partial closure of the wound resulted in significantly less pain perception on the first and third day after the surgery. There was no statistically significant difference in post-operative swelling between the two techniques (Anighoro et al., 2013).

Study	Year	Location	Design	(n)	Flap design	Co-intervention	Setting	Surgeons	Measured outcomes				
									P*	S*	T*	H*	B*
Xavier et al	2008	Brazil	Split-mouth cross-over	20	Triangular	NSAID	LA (Lidocaine 2%)	N/R	✓	✓	✓	✓	
Sanchis Bielsa et al	2008	Spain	Split-mouth cross-over	25	Triangular	AB NSAID CHX	N/R	N/R	✓	✓			
Bello et al	2011	Nigeria	Parallel	82	Triangular	AB NSAID	LA (Lidocaine 2%)	One	✓	✓	✓		✓
Osunde et al	2011	Nigeria	Parallel	50	Triangular	AB NSAID	LA (Lidocaine 2%)	One	✓	✓	✓		
Refo'a et al	2011	Iran	Parallel	32	Triangular	AB NSAID CHX Ice pack	LA (Lidocaine 2%)	One	✓	✓	✓		
Anighoro et al	2013	Nigeria	Parallel	120	Triangular	N/R	N/R	N/R	✓	✓	✓		
Gay-Escoda et al	2015	Spain	Split-mouth cross-over	40	Triangular	AB NSAID CHX	LA (Articaine 4%)	One	✓	✓	✓		

Table 3.1 Characteristics of studies investigating partial closure technique using fewer sutures.
*(P: pain S: swelling T: trismus H: healing of soft tissue B: bleeding)

b) Partial closure using suture-less technique (see Table 3.2)

Suture-less lower third molar surgery was first proposed by Waite and Cherala in 2006 (Waite and Cherala, 2006). This technique is based on the fact that in third molar region, the anatomy of ramus, gingiva and buccal mucosa will fall together during the healing phase, following lower third molar surgery, when a small "V" shaped incision is used (Waite and Cherala, 2006). Retrospectively, Waite and Cherala looked at six hundred and fifty-two lower third molar surgeries, that were carried out over a two-year period by one surgeon. Although 8.7% of lower third molar surgeries developed dry socket, investigators claimed having good outcomes post-operatively. Furthermore, they pointed out the benefits of suture-less technique in decreasing the surgical time, minimizing the soft tissue trauma and manipulation, and lowering the direct costs (Waite and Cherala, 2006).

A few years later, Hashemi *et al* in 2012 carried out the first prospective clinical trial, which examined the effect of suture-less wound closure, on post-operative complications, after impacted lower third molar surgery. Using a split-mouth design in thirty patients, investigators compared the suture-less technique to primary wound closure. They reported significantly less pain and swelling in the suture-less group on the third and seventh post-operative day. No cases of dry socket, infection, or excessive bleeding were reported. Additionally, no difference was found between the suture-less technique, and the primary closure technique in terms of pocket depth around the lower second molar at six-month time (Hashemi et al., 2012).

Similarly, but with bigger cohort, Osunde *et al* in 2012 compared the suture-less and multiple suture techniques in eighty patients. Those who were treated with suture-less

technique experienced significantly less pain, swelling, and trismus at twenty-four and forty-eight hours post-operatively, compared to the other patients. No significant difference, between the two techniques, was reported at one week post-operatively (Osunde et al., 2012).

Utilizing the small "V" shape flap design described earlier by Waite and Cherala (2006), Damodar *et al* in 2013 carried out a split-mouth study, to compare the suture-less technique to the primary closure technique, after surgical removal of both lower third molars in fifty patients. Suture-less technique was associated with less pain, and less swelling during the first five post-operative days, but no difference between the two techniques was observed by the seventh day. The authors conclude that secondary closure using suture-less technique, after lower third molar surgery, produces less post-operative discomfort than primary closure (Damodar et al., 2013).

In 2015, Ricard *et al* compared the suture-less technique to the primary closure technique in fifty-four patients undergoing surgical removal of lower third molars under general anaesthesia. Unlike previous published studies, which used the triangular flap, the surgeons used the envelope flap to access lower third molar in this parallel-design clinical trial. At the second and seventh post-operative days, the post-operative facial swelling, and the reduction in mouth opening were significantly greater in the patients receiving primary closure of the surgical site, while the pain experienced by the patients in the suture-less group was significantly less at the second post-operative day only. Although more food impaction was reported in the suture-less group, no infection or dry socket were reported among this group of patients. Conversely, two patients developed dry socket, and two patients experienced post-operative infection in the primary closure group (Ricard et al., 2015).

In a cross-over trial by Kazemian *et al* in 2016, nineteen patients underwent surgical removal of both lower third molar teeth, in which one side received no sutures and the other side received multiple sutures. The results revealed a statistically significant less pain score and less swelling in the suture-less group at the third and seventh post-operative days (Kazemian et al., 2016).

Recently, Quadri *et al* in 2016 have carried out a clinical trial based on a split-mouth design. One surgeon used a small "V" shape flap, to surgically remove both lower third molars in a single sitting. For fifty patients, primary closure was achieved on the right side using multiple sutures, while secondary closure utilizing the suture-less technique was carried out on the left side. Both statistical analysis and clinical observation revealed more pain and swelling on the sutured side compared to the side with no sutures during the first week. However, food impaction was reported in sockets left open to the oral cavity without suture (Quadri et al., 2016).

Study	Year	Location	Design	(n)	Flap design	Co-intervention	Setting	Surgeons	Measured outcomes				
									P*	S*	T*	H*	B*
Hashemi et al	2012	Iran	Split-mouth	30	Triangular	AB CHX	LA (Lidocaine 2%)	One	✓	✓		✓	✓
Osunde et al	2012	Nigeria	Parallel	80	Triangular	AB NSAID	LA (Lidocaine 2%)	One	✓	✓	✓		
Damodar et al	2013	India	Split-mouth	50	Small "V" shape	Nil	LA (Lidocaine 2%)	One	✓	✓			
Ricard et al	2015	France	Parallel	54	Envelope	NSAID Betadine 50%	GA (Ropivicaine 0.75% as LA)	Three	✓	✓	✓		
Kazemian et al	2016	Iran	Split-mouth cross-over	19	Triangular	AB NSAID Cold pack	LA (Lidocaine 2%)	One	✓	✓			
Quadri et al	2016	India	Split-mouth	50	Small "V" shape	AB NSAID CHX	LA (Lidocaine 2%)	One	✓	✓			

Table 3.2 Characteristics of studies investigating suture-less technique.
*(P: pain S: swelling T: trismus H: healing of soft tissue B: bleeding)

c) Wedge of mucosa excision (see Table 3.3)

The excision of a wedge of distal mucosa of the lower second molar before suturing the flap is another partial closure technique, advocated by several authors in order to facilitate inflammatory exudate drainage through patent opening between the extraction socket and the oral cavity (Carrasco-Labra et al., 2012).

A clinical trial by Dubois *et al* in 1982 examined the effect of partial closure, by excising a wedge of mucosa distal to the lower second molar, compared to primary closure, in fifty-six patients undergoing surgical removal of both lower third molars. The results indicated more post-operative pain and swelling in complete closure group at day five, with no difference between the two techniques at two- or three-week time. However, a lower level mucosal attachment distal to the lower second molar was reported in secondary closure sites, at the end of the third post-operative week (Dubois et al., 1982).

In another parallel-group clinical trial that includes two-hundred patients, Pasqualini *et al* in 2005 investigated the effect of wedge of mucosa excision following flap closure in lower third molar surgery, to allow healing to take place by secondary intention. The investigators reported statistically significant lower pain and swelling in the secondary healing group when compared to primary healing. Interestingly, one-third of the primary healing sites showed a dehiscence distal to the adjacent lower second molar on the seventh day after surgery (Pasqualini et al., 2005).

A split-mouth design clinical trial by Danda *et al* in 2010, included ninety-three participants, compared the primary closure technique to the secondary closure, using the wedge of mucosa excision technique. More swelling and more pain were experienced in the primary closure group. Statistically, the difference between the two groups reached a significant level (Danda et al., 2010).

The wedge of mucosa excision technique was used in clinical trial by Khande *et al* in 2011, to compare secondary closure and primary closure, after surgical removal of lower third molar teeth in sixty patients. The patients who received secondary closure demonstrated significantly less post-operative pain, less swelling, and less trismus (Khande et al., 2011). These findings have been confirmed by other investigators in later studies with different cohort sizes (Maria et al., 2012; Kakadia et al., 2013; Chaudhary et al., 2012). However, the earlier study by Khande *et al* has revealed a delayed wound healing in two-third of cases in the secondary closure group, whereas dehiscence of the suture line occurred in one-third of primary closure sites (Khande et al., 2011).

Study	Year	Location	Design	(n)	Flap design	Co-intervention	Setting	Surgeons	Measured outcomes				
									P*	S*	T*	H*	B*
Dubois et al	1982	USA	Split-mouth	56	Triangular	Nil	Sedation (Lidocaine 2% as LA)	One	✓	✓		✓	
Pasqualini et al	2005	Italy	Parallel	200	Triangular	AB NSAID CHX	LA (Mepivicaine 2%)	Three	✓	✓		✓	
Danda et al	2010	India	Split-mouth	93	Triangular	AB NSAID CHX	LA (Lidocaine 2%)	One	✓	✓		✓	
Khande et al	2011	India	Parallel	60	Triangular	AB NSAID CHX Ice pack	LA (Lidocaine 2%)	N/R	✓	✓	✓	✓	
Maria et al	2012	India	Parallel	60	Triangular	N/R	LA (Lidocaine 2%)	One	✓	✓	✓		
Chaudhary et al	2012	India	Parallel	12	Triangular	AB CHX	LA (Lidocaine 2%)	N/R	✓	✓			
Kakadia et al	2013	India	Parallel	50	Triangular	AB NSAID Serratiopeptidase Ice pack	LA (Lidocaine 2%)	N/R	✓	✓	✓	✓	

Table 3.3 Characteristics of studies investigating partial closure technique using wedge of mucosa excision
*(P: pain S: swelling T: trismus H: healing of soft tissue B: bleeding).

d) Tube drain placement (see Table 3.4)

Surgical drains have been widely used in oral and maxillofacial surgery in order to evacuate accumulated fluids at the surgical site, and improve wound healing (Flynn et al., 1983; Durai et al., 2009). Despite these clinical benefits, the use of a drain has been associated with some complications such as reaction to the drain material, irritation of adjacent structures, dead space creation around the drain, and infection potentiation in clean wounds (Flynn et al., 1983).

Regardless of the complications mentioned earlier, many surgeons have used a surgical drain of different materials, and sizes, with varying degree of success, for evacuating inflammatory exudates, and reducing post-operative pain, and swelling, following lower third molar surgery (Carrasco-Labra et al., 2012).

In 1995, Ayad *et al* studied the effect of submerging a Penrose rubber drain into the socket, after primary closure, following lower third molar surgery. In thirty-four patients, who underwent surgical removal of fifty-two lower third molars, twenty-seven surgical sites received primary closure with drain submerged partially into the socket, while the other twenty-five sites were closed primarily without drain placement. The investigators reported a significant difference in post-operative complications between the two closure methods. They conclude "the drain method appears to minimize post-operative oedema, trismus, pain and analgesic consumption, and thus contributes to enhanced patient comfort" (Ayad et al., 1995).

In a split-mouth cross-over study involving twenty-three patients, Rakprasitkul and Pairuchvej in 1997, investigated the effect of drain tube placement, after surgical removal of lower third molar teeth. Post-operative facial swelling was found to be significantly less in the drain group patients, when compared to patients received primary closure and no drain. The two groups showed no significant difference in the severity of post-operative pain. Additionally, wound breakdown, oedema, and bleeding were found to be less frequent in the drain group, than in the no-drain group (Rakprasitkul and Pairuchvej, 1997).

The use of a chlortetracycline-impregnated gauze drain for lower third molar surgery was investigated by Akota *et al* in 1998. For thirty patients, undergoing surgical removal of both lower third molars in cross-over pattern, the investigators demonstrated no beneficial effect of the drain on post-operative complications like pain, swelling, and trismus, when compared to primary closure without a drain. However, the effect of chlortetracycline-impregnated gauze drain on reducing post-operative alveolitis formation was evident (Akota et al., 1998).

Saglam in 2003 investigated the effect of a tube drain placement on facial swelling after lower third molar surgery. Thirteen patients underwent surgical removal of lower third molars in a cross-over split-mouth clinical trial. After primary closure of the surgical site, a tube drain was inserted on one side for three days, the other side was closed without tube placement. The swelling experienced in the drain group was significantly less than the no-drain group (Saglam, 2003). This finding has been shown in other studies by Cerqueira *et al* in 2004 (Cerqueira et al., 2004), Handa et al in 2016 (Handa et al.), and Kumar et al in 2016 (Kumar et al., 2016), all showed the same finding. Despite the reported positive effect of tube placement on post-operative swelling, Cerqueira *et al* in

2004, and Kumar *et al* in 2016, reported no positive effect of the tube drain on pain or trismus, following lower third molar surgery (Cerqueira et al., 2004; Kumar et al., 2016).

In a parallel-group study, involving one hundred patients undergoing surgical removal of lower third molars, Chukwuneke *et al* in 2008 showed that the use of a rubber drain, after lower third molar surgery, reduces post-operative swelling and trismus, but has no effect on pain (Chukwuneke et al., 2008). Two other later studies have reported less pain, swelling, and better mouth opening, when a tube drain is placed after primary closure in lower third molar surgery (Koyuncu et al., 2015; Obimakinde et al., 2010).

Unlike the clinical trials mentioned earlier, which investigated the effect of drain placement following primary closure in lower third molar surgery, de Brabander and Cattaneo in 1988, explored the effect of combining surgical drain with a secondary closure technique following lower third molar surgery, compared to secondary closure alone. In twenty-one patients undergoing one lower third molar surgery, the surgeon performed secondary closure technique by removing wedge of tissue distal to the lower second molar before suturing. After suturing, eleven patients received a Vaseline coated gauze drain, which was sutured to the flap, to prevent dislocation, while no drain was placed in the other ten patients. Clinically, the non-drain surgical sites looked better at the time of suture removal, however, statistically there was no significant difference between the two methods in post-operative pain, swelling, and trismus (de Brabander and Cattaneo, 1988).

Study	Year	Location	Design	(n)	Flap design	Co-intervention	Setting	Surgeons	Measured outcomes				
									P*	S*	T*	H*	B*
Rakprasitkul and Pairuchvej	1997	Thailand	Split-mouth cross-over	23	Envelope	NSAID	LA (Lidocaine 2%)	N/R	✓	✓	✓	✓	✓
Akota et al	1998	Norway	Split-mouth cross-over	26 (after exclusion of 4 patients)	Envelope	NSAID CHX	LA (Lidocaine 2%)	One	✓	✓	✓	✓	
Saglam	2003	Turkey	Split-mouth cross-over	13	Envelope	AB NSAID	LA (Articaine 4%)	One		✓	✓		
Cerqueira et al	2004	Brazil	Split-mouth	53	N/R	AB NSAID	LA (Lidocaine 2%)	One	✓	✓	✓		
Chukwuneke et al	2008	Nigeria	Parallel	100	Triangular	AB NSAID	LA (Lidocaine 2%)	One	✓	✓	✓		
Handa et al	2016	India	Parallel	25	Triangular	AB NSAID Betadine Ice pack	Sedation (Lidocaine 2% as LA)	One		✓	✓		
Kumar et al	2016	India	Split-mouth cross-over	30	Triangular	AB NSAID	LA (Lidocaine 2%)	N/R	✓	✓	✓		

Table 3.4 Characteristics of studies investigating partial closure technique using tube drain placement.
*(P: pain S: swelling T: trismus H: healing of soft tissue B: bleeding).

Study	Year	Location	Design	(n)	Flap design	Co-intervention	Setting	Surgeons	Measured outcomes				
									P*	S*	T*	H*	B*
de Brabander and Cattaneo	1988	USA	Parallel	21	Envelope	No AB	LA (Lidocaine 2%)	One	✓	✓	✓	✓	
Ayad et al	1995	Germany	Parallel	52	N/R	No AB	LA (Type N/R)	One	✓	✓	✓		
Srinivas	2006	India	Split-mouth cross-over	14	Envelope	No	LA (Lidocaine 2%)	One	✓	✓	✓		
Obimakinde et al	2010	Nigeria	Parallel	80	Triangular	AB NSAID	LA (Lidocaine 2%)	One	✓	✓	✓		
Koyuncu et al	2015	Turkey	Split-mouth cross-over	40	Triangular	AB CHX	LA (Lidocaine 2%)	One	✓	✓	✓		

Table 3.4 continued.
*(P: pain S: swelling T: trismus H: healing of soft tissue B: bleeding).

e) Partial closure with dressing (see Table 3.5)

More than thirty years ago, Holland and Hindle in 1984 suggested the use of Bismuth Iodoform Paraffin Paste (BIPP) dressing combined with partial closure for lower third molar surgery. They performed a split-mouth clinical trial, in which seventy patients underwent surgical removal of both lower third molar teeth. The surgeon used partial closure with BIPP dressing on one side, while the other side was closed primarily. Although no difference was reported between the two techniques in the time taken to achieve satisfactory healing, the complete closure sides showed more post-operative pain, and swelling (Holland and Hindle, 1984).

Thirty years later, Egbor and Saheeb in 2014 used a Whitehead's Varnish dressing with the partial closure technique, after surgical removal of lower third molar. The investigators compared this technique to the complete closure technique. In this parallel-group study, which includes seventy-two patients, undergoing surgical removal of lower third molars, the authors reported significantly less swelling and trismus in the dressing group. In contrast to the previous study by Holland and Hindle, Egbor and Saheeb demonstrated no significant effect of either closure technique on post-operative pain (Egbor and Saheeb, 2014).

Study	Year	Location	Design	(n)	Flap design	Co-intervention	Setting	Surgeons	Measured outcomes				
									P*	S*	T*	H*	B*
Holland and Hindle	1984	UK	Split-mouth	70	Triangular	No	GA	One	✓	✓		✓	
Egbor and Saheeb	2014	Nigeria	Parallel	72	Triangular	AB NSAID	LA (Lidocaine 2% as LA)	One	✓	✓	✓		

Table 3.5 Characteristics of studies investigating partial closure with dressing.
*(P: pain S: swelling T: trismus H: healing of soft tissue B: bleeding).

Study	Year	Intervention	Control	Outcome follow-up (days)	Pain scale	Outcome
Xavier et al	2008	Partial closure	Primary closure	2, 3, 7, 15	100 mm VAS - 4 grades	Less pain in the partial closure group at 48 hours.
Sanchis Bielsa et al	2008	Partial closure	Primary closure	6 h, 12 h, 1 to 7	VAS - 10 grades	Less pain in the partial closure group.
Bello et al	2011	Partial closure	Primary closure	1 to 7	VAS - 6 grades	No difference between the two groups
Osunde et al	2011	Partial closure	Primary closure	1, 2, 3, 5, 7	10 cm VAS	Less pain in partial closure group at post-operative days 1, 2, and 3.
Refo'a et al	2011	Partial closure	Primary closure	3	VAS - 6 grades	Significant lower pain in partial closure group.
Anighoro et al	2013	Partial closure	Primary closure	1, 3, 7	Verbal rating scale - 4 grades	Less pain in partial closure group at post-operative days 1and 3.
Gay-Escoda et al	2015	Partial closure	Primary closure	2, 7	VAS - 11 grades	No statistical significant difference between the two groups.
Hashemi et al	2012	Suture-less	Primary closure	1, 3, 7	VAS - 6 grades	Significant less pain in the suture-less group on 3rd and 7th day post-operatively.

Table 3.6 Summary of studies investigating closure technique by assessing post-operative pain.

Study	Year	Intervention	Control	Outcome follow-up (days)	Pain scale	Outcome
Osunde et al	2012	Suture-less	Primary closure	1, 2, 7	10 cm VAS	Significant less pain in the suture-less group at 24 h and 48 h post-operatively.
Damodar et al	2013	Suture-less	Primary closure	2, 5, 7	VAS - 6 grades	Significant less pain in suture-less group until day 5.
Ricard et al	2015	Suture-less	Primary closure	2 and 7	5 cm VAS	significant less pain in suture-less group at day 2.
Kazemian et al	2016	Suture-less	Primary closure	1, 3, 7	100 mm VAS	Significant less pain in the suture-less group on 3rd and 7th day.
Quadri et al	2016	Suture-less	Primary closure	6 h, 1to 7	5 cm VAS	Less pain in suture-less group during 1st post-operative week.
Dubois et al	1982	Wedge mucosa excision	Primary closure	5, 12, 22	Two grades: mild to moderate – moderate to severe.	Less pain in partial closure group at day 5.
Pasqualini et al	2005	Wedge mucosa excision	Primary closure	6 h, 1to 6	5 cm VAS	Significant less pain in partial closure group during 1st post-operative week.

Table 3.6 continued

Study	Year	Intervention	Control	Outcome follow-up (days)	Pain scale	Outcome
Danda et al	2010	Wedge mucosa excision	Primary closure	7	VAS - 5 grades	Significant less pain in partial closure group at one week post-operatively.
Khande et al	2011	Wedge mucosa excision	Primary closure	1-7	VAS - 5 grades	Significant less pain in partial closure group during 1st post-operative week.
Maria et al	2012	Wedge mucosa excision	Primary closure	1, 3, 7	VAS - 6 grades	Significant less pain in partial closure group during 1st post-operative week.
Kakadia et al	2013	Wedge mucosa excision	Primary closure	6 h, 2, 4, 7	VAS - 6 grades	Significant less pain in partial closure group during 1st post-operative week.
Chaudhary et al	2012	Wedge mucosa excision	Primary closure	6 h, 1to 6	VAS - 6 grades	Less pain in partial closure group during 1st post-operative week. Significant at day1, 2, and 4.
Rakprasitkul and Pairuchvej	1997	Tube drain	Primary closure	3and 7	VAS - 10 grades	Significant less pain in the drain group.

Table 3.6 continued

Study	Year	Intervention	Control	Outcome follow-up (days)	Pain scale	Outcome
Akota et al	1998	Tube drain	Primary closure	1, 3, 6	50 mm VAS	No statistically significant difference between the two groups.
Cerqueira et al	2004	Tube drain	Primary closure	1, 3, 7, 15	10 cm VAS	No statistically significant difference between the two groups.
Kumar et al	2016	Tube drain	Primary closure	1, 3, 7, 15	VAS - 6 grades	No statistically significant difference between the two groups.
Chukwuneke et al	2008	Tube drain	Primary closure	1, 3, 5	VAS - 10 grades	No statistically significant difference between the two groups.
Koyuncu et al	2015	Tube drain	Primary closure	1 to 7	VAS - 11 grades	Less pain in drain group during 1st post-operative week. Significant at day1, 2, and 3.
Obimakinde et al	2010	Tube drain	Primary closure	1, 2, 7	100 mm VAS	Significant less pain in drain group at day 1 and 2.

Table 3.6 continued

Study	Year	Intervention	Control	Outcome follow-up (days)	Pain scale	Outcome
Ayad et al	1995	Tube drain	Primary closure	1, 3, 7	Scale from 1 to 10	Significant less pain in drain group.
De Brabander and Cattaneo	1988	Tube drain+ Wedge mucosa excision	Wedge mucosa excision	2 and 7	VAS (mild to severe)	No statistically significant difference between the two groups.
Srinivas	2006	Tube drain	Primary closure	1, 2, 3, 7	Binary (Pain/no pain)	Less pain in drain group but not statistically significant.
Holland and Hindle	1984	Partial closure with BIPP dressing	Primary closure	1-18	Binary (Pain/no pain)	Significant less pain in dressing group at day 3 and 4.
Egbor and Saheeb	2014	Partial closure with whitehead varnish dressing	Primary closure	1, 2, 3, 5, 7	10 cm VAS	Lower pain score in dressing group but not statistically significant.

Table 3.6 continued

Study	Year	Intervention	Control	Method for Assessment	Outcome follow-up (days)	Outcome
Xavier et al	2008	Partial closure	Primary closure	Amin and Laskin method	3, 7, 15	No statistically significant differences between the two groups.
Sanchis Bielsa et al	2008	Partial closure	Primary closure	Subjective: using 4-point scale by patient and investigator. Objective: two lines on the face using tape	2 and 7	Significant less swelling in partial closure group in all measurement methods.
Bello et al	2011	Partial closure	Primary closure	Three lines on the face using tape	2, 5, 7	Significant less swelling in partial closure group at day 2, 5, and 7.
Osunde et al	2011	Partial closure	Primary closure	Five lines on the face; Neupert et al method modified by Filho et al (Laureano Filho et al., 2005)	1, 2, 3, 5, 7	Significant less swelling in partial closure group at day 1, 2, and 3.
Refo'a et al	2011	Partial closure	Primary closure	One vertical line on the face using tape	1, 3, 7	Significant less swelling in partial closure group at day 3 and 7.
Anighoro et al	2013	Partial closure	Primary closure	Two lines on the face, vertical and horizontal	1, 3, 7	No statistically significant differences between the two groups at any day.

Table 3.7 Summary of studies investigating closure technique by assessing post-operative swelling

Study	Year	Intervention	Control	Method for Assessment	Outcome follow-up (days)	Outcome
Gay-Escoda et al	2015	Partial closure	Primary closure	Three facial measurements (horizontal, oblique and vertical)	2 and 7	No statistically significant differences between the two groups at any day.
Hashemi et al	2012	Suture-less	Primary closure	One horizontal facial measurements	1, 3, 7	Significant less swelling in suture-less group at day 3 and 7.
Osunde et al	2012	Suture-less	Primary closure	Amin and Laskin method	1, 2, 7	Significant less swelling in suture-less group at 24 h and 48 h.
Damodar et al	2013	Suture-less	Primary closure	Amin and Laskin method	3, 5, 7	Significant less swelling in suture-less group at day 3 and 5.
Ricard et al	2015	Suture-less	Primary closure	One oblique facial measurements	2 and 7	Significant less swelling in suture-less group at day 2 and 7.
Kazemian et al	2016	Suture-less	Primary closure	One horizontal facial measurements	1,3, 7	Significant less swelling in suture-less group at all days.
Quadri et al	2016	Suture-less	Primary closure	Amin and Laskin method	3, 5, 7	Significant less swelling in suture-less group at all days.
Dubois et al	1982	Wedge mucosa excision	Primary closure	Subjective by patient using two-grade scale (mild to moderate – moderate to severe)	5, 12, 22	Significant less swelling in partial closure group at day 5.

Table 3.7 continued

Study	Year	Intervention	Control	Method for Assessment	Outcome follow-up (days)	Outcome
Pasqualini et al	2005	Wedge mucosa excision	Primary closure	Berge method using VAS 0-5 cm	6 h, 1, 2, 3, 4, 5, 6	Significant less swelling in partial closure group at all days.
Danda et al	2010	Wedge mucosa excision	Primary closure	Berge method using VAS 1-5	7	Significant less swelling in partial closure group.
Khande et al	2011	Wedge mucosa excision	Primary closure	Subjective by patient: Berge method using VAS 0-5 cm. Objective: Amin and Laskin method using silk suture.	Subjective: 1 to 7 Objective: 2 and 7	Significant less swelling in partial closure group in both methods at all days.
Maria et al	2012	Wedge mucosa excision	Primary closure	Berge method using VAS 0-5	1,3, 7	Significant less swelling in partial closure group at all days.
Kakadia et al	2013	Wedge mucosa excision	Primary closure	Three facial measurements (horizontal, oblique and vertical)	6 h,2,4, 7	Significant less swelling in partial closure group at all days.
Chaudhary et al	2012	Wedge mucosa excision	Primary closure	Berge method using VAS 0-5	6 h, 1, 2, 3, 4, 5, 6	Significant less swelling in partial closure group at day 1, 2, 3 and 4.
Rakprasitkul and Pairuchvej	1997	Tube drain	Primary closure	Subjective by patient using four-grade scale 0-3. Objective: Amin and Laskin method	3 and 7	Significant less swelling in drain group at all evaluation days.

Table 3.7 continued

Study	Year	Intervention	Control	Method for Assessment	Outcome follow-up (days)	Outcome
Akota et al	1998	Tube drain	Primary closure	Subjective by patient using 50 mm VAS	3 h, 7 h, 11 h, and 1-6	Significant less swelling in non-drain group at day 1.
Saglam	2003	Tube drain	Primary closure	Amin and Laskin method	1, 2, 3, 7	Significant less swelling in drain group at day 1 and 2.
Cerqueira et al	2004	Tube drain	Primary closure	Amin and Laskin method	1, 3, 7, 15	Significant less swelling in drain group at day 1 and 3.
Handa et al	2016	Tube drain	Primary closure	Three facial measurements (two horizontal and one vertical)	2 and 7	Significant less swelling in drain group at all evaluation days.
Kumar et al	2016	Tube drain	Primary closure	Amin and Laskin method	1, 3, 7, 15	Significant less swelling in drain group at day 3 and 7.
Chukwuneke et al	2008	Tube drain	Primary closure	Amin and Laskin method	1,3, 5	Significant less swelling in drain group at all evaluation days.
Koyuncu et al	2015	Tube drain	Primary closure	Three facial measurements (horizontal, oblique and vertical)	2 and 7	Significant less swelling in drain group at day 2.

Table 3.7 continued

Study	Year	Intervention	Control	Method for Assessment	Outcome follow-up (days)	Outcome
Obimakinde et al	2010	Tube drain	Primary closure	Three facial measurements (horizontal, oblique and vertical)	1, 2, 7	Significant less swelling in drain group at all evaluation days.
Srinivas	2006	Tube drain	Primary closure	Amin and Laskin method	1, 2, 3, 7	Less swelling in drain group but not statistically significant.
Ayad et al	1995	Tube drain	Primary closure	Four horizontal facial measurements	1, 3, 7	Significant less swelling in drain group at all evaluation days.
De Brabander and Cattaneo	1988	Tube drain+ Wedge mucosa excision	Wedge mucosa excision	Subjective: VAS by observer. Objective: Custom made U-shape calliper	2 and 7	No statistically significant differences between the two groups at any day.
Holland and Hindle	1984	Partial closure with BIPP dressing	Primary closure	Facebow apparatus by Holland et al 1979	1, 2, 7	Significant less swelling in dressing group at all evaluation days.
Egbor and Saheeb	2014	Partial closure with whitehead varnish dressing	Primary closure	Two horizontal facial measurements.	1, 2, 3, 5, 7	Significant less swelling in dressing group at day 2.

Table 3.7 continued

Study	Year	Intervention	Control	Method for Assessment	Outcome follow-up (days)	Outcome
Xavier et al	2008	Partial closure	Primary closure	Distance between central incisors using flexible ruler (mm)	3,7, 15	Significant less trismus in partial closure group at day 7.
Bello et al	2011	Partial closure	Primary closure	Distance between central incisors	2, 5, 7	No significant difference between the two groups.
Osunde et al	2011	Partial closure	Primary closure	Distance between right central incisors with Vernier calliper (cm)	1, 2, 3, 5, 7	Significant less trismus in partial closure group at day 1, 2 and 3.
Refo'a et al	2011	Partial closure	Primary closure	Distance between central incisors (mm)	1, 3, 7	Significant less trismus in partial closure group at day 3 and 7.
Anighoro et al	2013	Partial closure	Primary closure	Distance between central incisors (cm) with Vernier calliper	1,3, 7	Significant less trismus in partial closure group at day 7.
Gay-Escoda et al	2015	Partial closure	Primary closure	Maximum inter-incisors distance(cm) with Vernier calliper	2 and 7	No significant difference between the two groups.
Osunde et al	2012	Suture-less	Primary closure	Distance between right central incisors with Vernier calliper (cm)	1, 2, 7	Significant less trismus in suture-less group at day 1 and 2.

Table 3.8 Summary of studies investigating closure technique by assessing post-operative trismus.

Study	Year	Intervention	Control	Method for Assessment	Outcome follow-up (days)	Outcome
Ricard et al	2015	Suture-less	Primary closure	Maximum inter-incisors distance(cm)	2 and 7	Significant less trismus in suture-less group at all evaluation days.
Khande et al	2011	Wedge mucosa excision	Primary closure	Maximum inter-incisors distance(cm)	2 and 7	Significant less trismus in suture-less group at all evaluation days.
Maria et al	2012	Wedge mucosa excision	Primary closure	Maximum inter-incisors distance(mm) using simple graduated metallic scale	1,3, 7	Significant less trismus in partial closure group at all evaluation days.
Kakadia et al	2013	Wedge mucosa excision	Primary closure	Distance between right central incisors with Vernier calliper (cm)	6 h, 2, 4, 7	Significant less trismus in partial closure group at day 2, 4, and 7.
Rakprasitkul and Pairuchvej	1997	Tube drain	Primary closure	Distance between central incisors (mm)	3 and 7	Significant less trismus in drain group at day 3 and 7.
Akota et al	1998	Tube drain	Primary closure	Maximum inter-incisors distance(mm) using ruler	3 and 7	No significant difference between the two groups.
Saglam	2003	Tube drain	Primary closure	Distance between central incisors (mm)	1, 2, 3, 7	The degree of trismus was greater in the no drain group but the difference was not statistically significant.

Table 3.8 continued

Study	Year	Intervention	Control	Method for Assessment	Outcome follow-up (days)	Outcome
Cerqueira et al	2004	Tube drain	Primary closure	Maximum mouth opening (cm)	1,3,7, 15	No significant difference between the two groups.
Handa et al	2016	Tube drain	Primary closure	Maximum inter-incisors distance (mm) using divider and scale.	2 and 7	No significant difference between the two groups.
Kumar et al	2016	Tube drain	Primary closure	Maximum inter-incisors distance (cm) with Vernier calliper	1, 3, 7, 15	No significant difference between the two groups.
Chukwuneke et al	2008	Tube drain	Primary closure	Distance between right central incisors (cm) using dental calliper	1, 3, 5	Significant less trismus in drain group at all evaluation days.
Koyuncu et al	2015	Tube drain	Primary closure	Maximum inter-incisors distance (mm) using ruler	2 and 7	Significant less trismus in drain group at all evaluation days.
Obimakinde et al	2010	Tube drain	Primary closure	Maximum inter-incisors distance (cm) with Vernier calliper	1, 2, 7	Significant less trismus in drain group at all evaluation days.
Ayad et al	1995	Tube drain	Primary closure	Maximum inter-incisors distance (mm)	1, 3, 7	Significant less trismus in drain group at all evaluation days.

Table 3.8 continued

Study	Year	Intervention	Control	Method for Assessment	Outcome follow-up (days)	Outcome
De Brabander and Cattaneo	1988	Tube drain+ Wedge mucosa excision	Wedge mucosa excision	Maximum inter-incisors distance(mm)	2 and 7	No significant difference between the two groups.
Srinivas	2006	Tube drain	Primary closure	Distance between central incisors (mm)	1, 2, 3, 7	Less trismus in drain group but not statistically significant.
Egbor and Saheeb	2014	Partial closure with whitehead varnish dressing	Primary closure	Maximum inter-incisors distance (cm) with Vernier calliper	1, 2, 3, 5, 7	Significant less trismus in dressing group at day 2 and 3.

Table 3.8 continued

In a Cochrane review, which investigated different surgical techniques for the removal of lower third molar teeth, Coulthard *et al* in 2014 report insufficient evidence to support that any wound closure technique, primary versus secondary, was superior to another, in reducing dry socket, post-operative infection, or reactionary bleeding, or improving mouth opening at one week post-operatively (Coulthard et al., 2014).

However, the authors report a moderate quality evidence that secondary wound closure has a reduced post-operative pain at twenty-four hours, and slightly reduced swelling at one week post-operatively (Coulthard et al., 2014).

The authors also find 'some evidence' that the use of a surgical drain, for the lower third molar surgery, is associated with less post-operative swelling, and less trismus at one week after surgery. On the other hand, there was 'insufficient evidence' to determine whether the presence of a surgical drain has any effect on pain at twenty-four hours post-operatively (Coulthard et al., 2014).

Up to our knowledge, there is no previous randomised controlled trial comparing suture-less lower third molar surgery, to the one suture lower third molar surgery, in terms of post-operative complication and wound healing. We carried out this prospective, randomised, double-blind, split-mouth controlled study, in order to investigate the effect of wound closure technique, through using different number of sutures, on the post-operative complications and wound healing, following lower third molar surgery.

4. Materials and Methods

4.1 Ethical approval

Ethical approval for this clinical trial was granted from SJH/AMNCH Research Ethics Joint Committee.

4.2 Study design

This clinical trial is a prospective, randomised, double-blind, control trial, which is designed to investigate the effect of two secondary wound closure techniques, using different number of sutures, on the post-operative complications, following lower third molar surgery.

Both methods of treatment used in this trial were used in the same patient at the same time, so the participants act as their own controls. The use of such split-mouth design helps in reducing confounding variables that results from inter-patient variations, as the parameters we investigated in this study, such as pain, swelling, bleeding, and healing vary significantly between different patients undergoing the same surgery. In order to prevent the "carry-over "effect that happens in split-mouth design trials, when treatments are carried out at different times, we eliminated this effect by having the patient evaluating the effect of both treatments at the same time. On the other hand, we were unable to investigate the effect of both techniques on trismus; as mouth opening, unlike other variables, could be recoded only once for each patient at each time point.

4.2.1 Randomisation

Randomisation was carried out using random-numbers table generated using random sequence generator (RANDOM.ORG, 2016). Surgical sites were randomised into one of two Groups:

i) Group A: one suture

ii) Group B: suture-less

The trial was designed as a double-blind study in order to reduce observer, and participant bias. Participants were not informed, as which side of their mouth received the suture.

4.2.2 Patient selection

Patients were selected from those, who had been referred to the Dublin Dental University Hospital, for the removal of bilateral lower third molars. They were invited to take part in the study (see Appendix C). Patients who accepted the invitation, attended the Oral & Maxillofacial Surgery Department of the Dublin Dental University Hospital pre-operatively to determine whether they met the inclusion criteria, and they are requested to sign a written consent (see Appendix B), before taking part in the study.

4.2.3 Inclusion criteria

Consenting patients attending the Department of Oral and Maxillofacial Surgery at Dublin Dental University Hospital, who require the removal of both lower third molar teeth only, and fulfil the following requirements could be included in the study:

i) Suitable for treatment under local anaesthetic with intravenous conscious dental sedation

ii) Full thickness mucoperiosteal flap required, with bone removal with or without tooth sectioning for removal of both lower third molars which have similar eruptive state and similar difficulty

iii) American Society of Anaesthesiologists (ASA) Grade I or II (Grade I = no medical conditions; Grade II = medical conditions that are well controlled)

iv) No known congenital or acquired bleeding tendency

v) Aged between 18 and 45

vi) Participants, who are willing to cooperate with the requirements of the study protocol.

4.2.4 Exclusion criteria

Participants are excluded in any of the following circumstances:

i) Participant does not want to take part in the study, or is unable to give informed consent for the procedure involved

ii) Participant does not require the removal of both lower third molars in line with NICE guidelines

iii) Participant is not suitable for treatment under local anaesthetic with intravenous conscious sedation.

iv) Participant has a medical condition that could be complicated by the procedure (ASA >II).

v) Surgery doesn't require a full thickness mucoperiosteal flap or bone removal.

vi) Under 18 years of age or over 45 years of age.

vii) Participant is pregnant or a nursing mother.

viii) Participant who has an allergy or can't tolerate the antibiotic and the analgesics used in the study. All patients were given the same medications to decrease variances.

4.2.5 Sample size

The sample size in previous similar published studies have ranged from nineteen to fifty patients, with average thirty-seven patients who required seventy-four surgical removal of lower third molar (Hashemi et al., 2012; Damodar et al., 2013; Kazemian et al., 2016; Quadri et al., 2016).

In order to detect a difference in the mean change in continuous outcomes between the two treatment groups, a Power Calculation has shown that at least thirty-one participants with sixty-two surgical sites, are needed to achieve an Alpha of 0.05 and Power of at least 0.9.

4.3 Surgical procedure

Each participant underwent the surgical removal of bilateral lower third molars only, under local anaesthetic, and IV conscious sedation, in the same operative visit. All procedures were performed by the same surgeon (Third year Specialist Registrar in Oral Surgery), and under similar operative conditions.

4.3.1 Pre-operative

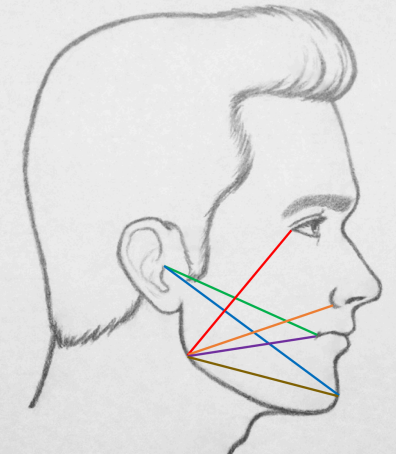
4.3.1.1 Pre-operative medications

Each participant received the following pre-operative medications as per the current policy in the Dublin Dental University Hospital:

1. Antibiotic: Amoxicillin 500 mg orally
2. Analgesics: Paracetamol 1 g and Ibuprofen 400 mg orally
3. Mouthwash: Chlorhexidine 0.2% (Kin)10 ml.

4.3.1.2 Pre-operative facial measurements

Using the method described by Montebugnoli *et al* (Montebugnoli et al., 2004), and used also by Szolnoky *et al* (Szolnoky et al., 2007), six baseline linear measurements were recorded in (mm) on each side of the face using six reproducible anatomical landmarks (Neupert et al., 1992), while patient is in neutral head position (see Figure 4.1).



Line 1: tragus-lip junction
Line 2: tragus - median point of chin
Line 3: mandibular angle - eye lateral canthus
Line 4: mandibular angle - ala nasi
Line 5: mandibular angle - lip junction
Line 6: mandibular angle - median point of chin

Figure 4.1 Facial measurements for evaluation of facial swelling.

One examiner recorded all measurements for all participants using a special measuring tape.

Mouth opening (MO) was also recorded pre-operatively by measuring the vertical distance between the upper right and lower right central incisors using a metallic ruler.

Each linear measurement was repeated twice, and the average was reported (see Appendix E).

4.3.1.3 Periodontal examination and impaction characteristics

Periodontal examination for the adjacent lower second molar was carried out using a William's probe. Pocket Depth (PD) and Clinical Attachment Level (CAL) were

recorded at three buccal sites; Mesio-buccal (M), Mid-buccal (MD) and Disto-buccal (D) (see Appendix H).

Clinical and radiographic characteristics of both impacted lower third molars and adjacent lower second molars were recorded (see Appendix D).

4.3.2 Peri-operative

In theatre, and immediately before the removal of both lower third molars, the surgical sites were allocated to the two intervention groups using the aforementioned randomization method. This allocation was carried out by a theatre nurse and was informed to the surgeon immediately before starting the surgery. Additionally, a coin was tossed to randomly determine which side the surgeon will start the surgical procedure on. Heads indicated the right side, and Tails indicated the left side.

After IV access was established using a 22G or a 20 G cannula, a conscious sedation agent, midazolam, was administered incrementally and titrated against the patient's response.

Anaesthesia was achieved by IAN block in addition to a buccal nerve block using lidocaine hydrochloride 2% with epinephrine 1:80,000. Two 2.2 ml cartridges were administered – one for the inferior alveolar and lingual nerves, and one for buccal nerve. Additional amount of local anaesthetic solution would be administered, if the patient felt pain during surgery.

One surgeon performed all the surgical procedures using the following standard surgical technique:

i) A type II buccal envelope flap (see Figure 4.2) was raised through crevicular incision from the distal of the third molar to the papilla between the first and second molar, including the papillae between the first, second and third molars. Another small distal reliving incision from the position that the distobuccal cusp of the third molar would occupy if the tooth were in a vertical position to a maximum of 5mm in length (Stassen modification).

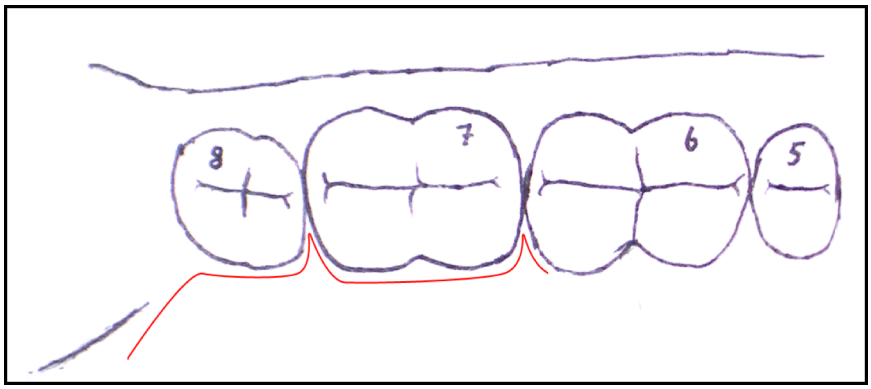


Figure 4.2 Modified buccal envelope flap for lower third molar surgery.

ii) Lingual nerve protection, when needed, was provided by raising a lingual flap using a Mitchell's trimer and using a Howarth's retractor as advised by Rogers and Stassen (Rogers and Stassen, 2010).

iii) Bone removal was carried out using a tungsten carbide fissure bur, in a straight handpiece, under sterile 0.9 normal saline continuous irrigation.

iv) When necessary, sectioning of the crown and roots was performed under sterile saline with continuous irrigation.

v) Once the tooth removal has been completed, removal of granulation tissue and gentle curettage of the socket were carried out, and followed by gentle irrigation using a twenty-ml sterile saline wash.

vi) The flap was repositioned. Surgical sites in Group A received one suture just distal to the lower second molar using 3/0 Vicryl Rapide placed through the

buccal and lingual papilla (see Figure 4.3). Surgical sites in Group B did not receive any suture.

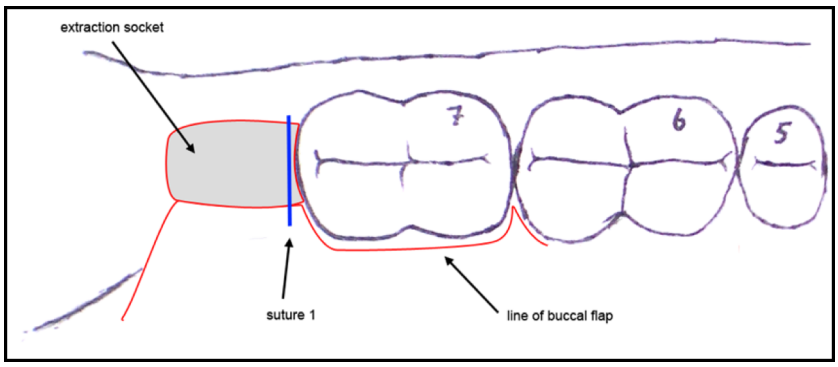


Figure 4.3 Suture site in one-suture technique.

vii) Direct pressure was applied to the surgical site using sterile gauze moistened with 0.9 normal saline.

viii) Once the first site had been completed, the surgeon performed the surgical removal on the opposite side using the same technique.

The operator recorded the following data about the procedure for each side (see Appendix G):

1. Amount of local anaesthetic given
2. Whether a lingual flap was raised or not
3. When bone removal was carried out, sites of bone removal (mesial / buccal/ distal), and the amount of bone removed occlusally were recorded
4. The number of times the tooth was sectioned
5. Intra-operative complications
6. Operative time in minutes (starting from the first incision until the procedure had been completed on that side)
7. Perceived level of difficulty by operator

8. Surgical trauma using three-grade difficulty scale (O'Neil and Stassen, 2014) (see Figure 4.4).

Difficulty grade	Bone removal	Tooth sectioning	Difficult surgery
Easy	✓	×	×
Medium	✓	✓	×
Difficult	✓	✓	✓

Figure 4.4 Surgical difficulty scale.

4.3.3 Post-operative

Following completion of the surgical procedure, all participants were instructed to use the following:

1. Amoxicillin 500 mg orally, three times daily for five days
2. Paracetamol 1 g orally, six hourly for three days, and then if needed
3. Ibuprofen 400 mg orally, six hourly for three days, and then if needed
4. Chlorhexidine mouth wash 0.2% 10ml, once daily, for one week
5. Salty mouth rinse, three times daily, for one week.

4.4 First post-operative week questionnaire

All participants were questioned as close as possible to post-operative hour 12, 24 and then daily up to the seventh day from completion of the surgery using a standardized questionnaire, to assess post-operative bleeding, post-operative discomfort, post-operative swelling, and compliance with post-operative instructions (see Appendices I, J, and M). The degree of pain and discomfort was rated by participant using an eleven-point Numeric Rating Scale (NRS) where 0 indicates “no

pain" and 10 indicates worst imaginable pain (McCaffery and Pasero, 1999) (see Figure 4.5).

This scale has been used in several clinical trials to accurately assess pain following lower third molar surgery.

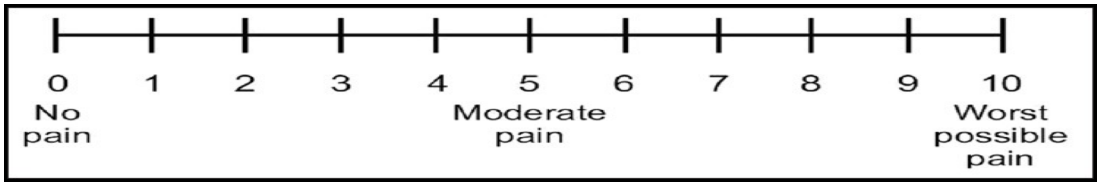
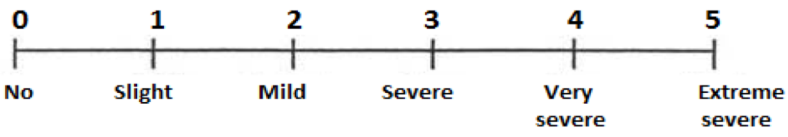


Figure 4.5 Eleven-point Numeric Rating Scale (NRS) for pain.

The degree of facial swelling was also evaluated by the participants using six-point Visual Analogue Scale (VAS), where 0 indicates "no swelling", and 5 indicates "extreme severe swelling" (Berge, 1988) (see Figure 4.6).



0	No swelling	The patient does not detect the slightest swelling
1	Slight swelling	The patient detects a slight swelling but is not very noticeable
2	Mild swelling	The swelling is noticeable but does not interfere with normal mastication & swallowing
3	Severe swelling	The swelling is evident & hinders normal mastication
4	Very severe swelling	The swelling is marked. Mastication is hindered but there is no reduction in mouth opening(no trismus)
5	Extremely severe swelling	The swelling is very evident & mouth opening is reduced (trismus)

Figure 4.6 VAS scale for swelling with references given to patient.

The degree of bleeding was evaluated for each side by counting the number of gauzes needed to stop bleeding on the day of surgery and the following post-operative days. Also, participants recorded the day on which they felt bleeding had stopped completely (see Appendix I).

4.5 First post-operative review at one week

All participants were reviewed one week following the procedure for the first post-operative review. Assessment of the degree of wound healing, and facial swelling were carried out at this appointment.

a) Facial swelling and mouth opening

The six linear measurements that were measured pre-operatively on each side of the face, were measured again by the same examiner, using the same reproducible anatomical landmarks, with the patient's head is in the neutral position. The difference between the two reading was used to evaluate the amount of residual swelling at one week post-operatively (see Appendix E).

Mouth opening (MO) was also recorded by measuring the vertical distance between the upper right and lower right central incisors using metallic ruler (see Appendix E).

The above measurements were all carried out by a single observer for all participants to decrease measurement bias.

b) Wound healing

The surgeon, who performed the surgery removed the suture before the other trained assessors carried out the wound healing assessment.

Three clinicians, who are specialist oral surgeons, carried out the assessments independently. All clinicians were informed of the study protocol, and were calibrated, and trained on using the indices according to the description of the evaluation criteria

using clinical photos. All clinicians were independent observers and were not involved in any aspects of the surgical procedure or sites allocation to either group. There was an agreement achieved between the assessors when they were asked to assess the same patient.

The degree of socket epithelization was graded by the examiner using standardized tick sheet (see Figure 4.7 and Appendix K).

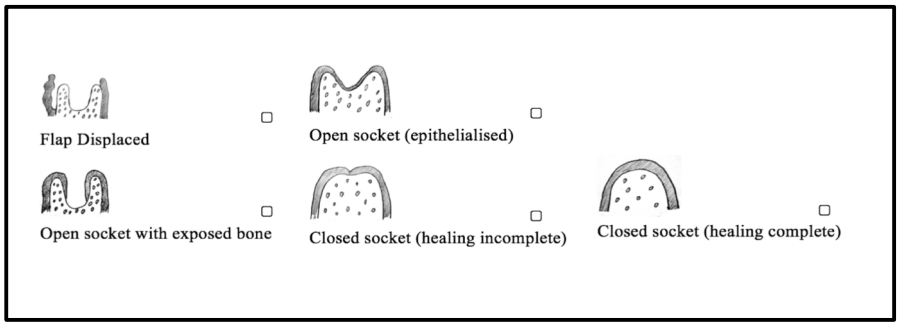


Figure 4.7 Grades of socket healing.

The extent of soft tissue healing in the surgical site was evaluated using the Healing Index for soft tissue by Landry (Landry, 1985). This index intended to grade healing into five grades, depending on the colour of tissues, epithelialisation of wound margins, presence of bleeding on palpation, granulation, and suppuration (see Figure 4.8 and Appendix F).

Healing index	Criteria
Very poor 1	Tissue colour: more than 50% of gingivae red Response to palpation: bleeding Granulation tissue: present Incision margin: not epithelialized, with loss of epithelium beyond margins Suppuration: present
Poor 2	Tissue colour: more than 50% of gingivae red Response to palpation: bleeding Granulation tissue: present Incision margin: not epithelialized, with connective tissue exposed
Good 3	Tissue colour: less than 50% of gingivae red Response to palpation: no bleeding Granulation tissue: none Incision margin: no connective tissue exposed
Very good 4	Tissue colour: less than 25% of gingivae red Response to palpation: no bleeding Granulation tissue: none Incision margin: no connective tissue exposed
Excellent 5	Tissue colour: all gingivae pink Response to palpation: no bleeding Granulation tissue: none Incision margin: no connective tissue exposed

Figure 4.8 Healing Index for soft tissue by Landry.

4.6 Second review appointment at one month

All participants except one attended the one month review appointment. At this appointment, the degree of socket healing was graded by the examiner using standardized tick sheet (see Appendix K).

Additionally, periodontal examination for lower second molar was carried out using a William's probe. Pocket depth (PD) and Clinical Attachment Level (CAL) were recorded at three buccal sites; Mesio-buccal (M), Mid-buccal (MD) and Disto-buccal (D) (see Appendix H).

4.7 Data management and analysis

The following parameters were evaluated:

1. Subjective pain evaluation, using eleven-point numerical rating scale with 0 indicates “no pain” and 10 indicates “worst imaginable pain”.

   Intensity of post-operative pain was recorded by participants at hour 12, and then on 1st, 2nd, 3rd, 4th, 5th, and 6th post-operative days.

   If participants took any extra analgesic medication, the type and amount of these medications were recorded by participants.
2. Subjective facial swelling evaluation, using a six-point numerical rating scale with 0 indicates “no swelling” and 5 indicates “extreme severe swelling”.

   Severity of post-operative swelling was recorded by participants on 1st, 2nd, 3rd, 4th, 5th, and 6th post-operative days.
3. Objective facial swelling evaluation, using six linear measurements on each side of the face recorded in (mm).

   The measurements were recorded by the examiner immediately pre-operatively, and by the same examiner post-operatively, at the one week review appointment.
4. Bleeding evaluation, was recorded by participants through counting the number of gauzes used to stop bleeding, and the duration the bleeding lasts.
5. Objective evaluation of socket healing, evaluated by examiner at one week and one month, using a five-category scale: a) flap displaced, b) open socket with exposed bone, c) open epithelized socket, d) closed socket (incomplete healing), and e) closed socket (complete healing). Presence of erythema, pus, food impaction, and dry socket were also recorded.
6. Objective evaluation of soft tissue healing, evaluated by examiner at one week according to a five-point category rating scale: 1- very poor, 2- poor ,3- good, 4- very good, and 5- excellent.

7. Objective evaluation of the adjacent lower second molar periodontal status, evaluated immediate pre-operatively and at one month by recording the following measurements at the buccal surface: average pocket depth (PD), deepest pocket depth (dPD), and the clinical attachment level (CAL).
8. Difficulty level of the surgery as perceived by the surgeon, rated by the surgeon at the completion of each surgery using a four-point category rating scale: low, medium, difficult, and very difficult.
9. Difficulty of the surgery according to the level of surgical trauma, based on three-grade difficulty scale: easy, medium, and difficult.
10. Details of the surgery that include: sites of bone removal; mesial, buccal and distal, amount of occlusal bone removal; low (< 3mm), medium (3-5mm), or large (>5 mm), the number of tooth sectioning, the need to raise a lingual flap, number of local anaesthetic cartridges, and any of the reported complications.
11. Duration of surgery for each side in minutes, which corresponded to the period between starting the incision and placement the suture in Group A, and between starting the incision and replacing the flap to its original position in Group B.
12. Compliance with post-operative instruction, evaluated by the patient by recording the duration (in days) of using the antibiotic, analgesics, chlorhexidine mouth wash, and warm salty water rinses.
13. The number of times participant attended A&E to manage post-surgical complications; dry socket, bleeding, infection, or pain.
14. Characteristics of lower third molar impaction within the study groups.
15. Age, gender, body mass index (BMI), smoking status, ASA grade, OCP use, amount of sedation given, and ethnicity distribution within the study population.

4.8 Statistical methods

Analysis of data was carried out using the statistical package SPSS. A p value ≤ .05 was accepted as statistically significant. A Wilcoxon Signed Ranks Test was used to assess for differences in pain and swelling, as rated by the patient, between the two groups. It was also used to assess for the difference between the two groups in socket healing and soft tissue healing. A McNemar's Test was used to assess differences in food impaction. Dependent t-tests were conducted to assess for difference in swelling measured at one week, bleeding, and a change in periodontal condition for lower second molar. We used Spearman Rho Correlation test rather than multivariate analysis, to assess the effect of surgical difficulty and operative time on the measured outcomes, as the use of multivariate analysis would require a larger sample size. The effect of impaction characteristics on surgical difficulty and operative time were assessed using Analysis of Variances (ANOVA), chi-square, and Spearman Rho Correlation tests.

5. Results

5.1 Sample characterises

5.1.1 Sample size

Out of one hundred and sixty patients who were deemed eligible to take part in this clinical trial, only thirty-seven patients accepted the invitation, and all were enrolled into this trial between May 2016 and April 2017. Of these thirty-seven participants, thirty-four successfully completed the study. Two were excluded, and one was lost at one month follow-up. Of those, who were excluded, one was excluded as surgical procedure of one side took longer time than usual, and the surgery on the other side was postponed, another participant was excluded, as one of the inclusion criteria was lost on the day of surgery.

5.1.2 Demographic variables

Thirty-five participants underwent bilateral lower third molar surgeries in this trial. The sample consisted of twenty-five females, and ten males, with an age range of 18 to 37, and a mean age of 26.6 (SD = 4.85). BMI of participants ranged from 18.7 to 39.9 (M = 25.25, SD = 4.87). All patients but one were Caucasian (97%) and one (3%) was Afro-American.

Twenty-nine patients (83%) were ASA grade I, while six patients (17%) were graded ASA II. Seven patients (20%) were regular smokers. Of the female participants, ten (40%) were on the OCP.

The use of the split-mouth design created no statistically significant difference between the two investigative groups in age, gender, BMI, OCP use, smoking, and ASA grade.

		Age (Years)			Total
		18-24	25-30	31-37	
Gender	Female	8	11	6	25
	Male	5	4	1	10
Total		13	15	7	35

Table 5.1 Age Groups and Gender of Study Participants

		BMI			Total
		18.5-24.9	25-29.9	30-39.9	
ASA	I	16	8	5	29
	II	4	1	1	6
Total		20	9	6	35

Table 5.2 ASA Grade and BMI Group of Study Participants

5.1.3 Teeth variables

All lower third molars were partially bony impacted that necessitated full thickness mucoperiosteal flap, and bone removal during the surgery. There was an identical bilateral teeth inclination in twenty- four patients (69%). Of the identical inclinations – twelve patients had bilaterally impacted mesioangular third molars; nine had bilaterally impacted distoangular third molars; and three had bilaterally impacted horizontal third molars. Eleven patients didn't have identical inclination of lower third molars; six patients had mesioangular impaction on one side and distoangular on the other side, three patients had vertical impaction on one side and distoangular on the other side; while the other two patients had horizontal impaction on one side and distoangular on the other side.

		Right 3rd Molar Inclination				Total
		Distoangular	Horizontal	Mesioangular	Vertical	
Left 3rd Molar Inclination	Distoangular	9	2	5	2	18
	Horizontal	0	3	0	0	3
	Mesioangular	1	0	12	0	13
	Vertical	1	0	0	0	1
Total		11	5	17	2	35

Table 5.3 Characteristics of Lower Third Molars for Study Participants

5.1.4 Operative variables

All patients received IV conscious sedation using midazolam, the dose of midazolam was titrated against the patient response; the mean total dose of midazolam given to patient was 6.2 mg with a range of 4 to 10 mg.

All seventy lower third molar surgeries required buccal full thickness mucoperiosteal flap, and bone removal. Tooth sectioning was performed when required. Bilateral lingual flaps were elevated in eighteen patients; unilateral lingual flap was elevated in eight patients; while nine patients didn't need lingual nerve protection on either side.

Operative time was recorded in minutes for each side. The mean operative time for the sutured side was 21.5 minutes with a range of 7 to 36 minutes; while the mean operative time for the suture-less side was 19.5 minutes with a range of 7 to 50 minutes.

A dependent t-test was utilized to assess for the differences in operative time between the sutured and suture-less sides. The results indicated that there was no statistical significant difference in operative time between the sutured side (M = 21.49, SD = 7.83) and the suture-less side (M = 19.51, SD = 9.15), t (34) = 1.022, p = 0.314.

Using the surgical difficulty scale described earlier, the sutured side was more difficult for seven patients, the suture-less side was more difficult for five patients, while there was no difference in surgical difficulty for the other twenty-three patients.

A Wilcoxon Signed Ranks Test was used to assess for differences in level of difficulty between the sutured and suture-less sides. The results indicated no statistical significant difference in surgical difficulty between the two sides ($z = -0.660$, $p = 0.505$).

5.2 Dry socket, infection, and neuropathy

During the first post-operative week, four patients attended A&E complaining of severe pain, which is consistent with dry socket. A diagnosis of dry socket was made clinically based on the description by Blum (Blum, 2002). Of the patients, who attended A&E, three developed bilateral dry socket, while one patient had a dry socket on one side. The incidence of dry socket in this cohort was reported as 10%.

One patient presented with a left temporary lip and chin paraesthesia at one week. This paraesthesia resolved completely eight weeks later. The incidence of temporary IAN injury in this cohort was reported as 1.4%.

One patient presented with left temporary tongue paraesthesia at one week, this tongue paraesthesia resolved completely at one month. The incidence of temporary LN injury in this cohort was reported as 1.4%.

No case of surgical site infection was reported in this clinical trial. There was no case of excessive post-operative bleeding that required any intervention, through hospital or dental clinics.

5.3 Pain during first post-operative week

The differences in post-operative pain perceived by the patient under the suture and non-suture conditions were assessed utilizing the Wilcoxon Signed Rank Test. The results are presented in Table 5.1. An inspection of this table reveals that there was a statistically significant difference on the fifth day, z = -1.99, p = 0.046 and on the sixth day, z = -2.12, p = 0.034. On day five, more patients (n= 13) experienced greater pain on the non-suture side, than patients (n= 8) who experienced greater pain on the sutured side. On day six, again more patients (n=14) reported greater pain on the non-sutured side, than did patients (n= 7) reported greater pain on the sutured side (see Figure 5.1).

Time	Condition	Mean	Std. Deviation	*z*	*p*
12 Hours	Suture	4.85	2.45	-.628	.530
	Non-Suture	5.25	2.41		
24 Hours	Suture	4.57	2.06	-1.10	.270
	Non-Suture	4.34	2.09		
48 Hours	Suture	4.65	2.09	-.811	.417
	Non-Suture	4.51	1.96		
72 Hours	Suture	4.28	2.44	-.230	.818
	Non-Suture	4.45	2.48		
Day 4	Suture	3.80	2.50	-1.29	.196
	Non-Suture	4.51	2.60		
Day 5	Suture	3.25	2.64	-1.99	.046
	Non-Suture	4.34	2.65		
Day 6	Suture	2.65	2.32	2.12	.034
	Non-Suture	3.74	2.58		

Table 5.4 Means and standard deviations and results of the Wilcoxon Signed Rank Tests for pain perceived by patient on days one to six under suture and non-suture conditions.

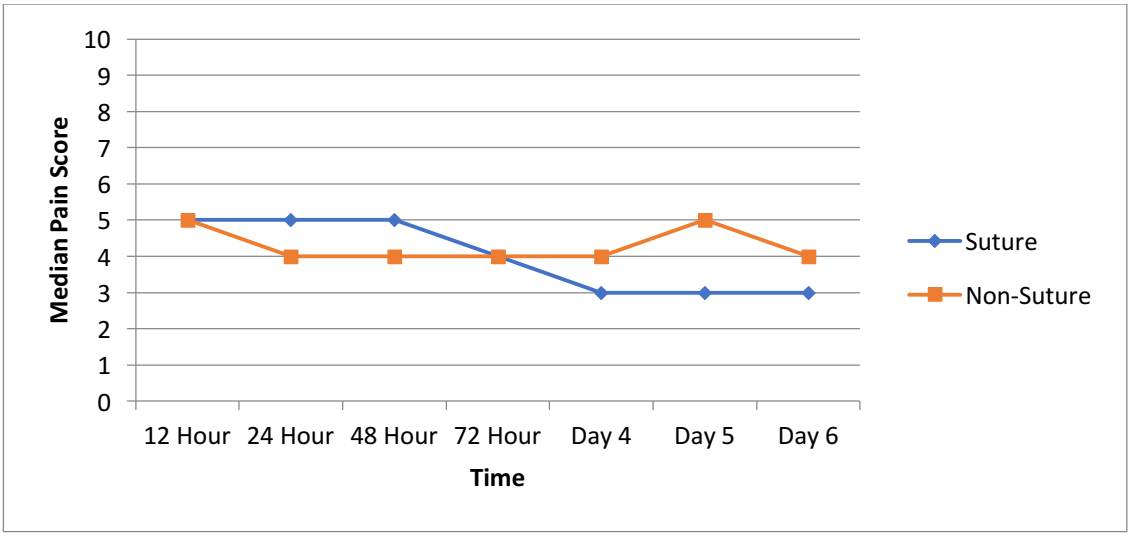


Figure 5.1 Median pain ratings for suture and non-suture conditions.

		12 Hours	24 Hours	48 Hours	72 Hours	Day 4	Day 5	Day 6
Operative Time	*r*	.372	.367	.522	.321	.342	.386	.306
	p	.028	.030	.001	.060	.045	.022	.074
	n	35	35	35	35	35	35	35
Difficulty Scale	*r*	.365	.386	.516	.541	.535	.519	.514
	p	.031	.022	.001	.001	.001	.001	.002
	n	35	35	35	35	35	35	35

Table 5.5 Spearman Rho Correlations between differences in operative time and difficulty of surgery and differences in pain perceived by the patient from day one to day six.

In order to assess if differences in operative time and level of surgical difficulty under the suture and non-suture conditions were related to the differences in the severity of pain from day one to day six, 'difference scores' were computed. The relationship between the 'difference scores' for operative time and surgical difficulty, and 'difference scores' for the pain were then assessed through a Spearman Rho Correlation. A Spearman Correlation was used due to the ordinal nature of the difference scores.

The results are presented in Table 5.2. A review of this table reveals that differences in degree of surgical difficulty were related to differences in severity of pain from day one to day six (all $p < 0.05$). Difference in operative time also was related to all measures of pain (all $p < 0.05$), with the exception at seventy-two hours, r (34) = 0.321, p = 0.060 and at day six, r (34) = 0.306, p = 0.074. These results indicate that, as the difference in the degree of surgical difficulty increased, so did the difference in severity of pain from day one to day six. In addition, as the difference in operative time increased, so did the pain severity at five of the seven measurement periods.

5.4 Facial swelling during first post-operative week

The differences in post-operative swelling as perceived by the patient under the suture and non-suture conditions were assessed utilizing the Wilcoxon Signed Rank Test. The results are presented in Table 5.3. An inspection of this table reveals that there were no differences between the sutured and non-sutured sides at all evaluation days (all $p > 0.05$).

Time	Condition	Mean	Std. Deviation	*z*	*p*
Day 1	Suture	2.62	1.330	-1.31	.190
	Non-Suture	2.40	1.264		
Day 2	Suture	2.74	1.357	-1.33	.183
	Non-Suture	2.48	1.291		
Day 3	Suture	2.28	1.250	-.835	.404
	Non-Suture	2.11	1.182		
Day 4	Suture	1.74	1.244	-.806	.420
	Non-Suture	1.60	1.034		
Day 5	Suture	1.05	.937	-.068	.946
	Non-Suture	1.11	.963		
Day 6	Suture	.828	.857	-.847	.397
	Non-Suture	.742	.852		

Table 5.6 Means and standard deviations and results of Wilcoxon Signed Rank Tests for swelling perceived by patient days one to six under suture and non-suture conditions.

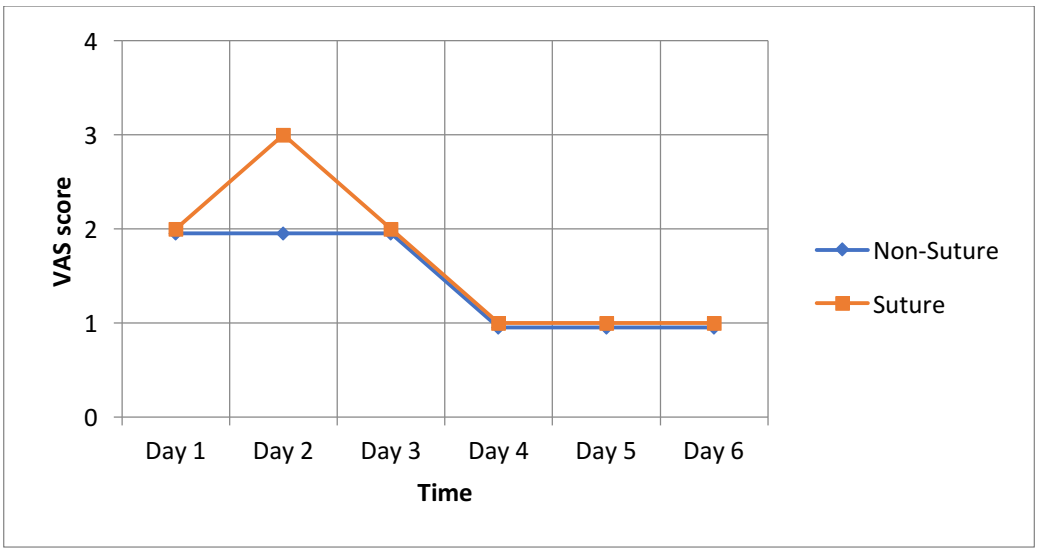


Figure 5.2 Median facial swelling for suture and non-Suture conditions. (0 = No Swelling, 1 = Slight Swelling, 2= Mild Swelling, 3 = Severe Swelling, 4= very severe swelling).

In order to assess if differences in operative time and level of surgical difficulty, under the suture and non-suture conditions were related to the differences in the severity of swelling perceived by patient from day one to day six, Spearman Rho Correlation was utilized.

Again, 'difference scores' were computed between the suture and non-suture conditions on operative time, and degree of surgical difficulty, as well on the post-operative swelling from day one to day six. The results are presented in Table 5.4. A review of this table reveals that, both differences in operative time and degree of surgical difficulty were related to differences in post-operative swelling from day one to day six (all p <0 .05).

		Day 1	Day 2	Day 3	Day 4	Day 5	Day 6
Operative Time	*r*	.537**	.501**	.536**	.538**	.395*	.478**
	p	.001	.002	.001	.001	.019	.004
	n	35	35	35	35	35	35
Difficulty Scale	*r*	.514**	.426*	.469**	.543**	.453**	.433**
	p	.002	.011	.005	.001	.006	.009
	n	35	35	35	35	35	35

Table 5.7 Spearman Rho Correlations between differences in operative time and difficulty of surgery and differences in swelling perceived by patient from day one to day six.

These results indicate that both differences in operative time, and degree of surgical difficulty were related to differences in severity of swelling perceived by patient from day one to day six. The greater the difference between sutured and non-sutured sides in operative time and degree of difficulty, the greater the difference in post-operative swelling perceived by the patient on day one through six.

5.5 Facial swelling measured at one week

The differences in facial swelling under the suture and non-suture conditions were assessed utilizing dependent t-tests. Table 5.5 contains the means, standard deviations, and t-tests for swelling measurements from line 1 to line 6, and the total reading. An inspection of this table reveals no differences between the two conditions on all swelling measures (all p >0 .05), although line 2, $t(34) = 1.92$, $p = 0$ .064, and total reading, $t(34) = 1.89$, $p = 0$ .067, did approach significance.

Line	Condition	Mean	Std. Deviation	*t*	*p*
Line 1	Suture	.1200	.272	1.062	.296
	Non-Suture	.0657	.250		
Line 2	Suture	.1343	.341	1.917	.064
	Non-Suture	-.0171	.315		
Line 3	Suture	.0829	.434	.865	.393
	Non-Suture	-.0086	.393		
Line 4	Suture	.1371	.548	1.172	.249
	Non-Suture	.0029	.586		
Line 5	Suture	.2200	.829	.576	.568
	Non-Suture	.1371	.586		
Line 6	Suture	.0743	.604	1.462	.153
	Non-Suture	-.1400	.796		
Total*	Suture	.7686	2.102	1.893	.067
	Non-Suture	.0400	2.001		

Table 5.8 Means, standard deviations, and dependent t-tests for difference in facial swelling measurements (* Total = summation of lines 1 to 6).

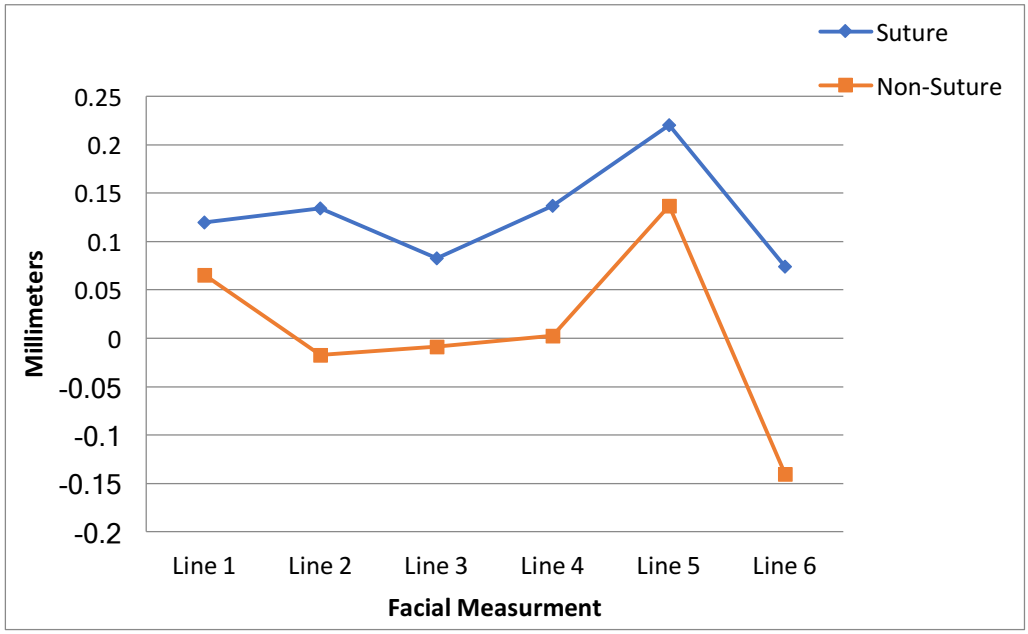


Figure 5.3 Means for differences between pre-operative and post-operative values for facial swelling measurements from Lines 1 to 6.

The relationship of differences between the suture and non-suture conditions in facial swelling and differences in operative time and degree of surgical difficulty were assessed again by computing 'difference scores'. A Spearman Rho Correlation was then utilized to assess the strength of the relationships. The results are presented in Table 5.6. An inspection of this table reveals a number of significant weak and moderate correlations. Differences in operative time between the two conditions were related to differences in swelling at Line 4, $r(34) = 0.357$, $p = 0.035$ and in total swelling reading, $r(34) = 0.357$, $p = 0.035$. Differences at Line 5 approached significance, $r(34) = 0.322$, $p = 0.059$. Differences in the level of difficulty of the surgeries were related to differences between suture and non-suture conditions at Line 4, $r(34) = 0.355$, $p = 0.037$, Line 5, $r(34) = 0.519$, $p = 0.001$, Line 6, $r(34) = 0.375$, $p = 0.027$, and total swelling reading, $r(34) = 0.387$, $p = 0.022$. The positive nature of the significant correlations indicates that, as the difference in difficulty of surgery and operative time increased, so did the difference in swelling between the two groups.

		Line1	Line2	Line3	Line4	Line5	Line6	Difference Total Swelling
Operation Time	*r*	.174	.196	.174	.357*	.322	.050	.357*
	p	.318	.259	.319	.035	.059	.774	.035
	n	35	35	35	35	35	35	35
Difficulty Scale	*r*	.012	.213	-.154	.355*	.519**	.375*	.387*
	p	.947	.220	.376	.037	.001	.027	.022
	n	35	35	35	35	35	35	35

Table 5.9 Spearman Correlations assessing the relationship of differences in operative time and surgical difficulty with differences in swelling.

The results of the analyses that assessed differences in facial swelling revealed no differences between the suture and non-suture conditions at all measured swelling sites. There were; however, relationships between the differences in difficulty of the surgeries and operative times, and differences in swelling, at certain facial measurements.

5.6 Post-operative bleeding

The differences in post-operative bleeding under the suture and non-suture conditions were assessed by utilizing dependent t-tests. Post-operative bleeding was measured by a count of the gauzes used by the patient to stop bleeding on days one through five, and time needed for bleeding to stop completely. The results of the t-tests are presented in Table 5.7. A review of this table reveals that for days where gauzes were used, there were no differences in the number of gauzes required to address the bleeding (all $p > 0.05$). There was also no difference in the duration of bleeding, $t(34) = -1.14$, $p = 0.263$. No gauzes were required on days four and five and therefore no t-test could be computed.

Time	Condition	Mean	Std. Deviation	*t*	*p*
Day 1	Suture	1.42	1.70	-1.23	.227
	Non-Suture	1.74	2.22		
Day 2	Suture	.657	1.37	.683	.499
	Non-Suture	.571	1.17		
Day 3	Suture	.057	.338	.442	.661
	Non-Suture	.028	.169		
Day 4	Suture	.000	.000	a	
	Non-Suture	.000	.000		
Day 5	Suture	.000	.000	a	
	Non-Suture	.000	.000		
Bleeding duration	Suture	1.31	.529	-1.14	.263
	Non-Suture	1.40	.553		

Table 5.10 Means and standard deviations and results of the t-tests for number of gauzes used through days one to five and duration of bleeding under suture and non-suture conditions (Note: a = no t-test could be computed due to no variation in gauze usage under both conditions).

The assessment of the relationship of differences in operative time and difficulty of surgery to differences in the number of gauzes used on days one to five and the duration of bleeding was again carried out by utilizing a Spearman Rho Correlation. Again, 'difference scores' were computed between the suture and non-suture conditions on operative time and degree of surgical difficulty, as well on the number of gauzes used from days one to five, and the duration of bleeding. The results are presented in Table 5.8. A review of this table reveals that differences in operative time and degree of surgical difficulty were not related to differences in number of gauzes required to address bleeding on days one to five and the duration of bleeding (all p <0 .05). No correlation was computed for days four or five due to no variation in gauze usage.

		Day 1	Day 2	Day 3	Day 4	Day 5	Bleeding Duration
Operative Time	*r*	.169	.170	.059	a	a	-.215
	p	.333	.329	.735			.216
	n	35	35	35	35	35	35
Difficulty Scale	*r*	.235	.313	.245	a	a	.040
	p	.173	.068	.155			.819
	n	35	35	35	35	35	35

Table 5.11 Spearman Rho Correlations between differences in operative time and difficulty of surgery and differences in gauze usage from day one to day five and duration of bleeding.

5.7 Degree of socket healing at one week post-operatively

The number and proportion of sockets at each level of healing under the suture and non-suture conditions are provided in Table 5.9. An inspection of this table further shows the difference between the two conditions. A larger proportion of sockets (68.6%) in the suture condition evidenced open epithelized socket when compared to only 37.1% under the non-suture condition. A greater proportion (48.6%) of sockets under the non-suture condition evidenced open socket not epithelized, while 28.6% under the suture condition showed healing at this level. Finally, 14.3% of the sockets under the non-suture condition only evidenced displaced flap, while 2.9% of sockets under the suture condition showed flap displacement (see Figure 5.4).

			Non-Suture			Total
			Displaced Flap	Open Socket Not Epithelized	Open Socket Epithelized	
Suture	Displaced Flap	Count	0	1	0	1 2.9%
	Open Socket Not Epithelized	Count	2	8	0	10 28.6%
	Open Socket Epithelized	Count	3	8	13	24 68.6%
Total		Count	5 14.3%	17 48.6%	13 37.1%	35 100.0%

Table 5.12 Number and proportion of sockets at each level of healing under the suture and non-suture conditions.

In order to assess if there was a difference between the suture and non-suture conditions in the degree of socket healing, a Wilcoxon Signed Ranks Test was utilized. The Wilcoxon Tests is used when there are dependent samples that are measured on an ordinal variable. The results indicated that under the suture condition, there was greater degree of healing for the socket when compared to under the non-suture condition, $z = -3.10$, $p = 0.002$. Further analysis of the results revealed that thirteen patients evidenced greater healing on the sutured side, one on the non-sutured side, and twenty-one showed no difference in healing between the sutured and the non-sutured sides.

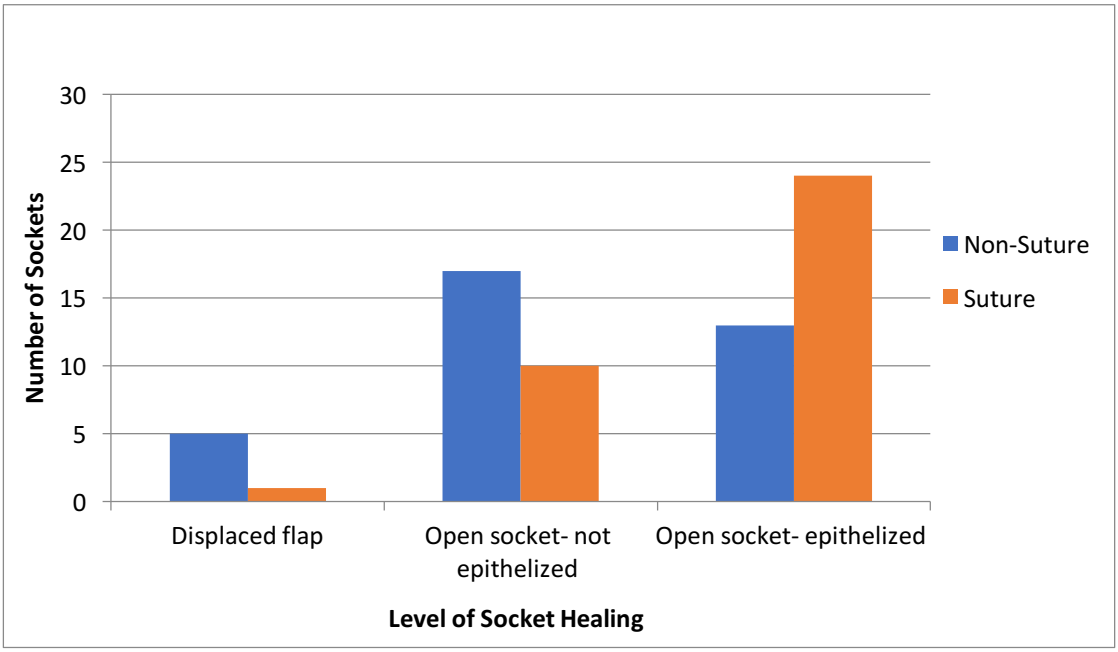


Figure 5.4 Histogram of suture and non-suture conditions for socket healing at one week.

In order to assess if differences in operative time and level of surgical difficulty under the suture and non-suture conditions were related to the differences in the degree of socket healing, 'difference scores' were computed. The data from the non-suture condition was subtracted from the suture condition. The relationship between the 'difference scores' for operative time and surgical difficulty and 'difference scores' for the degree of socket healing were then assessed through a Spearman Rho Correlation. A Spearman Correlation was used due to the ordinal nature of the 'difference scores'. The results indicated no relationship between differences in operative time and differences in degree of socket healing, $r(34) = 0.186$, $p = 0.284$, and no relationship between differences in difficulty of surgery and differences in degree of socket healing, $r(34) = -0.084$, $p = 0.632$.

5.8 Soft tissue healing at one week

Wilcoxon Signed Ranks Test was applied to assess the differences between the suture and non-suture conditions on the soft tissue healing at one week. The results indicated that under the suture condition, surgical sites evidenced a greater level of soft tissue healing than under the non-suture condition, z = -2.41, p = 0.016. Further analysis revealed that seventeen patients showed greater healing in the sutured side, seven in the non-sutured side, and eleven did not show a difference between the two sides.

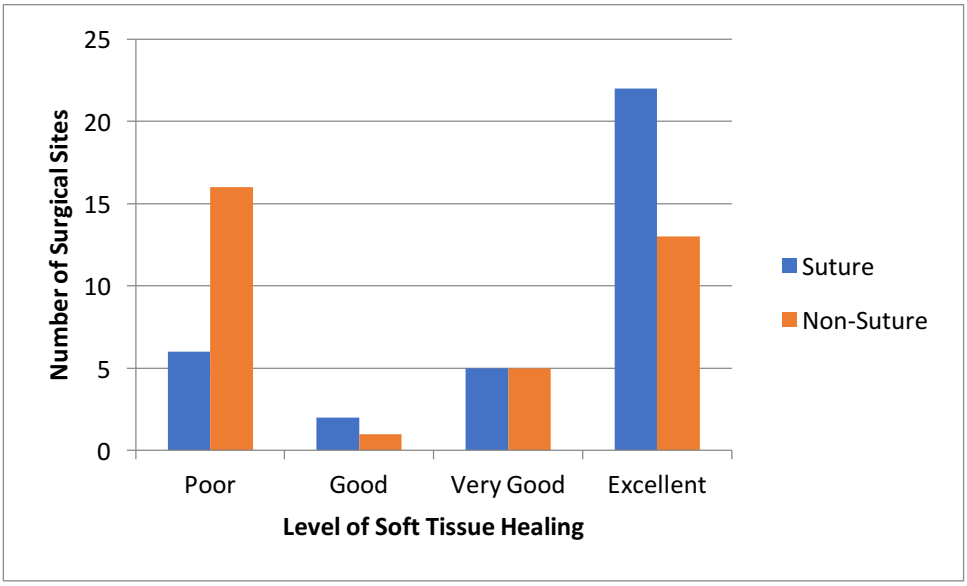


Figure 5.5 Histogram of suture and non-suture conditions for soft tissue healing at one week.

The relationship of differences in operative time, and level of surgical difficulty with differences in the soft tissue healing were again assessed by first computing 'difference scores' and then utilizing a Spearman Rho Correlation. The results indicated no relationship between differences in operative time and differences in the soft tissue healing, $r(34) = 0.046$, $p = 0.792$, and no relationship between differences in difficulty of the surgery and differences in the soft tissue healing , $r(34) = -0.118$, $p = 0.500$.

5.9 Food impaction at one week

A McNemar's Test was used to assess differences in food impaction under the suture, and non-suture conditions. The results indicated there was no difference in food impaction between the sutured and non-sutured sides, $p = 0.508$. An inspection of Table 5.10, reveals that 51.4% of sockets under the suture condition had food impaction, which is similar to the 60% of sockets under the non-suture condition.

Suture		Non- suture		Total
		No food impaction	Food Impaction	
No food Impaction	Count	11	6	17 48.6%
Food Impaction	Count	3	15	18 51.4%
	Count	14 40.0%	21 60.0%	35

Table 5.13 Food impaction under suture and non-suture conditions at one week.

5.10 Degree of Socket Healing at one month

The number and proportion of sockets at each level of healing under the suture and the non-suture conditions are provided in Table 5.11. An inspection of this table further shows the difference between the two conditions. A larger proportion of sockets (44.1%) in the suture condition evidenced healing at the 'closed socket with incomplete healing' when compared to only 26.5% under the non-suture condition. A greater proportion (73.5%) of sockets under the non-suture condition only evidenced healing at 'the open socket epithelized level', when only 55.9% under the suture condition showed healing at this level.

			Non-Suture		
			Open Socket Epithelized	Closed Socket Incomplete Healing	Total
Suture	Open Socket Epithelized	Count	19	0	19 55.9%
	Closed Socket Incomplete Healing	Count	6	9	10 44.1%
Total		Count	25 73.5%	9 26.5%	34

Table 5.14 Number and proportion of sockets at each level of healing under the suture and non-suture conditions.

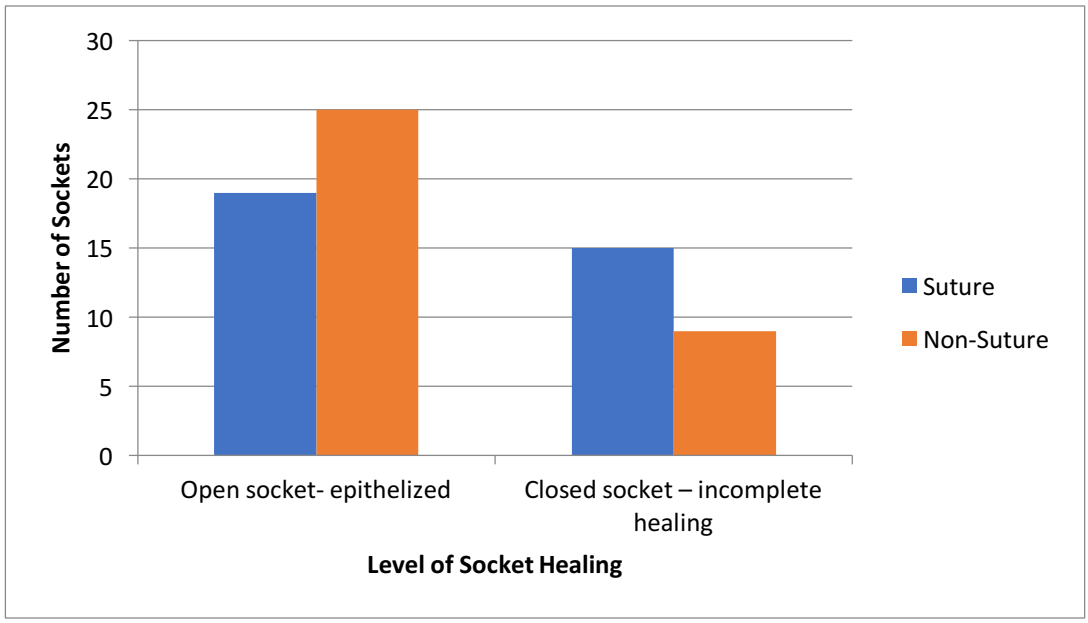


Figure 5.6 Histogram of suture and non-suture conditions for socket healing at one month.

In order to assess if there was a difference between the suture and non-suture conditions in the degree of socket healing at one month, a Wilcoxon Signed Ranks Test was utilized. The results indicated that under the suture condition, there was greater degree of socket healing than under the non-suture condition, $z = -2.45$, $p = 0.014$. Further analysis of the results revealed that six patients evidenced greater socket healing on the sutured side, none on the non-sutured side, and twenty-eight showed no difference in socket healing between the sutured and non-sutured sides.

In order to assess if differences in operative time and level of surgical difficulty under the suture and non-suture conditions were related to the differences in the degree of socket healing at one month, 'difference scores' were computed. The relationship between the 'difference scores' computed for operative time and surgical difficulty and 'difference scores' for the degree of socket healing were then assessed through a Spearman Rho Correlation. The results indicated no relationship between differences in operative time and differences in degree of socket healing, $r(33) = -0.130$, $p = 0.464$, and no relationship between differences in difficulty of surgery and differences in degree of socket healing, $r(33) = -0.037$, $p = 0.836$.

5.11 Food impaction at one month

A McNemar's Test was used to assess differences in food impaction under the suture and non-suture conditions at one month. The results indicated that there was no difference in food impaction between the suture and non-suture conditions, $p = 1.00$. An inspection of Table 5.12, reveals that 17.6% of sockets under the suture condition had food impaction, which is similar to the 20.6% of sockets under the non-suture condition.

Suture		Non- suture		Total
		No food Impaction	Food Impaction	
No food Impaction	Count	25	3	28 82.4%
Food Impaction	Count	2	4	6 17.6%
	Count	27 79.4%	7 20.6%	34

Table 5.15 Food impaction under suture and non-suture conditions at one month.

5.12 Periodontal status of lower second molar at one month

The differences in periodontal status of the adjacent lower second molar at one month under the suture and non-suture conditions were assessed by utilizing dependent t-tests. The results of the t-tests are presented in Table 5.13. A review of this table reveals there were no differences between the two conditions in the three measures of periodontal status for lower second molar at one month, all p >0 .05.

Parameter	Condition	Mean	Std. Deviation	*t*	*p*
Average PD change	Suture	1.42	1.70	-.708	.484
	Non-Suture	1.74	2.22		
CAL change	Suture	.657	1.37	-.159	.875
	Non-Suture	.571	1.17		
Deepest PD change	Suture	.057	.338	-.903	.373
	Non-Suture	.028	.169		

Table 5.16 Means, standard deviations and results of the t-tests for measures of periodontal status at one month under suture and non-suture conditions.

The assessment of the relationship of differences in operative time and difficulty of surgery, to the differences in change in periodontal status, under the suture and non-suture condition, was again carried out by utilizing a Spearman Rho Correlation. Again, 'difference scores' were computed between the suture and non-suture conditions on operative time and degree of surgical difficulty, as well on the three measures of periodontal status of lower second molar at one month. The results are presented in Table 5.14. A review of this table reveals that differences in operative time and degree of surgical difficulty were not related to differences in the three measurements of periodontal status of lower second molar at one month, all $p < 0.05$.

		Change in Average PD	Change in CAL	Change in Deepest PD
Operative Time	*r*	-.217	-.132	-.248
	p	.217	.457	.158
	n	34	34	34
Difficulty Scale	*r*	-.238	-.169	-.245
	p	.175	.338	.162
	n	34	34	34

Table 5.17 Spearman Rho Correlations between differences in operative time and difficulty of surgery and differences in measures of periodontal status at one month under suture and non-suture conditions.

5.13 Relationship between operative time and surgical difficulty

A series of Spearman Rho Correlations were also used to assess the relationship of operative time and degree of difficulty of the surgery. The results indicated that under the suture condition, there was a relationship (moderate correlation), $r(34) = 0.442$, $p = 0.008$. There was also a relationship under the non-suture condition (strong correlation), $r(34) = 0.755$, $p < 0.001$. There was also a relationship in the operative time difference score and the surgical difficulty difference score, $r(34) = 0.687$, $p < 0.001$.

5.14 Effect of impaction characteristics on operative time

A series of Analysis of Variances (ANOVA) was computed to assess the relationship of impaction characteristics to operative time.

5.14.1 Effect of Pell and Gregory Classification on operative time

A series of Analysis of Variances (ANOVA) was computed to assess the relationship of Pell and Gregory Classification to the operative time. The results are provided in Table 5.15. An inspection of this table reveals that the impaction depth, ramus relationship and their interaction was not related to operative time, all $p > 0.05$.

Source	Sum of Squares	df	Mean Square	F	Sig.
Ramus Relationship (RR)	12.660	2	6.330	.083	.921
Impaction Depth (ID)	35.603	2	17.801	.233	.793
RR by ID	37.721	2	18.861	.246	.782
Error	4821.537	63	76.532		
Total	34419.000	70			
Corrected Total	5001.500	69			

Table 5.18 Analysis of Variance summary table for operative time by Ramus Relationship and Impaction Depth.

5.14.2 Effect of root morphology on operative time

The relationship of the root morphology to the operative time and its interaction with Pell and Gregory Classification was tested using Analysis of Variances (ANOVA) and is presented in Table 5.16. An inspection of this table reveals that the root morphology was related to the operative time $F(2,58) = 3.98$, $p = 0.024$. No other effects were significant, all $p > .05$. Post-hoc analyses utilizing the Bonfferroni procedure to address

type I errors revealed that there was a significant main effect of root morphology, there were no pair wise differences between the root morphology groups, all $p > 0.05$.

Source	Sum of Squares	df	Mean Square	F	Sig.
Root Morphology	555.605	2	277.802	3.977	.024
Ramus Relationship (RR)	69.701	2	34.851	.499	.610
Impaction Depth (ID)	40.632	2	20.316	.291	.749
RR by ID	41.269	1	41.269	.591	.445
Root Morphology by ID	243.738	1	243.738	3.490	.067
Root Morphology * RR	25.752	2	12.876	.184	.832
Error	4051.139	58	69.847		
Total	34419.000	70			

Table 5.19 Analysis of Variance summary table for operative time by Ramus Relationship, Impaction Depth and Root Morphology.

5.14.3 Effect of tooth inclination on operative time

The relationship of the tooth inclination to operative time and its interaction with Pell and Gregory Classification was then tested using ANOVA, and is presented in Table 5.17. An inspection of this table reveals that no effects were significant, all $p > 0.05$.

Source	Sum of Squares	df	Mean Square	F	Sig.
Inclination	302.868	3	100.956	1.344	.270
Ramus Relationship (RR)	21.699	2	10.849	.144	.866
Impaction Depth (ID)	29.502	2	14.751	.196	.822
Inclination by RR	180.346	3	60.115	.800	.499
Inclination by ID	106.320	2	53.160	.707	.497
RR by ID	9.148	1	9.148	.122	.728
Error	4132.912	55	75.144		
Total	34419.000	70			

Table 5.20 Analysis of Variance summary table for operative time by Ramus Relationship, Impaction Depth and Inclination.

5.15 Effect of impaction characteristics on surgical difficulty

A series of chi-square analyses were computed to assess the relationship of Pell and Gregory Classification, tooth inclination, and root morphology, to the difficulty of the surgery assessed using the difficulty scale.

The Ramus Relationship was not related to the surgical difficulty, chi-square (4) = 8.81, $p = 0.066$. The depth of impaction was also not related to the surgical difficulty, chi-square (4) = 3.55, $p = 0.471$. The root morphology was also not related to the surgical difficulty, chi-square (4) = 6.92, $p = 0.140$. Finally, the tooth inclination was related to the difficulty of the surgery, chi-square (4) = 43.24, $p < 0.001$. The cross tabulation for this analysis is provided in Table 5.18. An inspection of this table reveals that those lower third molars with a mesioangular inclination, a majority (83.3%) had surgeries that were considered of medium difficulty. There was a similar finding with those third molars which had a horizontal inclination, where 87.5% had a surgery that was of medium difficulty. This contrasts with the majority (79.3%) of lower third molars with a distoangular inclination that had surgery that was considered easy. There was a similar finding in lower third molars which had a vertical inclination, where 66.7% had a surgery that was considered easy.

			Difficulty scale			Total
			Easy	Medium	Difficult	
Inclination	Mesioangular	Count	3	25	2	30
		within Inclination	10.0%	83.3%	6.7%	100.0%
	Distoangular	Count	23	3	3	29
		within Inclination	79.3%	10.3%	10.3%	100.0%
	Horizontal	Count	0	7	1	8
		within Inclination	0.0%	87.5%	12.5%	100.0%
	Vertical	Count	2	0	1	3
		within Inclination	66.7%	0.0%	33.3%	100.0%
Total		Count	28	35	7	70
		within Inclination	40.0%	50.0%	10.0%	100.0%

Table 5.21 Inclination of tooth by Difficulty Scale cross tabulation.

5.16 Summary

The results show that the two investigative groups included in the study have similar characteristics. There was no significant difference between the two groups in age, gender, BMI, ethnicity, operative time, and surgical difficulty. Therefore, the confounding effect of these factors was eliminated.

5.16.1 Primary outcomes

The results showed a statistically significant difference between the two groups in the following outcomes: a) less post-operative pain in one suture technique at day five (p = 0.046), and six (p = 0.034), b) better socket healing at one week (p = 0.002), and one month (p = 0.014) in one suture technique, and c) better soft tissue healing at one week (p = 0.016) in one suture technique.

The results show no statistical significant difference between the two groups in a) post-operative pain during the first four days, b) post-operative swelling, c) post-operative bleeding, d) food impaction within surgical site, and e) periodontal health of buccal site for lower second molar at one month.

Therefore, the results suggest that one suture technique for lower third molar surgery is superior to suture-less technique in reduction of post-operative pain, and improve a wound healing during early post-operative period. However, there is no difference between the two techniques in reduction of post-operative swelling.

This rejects the null hypothesis that there is no difference between one suture lower third molar surgery and suture-less lower third molar surgery in degree of wound healing at one week and one month, and post-operative pain during the first post-operative week. At the same time, this also reject the alternative hypothesis that there is a difference between one suture lower third molar surgery and suture-less lower third molar surgery in post-operative bleeding and post-operative swelling during the first post-operative week, and post-surgical periodontal status of the lower second molar at one month.

5.16.2 Secondary outcomes

The results show the following:

I) Significant effect was found for operative time and surgical difficulty on post-operative pain, and swelling during the first week, while no significant effect was found on post-operative bleeding, socket healing at one week and one month, soft tissue healing at one week, and periodontal health of buccal side for the lower second molar at one month.

II) There was a significant, moderate to strong correlation, between operative time measured in minutes and surgical difficulty measured by difficulty scale.

III) Significant relationship was found between lower third molar inclination, and level of surgical difficulty measured by difficulty scale.

IV) Significant relationship was found between root morphology of lower third molar and operative time measured by minutes. Third molars with separated roots have longer operative time than fused roots third molars.

V) No significant relationship was found between Pell and Gregory Classification of the lower third molar and operative time measured in minutes, also no significant relationship was found between Pell and Gregory Classification and the level of surgical difficulty measured by difficulty scale.

6. Discussion

6.1 Study overview

Lower third molar surgery is one of the most common surgical procedure in oral and maxillofacial surgery (Jerjes et al., 2010). As for any other surgical procedures, lower third molar surgery has its own risks and post-operative complications, that influence the recovery period and affect the patient's quality of life (Colorado-Bonnin et al., 2006; White et al., 2003). Pain, limitation of mouth opening, and clinical evidence of swelling have a significant effect on the oral health related quality of life during the immediate post-operative period following lower third molar surgery (McGrath et al., 2003). Wound healing after lower third molar surgery has a significant clinical importance for the clinician, as delayed healing and wound dehiscence make hygiene more difficult and may require intense follow-up treatment, which potentially extends the time of post-surgical treatment (Jakse et al., 2002). From the patient's point of view, delayed healing could result in a longer period of discomfort and continuous pain which is caused by hypersensitivity in the exposed distal root surface of the adjacent second molar (Jakse et al., 2002).

Closure technique is an operative factor that has been linked to early post-operative complications after lower third molar surgery (Holland and Hindle, 1984; Dubois et al., 1982). When compared to primary closure, secondary closure techniques have shown better reduction in post-operative pain (Xavier et al., 2008; Sanchis Bielsa et al., 2008; Osunde et al., 2011; Refo'a et al., 2011; Anighoro et al., 2013; Hashemi et al., 2012; Osunde et al., 2012; Damodar et al., 2013; Ricard et al., 2015; Quadri et al., 2016; Kazemian et al., 2016; Dubois et al., 1982; Pasqualini et al., 2005; Danda et al., 2010; Khande et al., 2011; Maria et al., 2012; Kakadia et al., 2013; Chaudhary et al., 2012;

Holland and Hindle, 1984; Egbor and Saheeb, 2014), post-operative swelling (Sanchis Bielsa et al., 2008; Bello et al., 2011; Osunde et al., 2011; Hashemi et al., 2012; Osunde et al., 2012; Refo'a et al., 2011; Damodar et al., 2013; Ricard et al., 2015; Kazemian et al., 2016; Quadri et al., 2016; Dubois et al., 1982; Pasqualini et al., 2005; Danda et al., 2010; Khande et al., 2011; Maria et al., 2012; Chaudhary et al., 2012; Kakadia et al., 2013; Holland and Hindle, 1984; Egbor and Saheeb, 2014), and trismus (Xavier et al., 2008; Osunde et al., 2011; Refo'a et al., 2011; Anighoro et al., 2013; Osunde et al., 2012; Ricard et al., 2015; Khande et al., 2011; Maria et al., 2012; Kakadia et al., 2013; Egbor and Saheeb, 2014; Suddhasthira et al., 1991) following lower third molar surgery.

Suture-less technique, a relatively new secondary closure technique, has shown good outcomes following lower third molar surgery (Waite and Cherala, 2006). Regardless of the flap design used for lower third molar surgery, suture-less technique has proven to be superior to primary closure technique in reducing post-operative pain, swelling, and trismus (Hashemi et al., 2012; Osunde et al., 2012; Damodar et al., 2013; Ricard et al., 2015; Quadri et al., 2016; Kazemian et al., 2016). In addition to its desirable effect on post-operative complications, suture-less technique decreases surgical time, minimizes the trauma resulting from soft tissue manipulation, and decreases direct costs (Waite and Cherala, 2006).

In this clinical trial, we investigated the effect of closure technique on post-operative complications, and wound healing following lower third molar surgery. We compared two secondary closure techniques; partial wound closure using one suture and the suture-less technique, after using a modified buccal envelope flap for accessing lower third molar surgery.

6.2 Post-operative pain

"Pain is entirely subjective and its links with pathology are indirect, the only way to successfully assess pain is to believe the patient. Pain is what the patient says it is" (McCaffrey and Beebe, 1989).

In this clinical trial, we used an 11-point Numeric Rating Scale (NRS), to assess pain severity, at seven different time points- hour twelve, day one, two, three, four, five and six. The validity of this pain scale has been demonstrated and proven to correlate significantly with other pain scales such as the Visual Analogue Scale (VAS) (Kremer et al., 1981; Jensen et al., 1986; Jensen et al., 1989; Seymour, 1982). In addition to its easy administration to the patient, it is more useful than other scales for audit ,and research (Williamson and Hoggart, 2005).

Across seven evaluation time points in this clinical trial, the pain intensity was reported to be a maximum at twelve hours post-operatively, this is in agreement with findings from several studies in the literature which suggest that pain following lower third molar surgery reaches its maximum intensity in the first twelve hours (Seymour et al., 1985).

The difference in pain scores between the two techniques from day one to day four was not significant ($p > 0.05$) in this clinical trial. This is in agreement with the findings by De Brabander and Cattaneo in 1988, who compared two secondary closure techniques ; wedge mucosa excision to wedge mucosa excision with tube drain, and found no statistical significant difference in pain intensity at day two and day seven between the two techniques (de Brabander and Cattaneo, 1988). This could be explained by the fact that acute inflammatory response peaks within seventy-two hours after the surgery and

then diminishes gradually, and in both techniques, there is an outlet for these inflammatory mediators to be washed out.

The results of this clinical trial demonstrated a significant difference in the median pain scores, between the two closure techniques, at day five and day six post-operatively ($p \leq 0.05$). Greater pain scores were reported in the suture-less sides at day five ($p = 0.046$) and day six ($p = 0.034$). This could be related to the delayed wound healing being observed in the suture-less sites at one week following the surgery.

In the literature, the suture-less technique has been found to have a decreased pain intensity during the early few days following lower third molar surgery when compared to primary closure (Hashemi et al., 2012; Osunde et al., 2012; Damodar et al., 2013; Ricard et al., 2015; Quadri et al., 2016; Kazemian et al., 2016). These findings have been also reported when the one-suture technique is compared to the primary closure technique, one suture technique has demonstrated significant reduction in pain intensity during the first seventy-two hours after the surgery (Osunde et al., 2011). However, there are no previously published studies comparing the suture-less technique to the one-suture, or other secondary closure techniques.

6.3 Post-operative swelling

There are different methods described in the literature to measure facial swelling, some of them are easy to use while the others are sophisticated or too complex for clinical use (Pasqualini et al., 2005). These methods use either subjective or objective evaluation. Objective methods used in the literature include photographic techniques (Van Gool et al., 1975), Magnetic Resonance Imaging (MRI) (Llewelyn et al., 1996), stereo-photographic techniques (Pedersen and Maersk-Moller, 1985; Mocan et al., 1996),

ultrasound (Holland, 1979), facebow apparatus (Holland and Hindle, 1984), cephalostat (Berge, 1988), 3-D optical scanning technique (Rana et al., 2011), and craniometrics measurements using different methods (Neupert et al., 1992; Amin and Laskin, 1983; de Brabander and Cattaneo, 1988).

In 1982, Dubois *et al* used a two-grade scale as a self-assessment method by the patient to measure the swelling following lower third molar surgery. A few years later, Henrikson *et al* in 1985 proposed the use of VAS as a subjective method to measure facial swelling, when they compared the effect of two anti-inflammatory drugs, on the post-operative complications, following lower third molar surgery (Henrikson et al., 1985). This self-assessment method has been proven to be reliable and accurate in assessing facial swelling, when compared to observer assessment (Berge, 1989), or 3-dimesional mechanical measurement using an extra-oral cephalostat (Berge, 1988). In later clinical trials, subjective evaluation of swelling by the patient has been utilized using different scales, for measuring facial swelling, following lower third molar surgery (Sanchis Bielsa et al., 2008; Pasqualini et al., 2005; Danda et al., 2010; Khande et al., 2011; Maria et al., 2012; Chaudhary et al., 2012; Rakprasitkul and Pairuchvej, 1997; Akota et al., 1998).

In this clinical trial, we used two methods to evaluate facial swelling; 1) objective method to measure swelling at one week time using craniometrics measurements described by Montebugnoli *et al* in 2004 (Montebugnoli et al., 2004) and used also by Szolnoky *et al* in 2007 (Szolnoky et al., 2007), and 2) subjective self-assessment method using VAS described by Berge (Berge, 1988) , to assess swelling from post-operative day one to day six by the patient.

In the present study, the reported facial swelling reaches its maximum at forty-eight hours post-operatively, these results match those observed in earlier studies, which suggest that facial swelling following lower third molar surgery reaches its maximum intensity at forty-eight hours following the surgery (Osunde et al., 2011; Bamgbose et al., 2005; van der Westhuijzen et al., 2005; Troullos et al., 1990; Chukwuneke et al., 2008; Sanchis Bielsa et al., 2008; Anighoro et al., 2013).

The result of this clinical trial revealed no significant difference between the two techniques in facial swelling as measured by the patient from day one to day six ($p > 0.05$). Also, there was no significant difference between the two techniques in the objective facial swelling measurements at one week ($p > 0.05$). These results are consistent with those of De Brabander and Cattaneo in 1988, who compared two secondary closure techniques; wedge mucosa excision to wedge mucosa excision with tube drain, and found no statistical significant differences in facial swelling at day two, and day seven between the two techniques (de Brabander and Cattaneo, 1988). A possible explanation for this might be that both techniques investigated in the present study have an outlet for the accumulated fluids and the inflammatory exudates to escape, which results in reduced post-operative facial swelling (Carrasco-Labra et al., 2012).

Several studies have reported significantly less post-operative facial swelling in suture-less technique when compared to primary wound closure following lower third molar surgery (Hashemi et al., 2012; Osunde et al., 2012; Damodar et al., 2013; Ricard et al., 2015; Quadri et al., 2016; Kazemian et al., 2016). This significant reduction in facial swelling has been also reported in the one-suture technique when compared to the primary closure technique, where the former has shown significant reduction in facial swelling during the first seventy-two hours after lower third molar surgery (Osunde et

al., 2011). Although these findings have been also reported when other partial closure techniques are compared to primary closure (Sanchis Bielsa et al., 2008; Bello et al., 2011; Refo'a et al., 2011), other studies showed no benefits of secondary closure over primary closure technique in reducing facial swelling following lower third molar surgery (Xavier et al., 2008; Anighoro et al., 2013; Gay-Escoda et al., 2015; Suddhasthira et al., 1991).

6.4 Wound healing

In the literature, different methods have been used to assess wound healing following lower third molar surgery, these methods include: recording dehiscence at the incision lines (Dubois et al., 1982; Pasqualini et al., 2005; Khande et al., 2011), time to achieve satisfactory healing (Holland and Hindle, 1984; Khande et al., 2011), mucosal attachment level and periodontal health around the adjacent lower second molar (Dubois et al., 1982; Hashemi et al., 2012; Xavier et al., 2008), presence of infection or dry socket (Pasqualini et al., 2005; Dubois et al., 1982; Ricard et al., 2015; Danda et al., 2010; Akota et al., 1998; Hashemi et al., 2012; Ayad et al., 1995), the need for additional treatment (Holland and Hindle, 1984), food debris lodgement, and cleansablility of the extraction socket (Kakadia et al., 2013; Quadri et al., 2016; Ricard et al., 2015; Dubois et al., 1982).

Unlike the previously mentioned studies, which didn't use specific scale to assess wound healing, Rakprasitkul and Pairuchvej in 1997, described a four-grade index to assess wound healing following lower third molar surgery, this index depends on degree of wound breakdown, and exposure of the extraction socket (Rakprasitkul and Pairuchvej, 1997).

The wound healing in the present clinical trial was assessed by measuring different clinical parameters. The parameters comprise degree of socket healing, soft tissue healing, presence of infection or dry socket, presence of food impaction within the socket, and periodontal health at the buccal site of the adjacent lower second molar.

The assessment of socket healing was carried out using a five-grade index to measure the degree of socket epithelization, which is designed specifically for the purpose to be used by investigators in this study.

The results of this trial demonstrated a statistically significant better socket healing on sites received one suture, at one week ($p = 0.002$) and one month ($p = 0.014$) following lower third molar surgery. Incision line dehiscence and flap displacement were reported at one week post-operatively in five suture-less flap (14.3%) and one sutured flap (2.9%).

The degree of soft tissue healing at the surgical site was evaluated using Landry's index (Landry, 1985), in which each surgical site is given a score from one to five , the higher the score the better the healing of soft tissue at that surgical site. The results of this study showed a statistically significant better soft tissue healing at one week post-operatively, on sites received one suture, compared to suture-less sites ($p = 0.016$).

There are no previous published studies in the literature comparing wound healing between secondary closure techniques. Some investigators reported better wound healing associated with primary closure, when compared to various secondary closure techniques (Holland and Hindle, 1984; Dubois et al., 1982; Khande et al., 2011), Rakprasitkul and Pairuchvej in 1997 reported no difference in wound healing, when compared primary closure alone to primary closure with tube drain placement.

Seven cases of dry socket were reported in this clinical trial (10%), three patients developed bilateral dry sockets, and one patient suffered dry socket at the suture-less side. No cases of infection arouse during the evaluation period. When compared to primary closure technique, Hashemi *et al* in 2012 reported no dry socket in suture-less group, neither on primary closure group (Hashemi et al., 2012), however , Ricard *et al* in 2015 reported two cases of dry socket and two cases of infection in primary closure group , and no cases reported in the suture-less group (Ricard et al., 2015).
Interestingly, a study by Akota *et al* in 1998 reported a significant increase in dry socket incidence when the wound closed primarily compared to wound received gauze drain (Akota et al., 1998).

The results of this trial showed no significant difference between the two techniques in food impaction within the socket at one week ($p = 0.508$) and one month ($p = 1.00$) post-operatively. A few studies have reported a higher incidence of food impaction in the suture-less technique (Ricard et al., 2015; Quadri et al., 2016), and other secondary closure techniques (Kakadia et al., 2013), when compared to primary closure.

Looking at the periodontal condition buccal to the adjacent lower second molar at one month following the surgery, there were no statistically significant differences in the change from pre-operative values of the pocket depth ($p = 0.484$), and clinical attachment level (CAL) ($p = 0.875$) between the two groups. Comparing suture-less technique to primary closure at six month following lower third molar surgery, Hashemi *et al* in 2012 reported no significant change in pocket depth around the lower second molar from pre-operative value on either technique (Hashemi et al., 2012). Interestingly, three months following lower third molar surgery, Xavier *et al* in 2008 reported greater pocket depths

at three sites on the buccal surface of lower second molar in primary closure compared to secondary closure, and this difference was statistically significant at one site (Xavier et al., 2008).

6.5 Post-operative bleeding

A subjective method was used to compare post-operative bleeding between the two techniques in this clinical trial. The patient was asked to count the number of gauzes used to stop bleeding, for each surgical site, on each day post-operatively, also, the patient reported the time needed to achieve a bleeding-free surgical site. The results of this trial showed no significant difference between the two techniques in post-operative bleeding. There were no reported cases of excessive bleeding that needed any intervention through a local dentist or A&E. These results are in line with those observed by Hashemi *et al* in 2012, who reported no cases of excessive bleeding when they compared suture-less technique to primary closure (Hashemi et al., 2012). The same observation was reported by Pasqualini *et al* in 2005, who compared secondary closure to primary closure technique, they reported no cases of haemorrhage on either technique (Pasqualini et al., 2005). Contrary to Pasqualini *et al* , Bello *et al* in 2011 reported a significant higher incidence of reactionary bleeding at forty-eight hours in the secondary closure technique cases compared to primary closure (Bello et al., 2011).

Using a four-grade scale to measure post-operative bleeding , Rakprasitkul and Pairuchve in 1997 reported less bleeding in patients who received a tube drain compared to patients receiving primary closure only (Rakprasitkul and Pairuchvej, 1997).

6.6 Effect of operative time and surgical difficulty on post-operative complications

In this clinical trial, we were able to demonstrate a strong correlation between the level of surgical difficulty measured on the difficulty index and the operative time measured in minutes. This finding seems to be consistent with other research, which stated that the duration of lower third molar surgery reflects its level of difficulty (Jain et al., 2016; Valmaseda-Castellon et al., 2001), and hence operative time has been used in several studies as a tool to measure the difficulty of surgery (Diniz-Freitas et al., 2007; Benediktsdottir et al., 2004; Alvira-Gonzalez et al., 2017; White et al., 2003; Renton et al., 2001).

The results of this trial showed that, as the difference in the degree of surgical difficulty increased between lower third molar surgeries, so did the difference in severity of post-operative pain from day one to day six. In addition, as the difference in operative time increased, so did the pain severity at five of the seven measurement periods.
This agrees with most of the studies, which reported increased pain severity and discomfort when lower third molar surgery takes longer time (Pedersen, 1985; Berge and Gilhuus-Moe, 1993; Oikarinen and Rasanen, 1991; Hellem and Nordenram, 1973; Bello et al., 2011; de Brabander and Cattaneo, 1988), and when the lower third molar surgery reaches a higher level of difficulty (Lago-Mendez et al., 2007; Oikarinen and Rasanen, 1991; Phillips et al., 2003; Yuasa and Sugiura, 2004).

The results demonstrate that differences in operative time and degree of surgical difficulty are related to differences in post-operative swelling; the greater the difference between lower third molar surgeries in operative time and degree of difficulty, the greater the difference in post-operative swelling. These results are in keeping with previous

studies, which showed more post-operative swelling in difficult lower third molar surgery (Osunde and Saheeb, 2015), or when surgery takes longer time (Capuzzi et al., 1994; van Gool et al., 1977).

6.7 Limitations of this study

One of this study limitations is the short follow-up period which was not long enough to fully assess the periodontal condition around the lower second molar. We were unable to measure the PD and CAL at the distal site of the second molar as the wound healing hasn't been completed at one month time following the surgery. Ideally, an additional three to six-month follow up appointment is required to investigate the periodontal condition at the distal surface of the lower second molar (Xavier et al., 2008; Hashemi et al., 2012; Arta et al., 2011; Baqain et al., 2012; Chaves et al., 2008; Korkmaz et al., 2015; Monaco et al., 2009; Suarez-Cunqueiro et al., 2003).

A further limitation is that we didn't evaluate the intra examiner reliability in measuring the proposed outcomes. We were also unable to investigate the effect of the two closure techniques on the post-operative trismus, as both treatments were carried out at the same time.

6.8 Future directions

It will be of interest to compare the one-suture closure technique to the two-suture closure technique in order to assess the ideal number of sutures following lower third molar surgery. A multi-centric, double blind trial with large cohort size, and split-mouth design would be the ideal.

A clinical trial of parallel-group design is required in order to investigate the effect of closure technique on trismus following lower third molar surgery.

7. Conclusion

Minimizing post-operative complications following lower third molar surgery is a key component of patient care. The clinician should take into consideration all the factors that might affect the incidence of post-operative complications, and should be aiming to improve the post-operative patient's quality of life by preventing, or at least minimizing the severity of these complications. There is a vast range of effective strategies that have been utilized to achieve this aim. Modification of the wound closure technique is one of these simple measures which has a crucial effect on the post-operative course, in patients undergoing lower third molar surgery.

This study investigated two secondary wound closure techniques, and their effect on post-operative complications, following lower third molar surgery.

The results demonstrated that post-operative pain and wound healing are influenced by the type of the closure technique used by the surgeon. The results also showed that operative time and difficulty of surgery have an impact on the severity of post-operative complication.

The results of this clinical trial suggest that the placement of one suture, distal to the lower second molar, after raising a small buccal envelope flap (Stassen modification) for lower third molar surgery, is superior to the suture-less technique, in decreasing post-operative pain and enhancing wound healing. Although this difference has been shown to be statistically significant, it may have no significant clinical importance.

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9. Appendix

Appendix A – Patient information leaflet

Patient Information Leaflet

1. Title of study:
"A Comparison of one-suture and suture-less lower third molar surgery"

2. Introduction:

This study is being carried out to investigate the ideal number of stitches required after having a wisdom tooth removed. If you wish to be involved, after your wisdom tooth is removed your dentist will place one stitch, two stitches or no stitches in the gums around your wisdom teeth. You will be asked to fill questionnaire about your experience during the 1st week after the procedure. You will also be asked to attend the Dublin Dental Hospital for a review one week and then again one month after the procedure. At these stages, your mouth will be examined and you may again be asked some questions about your experience.

3. Procedures:

You will only be asked to take part in this study if your dentist feels that your lower wisdom teeth need to be removed. This is most often due to recurrent pain, infection or dental decay related to your wisdom teeth. If you have some medical conditions or could be pregnant you will be asked not to take part in the study.
After being fully assessed in the Dental School and Hospital, your wisdom teeth will be removed under local anaesthetic (injection in your mouth) with or without intravenous sedation (injection in your arm to make you feel sleepy and comfortable during the procedure). Removing your wisdom teeth will involve cutting the gums around your wisdom teeth and may require some of the bone around the tooth to be removed or the tooth to be divided into two or more sections. One or no stitches will then be placed in the gums where the wisdom tooth has been removed. You will not be told the number of stitches that were placed. You will be asked to take some painkillers and/or antibiotics after the procedure as is the norm. When you are reviewed one week after the procedure, you will be asked to have complete the questionnaire completed , and a dentist will examine your mouth. This will also be carried out one month after the procedure.

4. Benefits:

By taking part in this study, you are helping to improve the way in which this treatment is carried out. After having your wisdom tooth removed, you may experience quicker healing or decreased pain by taking part in the study. The results are likely to benefit patients in the future, but may not have any direct benefit to you.

5. Risks:

The removal of wisdom teeth can lead to pain, bleeding and discomfort as well as loss of gum support for the last remaining tooth. This study is simply assessing if we can limit these risks. There is also a small risk of temporary or permanent numbness to the lip, chin and tongue. This is not affected by taking part in the study.

6. Exclusion from participation:

Your dentist has told you that you cannot be in this study if any of the following are true:

1. You do not want to take part in the study
2. You do not require the removal of a wisdom teeth in line with International guidelines
3. You are not suitable for treatment under local anaesthetic or local anaesthetic and sedation
4. You have a medical condition that could be complicated by taking part in this study
6. You are pregnant or could be pregnant
7. You are allergic or can't tolerate the antibiotic and the analgesics used in the study.

7. Alternative treatment:

You do not have to be a part of this study to be treated. If you do not take part, your wisdom teeth will be removed in a manner decided by your dentist / surgeon and you.

8. Confidentiality:

Your identity will remain confidential. Your name will not be published and will not be disclosed to anyone outside the hospital.

9. Compensation:

Your dentists are covered by standard medical / dental malpractice insurance. You will not receive any financial compensation as a result of taking part in this study. Nothing in this document restricts or curtails your rights.

10. Voluntary Participation:

You have volunteered to participate in this study. You may quit at any time. If you decide not to participate, or if you quit, you will not be penalised and will not give up any benefits which you had before entering the study.

11. Stopping the study:

You understand that your dentist may stop your participation in the study at any time without your consent.

12. Permission:

This study has been approved by the Joint Ethical Committee of St James' Hospital (SJH) and Adelaide and Meath Hospital Dublin incorporating the National Children's Hospital (AMNCH).

13. Further information:

You can get more information or answers to your questions about the study, your participation in the study, and your rights, from Dr Saleh Alkadi , who can be telephoned at 086087547. If your dentist learns of important new information that might affect your desire to remain in the study, he or she will tell you.

Appendix B – Consent form

Consent Form For Participation in Study

Title of the study: "A Comparison of one-suture and sutureless lower third molar surgery "

Names of researchers :
Prof. Leo F A Stassen (Dublin Dental university Hospital / St James's Hospital)
Dr. Saleh Alkadi (Dublin Dental University Hospital)

I …….. confirm that I have read and understand the information sheet for the above study and have had the opportunity to ask questions .

I understand that my participation is voluntary and that I am free to withdraw at any time, without giving reasons .

I agree to take part in the above study .

Name of Participant	Date	Signature
Name of Researcher	Date	Signature

Contact Details:

Dr Saleh Alkadi
SpR Oral Surgery
Dublin Dental University Hospital
Lincoln Place
Dublin 2
Tel: 0860875470

Appendix C – Invitation letter

Ospidéal Ollscoil Déadach Bhaile Átha Cliath
Plás Lincoln, Baile Átha Cliath 2, Éire

Dublin Dental University Hospital
Lincoln Place, Dublin 2, Ireland

Re: Invitation to participate in clinical study

Dear patient,

Prof Stassen, Chair of Oral and Maxillofacial Surgery TCD and I, Dr.Saleh, are undertaking a study on patients, who require removal of their lower wisdom teeth. We are simply looking at different ways that oral surgeons suture (stitch) the gum after the surgery. We are writing to you to ask you to consider being part of the study.

It will be necessary for me to meet you, explain the study, confirm your willingness to be involved and your suitability for the study. There will be no charge for this screening. Any of the usual surgical charges for the surgery must still stand.

Please return this letter in the stamped addressed envelope with your signature and date confirming your agreement to take part in our research. If you decide not to take part in the study, this will not affect your position on the waiting list for the previously agreed treatment.

Yours sincerely,

Leo F A Stassen.

Prof Leo F A Stassen
FRCSI, FDSRCS, MA, FTCD, FFSEM, FFDRCSI, FICD
Professor/Chair of Oral & Maxillofacial Surgery, IMC 02270

Saleh Alkadi

Dr. Saleh Alkadi BDS , MFDRCSI , NBDE
Specialist Registrar Oral Surgery

Patients Signature: Date:

Department of Oral Surgery, Oral Medicine & Oral Pathology
Dublin Dental University Hospital, Lincoln Place, Dublin 2.
Tel: (01) 612 7314
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Web: www.dentalhosptial.ie

Appendix D – Impaction characteristics

Classification of lower 3rd molar

Tooth		LR 8	LL 8
Nature of overlying tissue:	(F)Fully bony impacted		
	(P)Partially bony impacted		
	(S)Soft tissue impacted		
	(E)Erupted		
Inclination to long axis of 2nd molar:	(M)Mesio angular		
	(D)Distoangular		
	(H)Horizontal		
	(V)Vertical		
	Transverse buccal		
	Transverse lingual		
Relation to ramus of mandible :	Class 1		
	Class 2		
	Class 3		
Relation to occlusal surface of 2nd molar :	Class A		
	Class B		
	Class C		
Root morphology	**C**onical **F**used  Separate converging (SC)  Separate Diverging (SD) 		
Adjacent lower 7	Eruption Caries Fillings Roots Periodontal condition Periapical condition		

Appendix E – Measurement of facial swelling and mouth opening

Facial Swelling and Mouth opening

		Pre-operative	1 week postoperative
Line 1 (cm) **(tragus-lip junction)**	**Right** **Left**		
Line 2 (cm) **(tragus- median point of chin)**	**Right** **Left**		
Line 3 (cm) **(Mandibular angle-eye lateral canthus)**	**Right** **Left**		
Line 4 (cm) **(Mandibular angle – ala nasi)**	**Right** **Left**		
Line 5 (cm) **(Mandibular angle – lip junction)**	**Right** **Left**		
Line 6 (cm) **(Mandibular angle – median point of chin)**	**Right** **Left**		
Mouth opening **(Incisal edge upper central-incisal edge lower central)**			

Appendix F – Soft tissue healing index

HEALING INDEX **One Week**

PARAMETER	RIGHT SITE	LEFT SITE
TISSUE COLOR		
BLEEDING ON PALPATION		
GRANULATION TISSUE		
SUPPURATION		
WOUND MARGIN		
OVERALL SCORE		

One Month

PARAMETER	RIGHT SITE	LEFT SITE
TISSUE COLOR		
BLEEDING ON PALPATION		
GRANULATION TISSUE		
SUPPURATION		
WOUND MARGIN		
OVERALL SCORE		

Appendix G – Operative details

Intra-Operative Difficulty

		LR 8	LL 8
Lingual flap raised	Yes		
	No		
Amount of bone removed Bucco-lingual :	Large (> 2mm)		
	Medium (2mm)		
	Small (< 2mm)		
Amount of bone removed occlusaly :	Large(>5mm)		
	Medium (3-5 mm)		
	Small (< 3mm)		
Tooth sectioned	Once		
	Twice		
	>twice		
Injury to ID	Yes		
	No		
Injury to lingual nerve	Yes		
	NO		
Flap tearing	Yes		
	NO		
Overall difficulty	Very difficult		
	Difficult		
	Medium difficulty		
	Low difficulty		
Operative time			
Other complications:			

Appendix H – Periodontal examination of lower second molar

Periodontal chart for lower second molars

Tooth	Parameter (mm)	Pre-operative	1 month postoperative
37	PD(DB) PD(MID) PD (MB) PD (Mean) GMP CAL		
47	PD(DB) PD(MD) PD (DL) PD (Mean) GMP CAL		

PD(DB): Pocket depth at disto-buccal point

PD(MID): Pocket depth at mid-buccal point

PD (MB): Pocket depth at mesio-buccal point

PD (Mean): Mean pocket depth at buccal surface

GMP: Gingival margin position in relation to cement-enamel junction

CAL: Clinical attachment level (CAL = PD- GMP).

Appendix I – Patient questionnaire for first post-operative week

Patient Questionnaire

- How many times did you need to use a gauze pack to **stop bleeding**?

RIGHT	**Day 1**	1	2	3	4	5	6	7	8	9	10
	Day 2	1	2	3	4	5	6	7	8	9	10
	Day 3	1	2	3	4	5	6	7	8	9	10
	Day 4	1	2	3	4	5	6	7	8	9	10
	Day 5	1	2	3	4	5	6	7	8	9	10
	Day 6	1	2	3	4	5	6	7	8	9	10
	Day 7	1	2	3	4	5	6	7	8	9	10

LEFT	**Day 1**	1	2	3	4	5	6	7	8	9	10
	Day 2	1	2	3	4	5	6	7	8	9	10
	Day 3	1	2	3	4	5	6	7	8	9	10
	Day 4	1	2	3	4	5	6	7	8	9	10
	Day 5	1	2	3	4	5	6	7	8	9	10
	Day 6	1	2	3	4	5	6	7	8	9	10
	Day 7	1	2	3	4	5	6	7	8	9	10

- How many times did you need to **attend A&E** to stop any bleeding?

  _____

- For how long did the bleeding last :

Right side :_____ Left Side : _____

For **how long** did you use the following:

Antibiotics? (Amoxil /Clindamycin)

Never 1 day 2 days 3 days 4 days 5 days 6 days 7 days

Painkillers? (Paracetamol, Panadol, Solpadeine, Neurofen, etc..)

Never 1 day 2 days 3 days 4 days 5 days 6 days 7 days

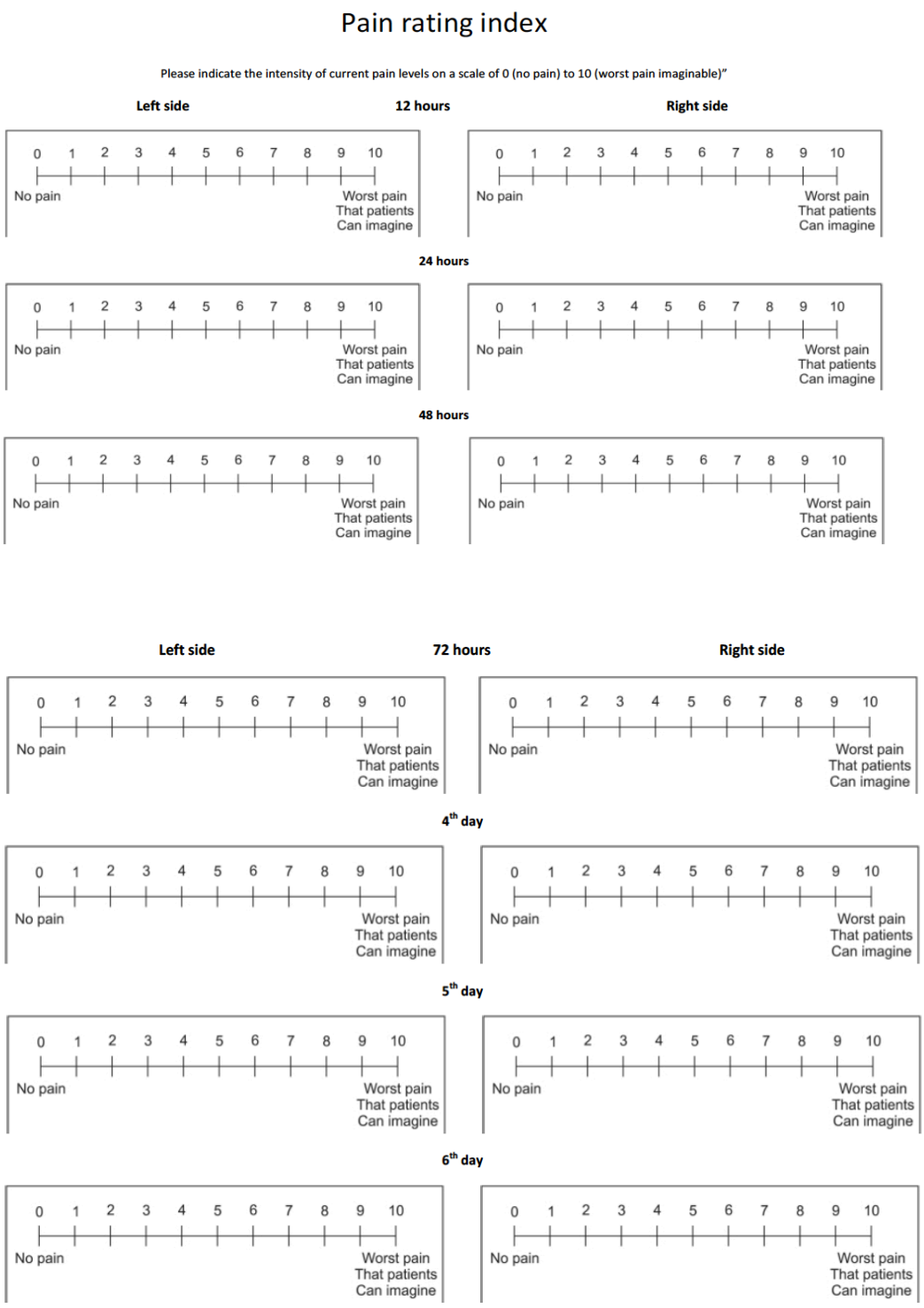
Salty water mouthwash?

Never 1 day 2 days 3 days 4 days 5 days 6 days 7 days

Chlorhexidine mouthwash?

Never 1 day 2 days 3 days 4 days 5 days 6 days 7 days

Appendix J – Pain rating for first post-operative week



Please enlist any extra analgesic medications that have been taken for pain relief

Medication	Dose (mg)	Number of tablets	Time (am/pm)	Day (1^{st} , 2^{nd}, 3^{rd} ,4^{th}, 5^{th},....)	RHS / LHS Pain

Appendix K – Socket healing assessment

Socket Healing

LR8 LL8

One week / One month
Review

Observer Code: _____

Degree of Healing (please mark X)

 ☐
Flap Displaced

 ☐
Open socket with exposed bone

 ☐
Open socket (epithelialised)

 ☐
Closed socket (healing incomplete)

 ☐
Closed socket (healing complete)

Pus	Yes	No
Erythema	Yes	No
Food Imp	Yes	No
Dry Socket	Yes	No
Anaerobic smell	Yes	No

Observer Code: _____

Degree of Healing (please mark X)

 ☐
Flap Displaced

 ☐
Open socket with exposed bone

 ☐
Open socket (epithelialised)

 ☐
Closed socket (healing incomplete)

 ☐
Closed socket (healing complete)

Pus	Yes	No
Erythema	Yes	No
Food Imp	Yes	No
Dry Socket	Yes	No
Anaerobic smell	Yes	No

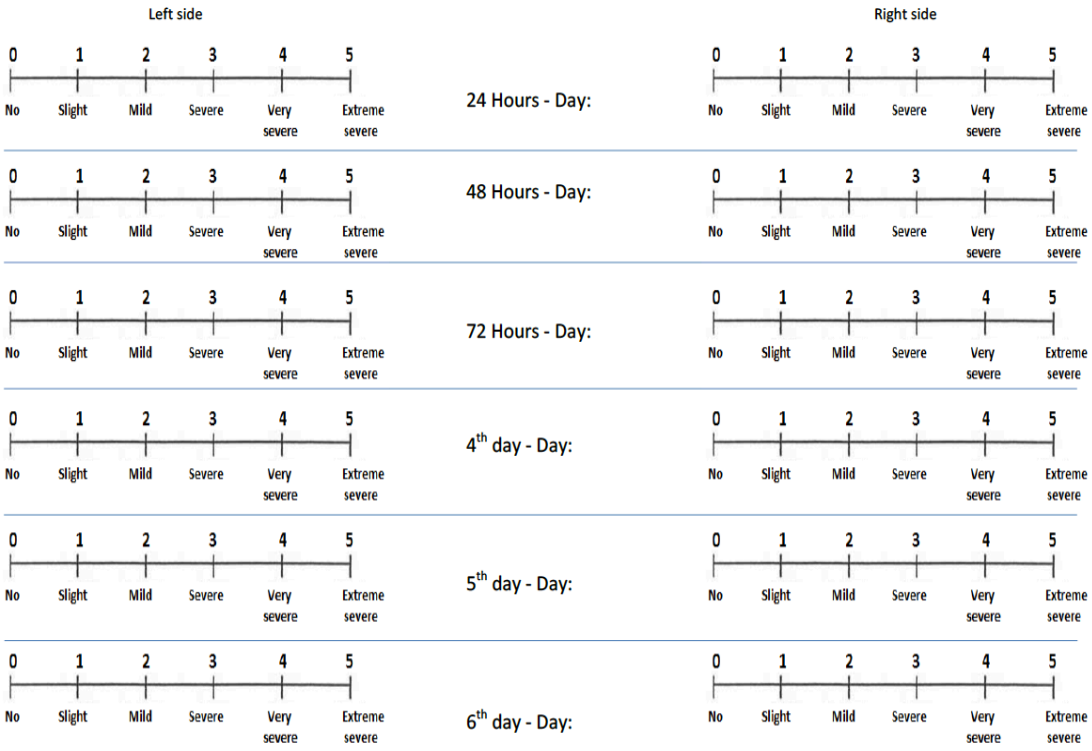
Appendix L – Neuropathy assessment

Neurological Test
One week / one month

Side	Right			Left		
	Lingual nerve	ID nerve	Mylohyoid nerve	Lingual nerve	ID nerve	Mylohyoid nerve
Light touch						
Pin-prick						
Two points discrimination						
Paraesthesia						
Dysaesthesia						
Anasesthesia						

Appendix M – Facial swelling rating for the first post-operative week

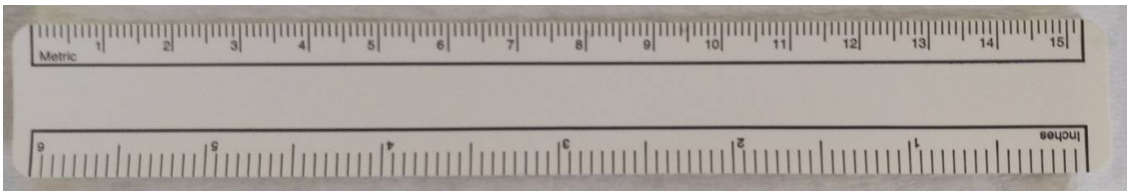
How do you rate your facial swelling?



0 No swelling	The patient does not detect the slightest swelling
1 Slight swelling	The patient detects a slight swelling but is not very noticeable
2 Mild swelling	The swelling is noticeable but does not interfere with normal mastication & swallowing
3 Severe swelling	The swelling is evident & hinders normal mastication
4 Very severe swelling	The swelling is marked. Mastication is hindered but there is no reduction in mouth opening(no trismus)
5 Extremely severe swelling	The swelling is very evident & mouth opening is reduced (trismus)

Appendix N – Armamentarium and instruments

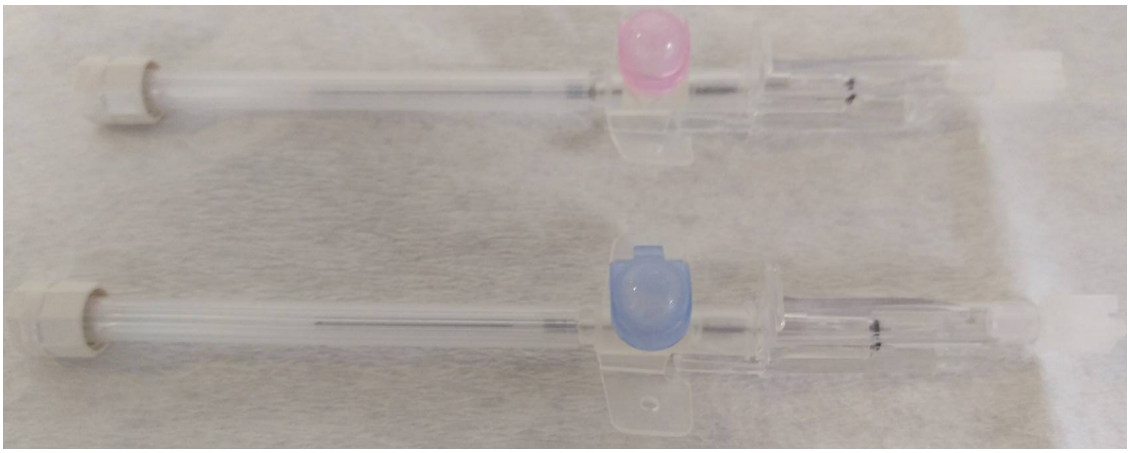
Marking pen to mark anatomical landmarks for facial measurements



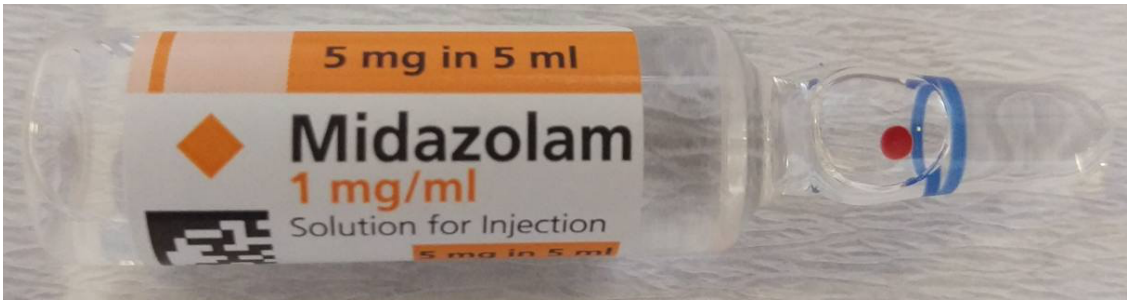
Flexible tape for facial measurements

William's Probe for periodontal examination

Metallic ruler to measure mouth opening



20 G and 22 G cannulas for IV line



Midazolam 5mg/5ml for conscious sedation

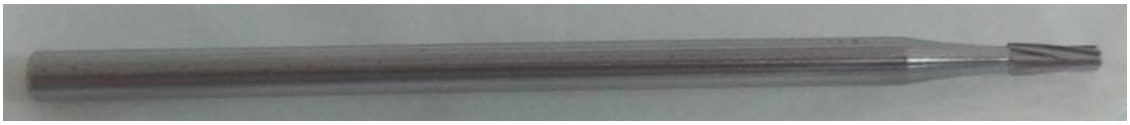
27 G long needle for local anaesthetic injection

2% Lidocaine 1:80000 epinephrine for local anaesthesia

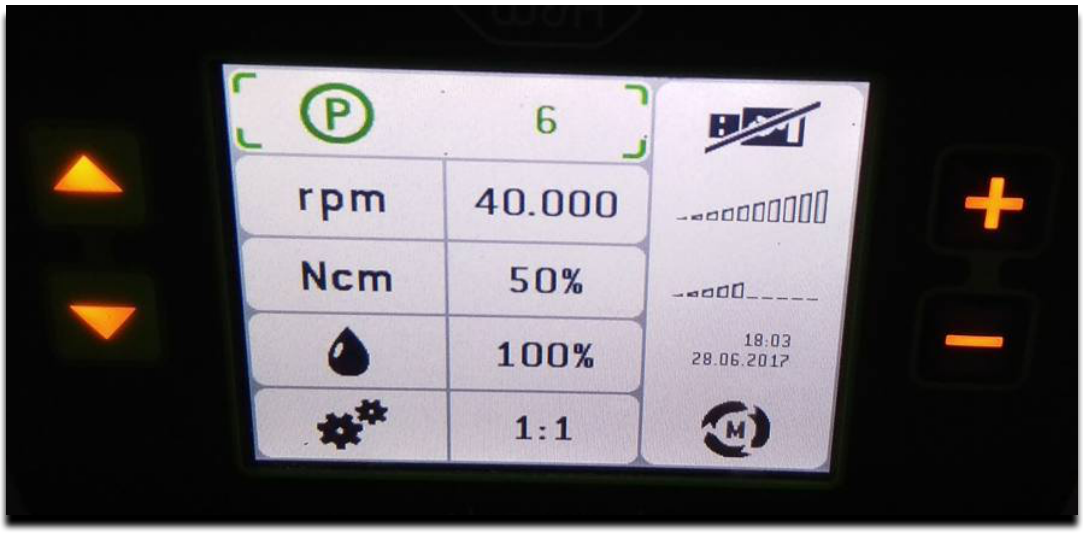
Number 15 blade and scalpel handle


Mitchell's trimer

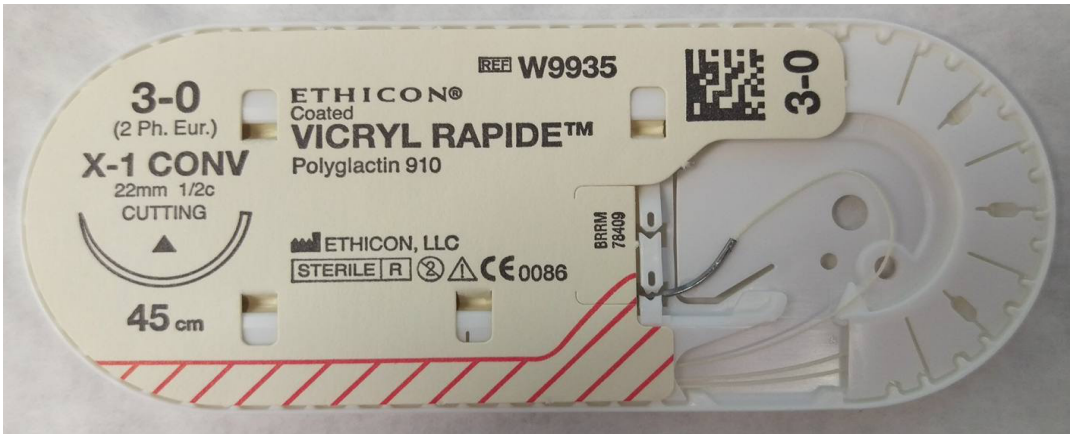

Howarth's periosteal elevator



Tungsten Carbide bur for bone removal



Control panel for the motor unit showing speed of the headpiece during bone removal



3-0 Vicryl Rapide for suturing

Stopwatch to measure operative time