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Review

Comprehensive review of lower third molar management: a guide for improved informed consent

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Abstract

Lower third molar removal is the most commonly performed dental surgical procedure. Nevertheless, it is difficult to ensure that all the informed consent forms given to patients are based on the best evidence as many newer publications could change the conclusions of previous research. Therefore, the goal of this review paper is to cover existing meta-analyses, randomized control trials, and related articles in order to collect data for improved and more current informed consent.

Keywords

Wisdom tooth, oral surgery, tooth extraction, complications, nerve injury, iatrogenic

Introduction

Removal of the lower third molar is the most common dental surgical procedure (Shepherd and Brickley, 1994; Kunkel et al., 2006). One critical complication of the procedure is inferior alveolar nerve (IAN) injury caused by invasion of the mandibular canal (MC). A number of clinical, anatomical and radiological studies of the MC and related structures has been conducted since cone beam computed tomography (CBCT) was developed (Naitoh et al., 2009; Kawai et al., 2011; Guerrero et al., 2014; Iwanaga et al., 2020a; Iwanaga et al., 2020b; Iwanaga et al., 2020c; Ngeow and Chai, 2020). However, there is still controversy about the management of the lower third molar. Recently, several position papers/guidelines have been published in, for example, the Agency for Quality in Dentistry (2006), the American Association of Oral and Maxillofacial Surgeons (2016), and the French Society of Stomatology, Maxillo-Facial Surgery and Oral Surgery (2020). Each of these was based on systematic reviews and randomized control trials that could potentially exclude some important information because they focus on specific single topics. To cover this subject thoroughly, a narrative review would be a better option. Dentists could then choose the information that is most likely to help them provide better informed consent to their patients. In this paper, published reports are reviewed to provide such a guide for dentists involved with the management of lower third molar removal.

General information

Epidemiology and pathology

Pericoronitis and caries

The prevalence of third molar impaction is estimated to be 24% worldwide (Carter and Worthington, 2016; Vandeplas et al., 2020). A number of studies suggests that third molar impaction rates increase up to approximately 30 years of age (Yamaoka et al., 1995; Venta, 2012). Most clinicians view the lower third molar teeth as "ticking time bombs" that can eventually become impacted if they are not removed (Carter and Worthington, 2016). The available data show it is very rare to keep the third molar disease-free. The lower third molars typically erupt between the ages of 17 and 24 years (Vandeplas et al., 2020). In view of this, it is not surprising that the third molar and distal surface of the second molar teeth are significantly more likely to be caries in patients over 25 years old. The prevalence of caries ranges from 24% to 80% depending on the age of the patient (Shugars et al., 2004; Fisher et al., 2010; Garaas et al., 2012; Venta et al., 2015). Studies from Europe suggest that up to 20% of lower third molar referrals and 23% of patients referred for assessment have caries on the distal surface of the second molar tooth. Fisher et al. (2010) reported that third molar caries (upper and lower) were detected in 77% of 2003 subjects with visible third molars in middle-aged and older Americans (52-74 years old, Caucasians and African-Americans). It was significantly more prevalent in mesial and horizontal angulations of the third molar than in distal and vertical angulations

(Toedtling et al., 2019). Similarly, lower third molar pericoronitis is nearly doubled in patients older than 25 years (Blakey et al., 2002). Another study showed that most lower third molars (59%) are removed due to a history of pericoronitis (Carmichael and McGowan, 1992). Retention of the third molar is significantly related to an increased risk of pathology (periocoronitis and caries), especially with partially erupted, mesially-angulated lower third molars (Vandeplas et al., 2020). According to Garaas et al. (2011), 2064 out of 6793 subjects (30.4%) with a mean age of 61.5 years had at least one visible third molar. The third molars in fewer than 2% of the 2064 subjects were free of caries and periodontal pathology.

Mandibular angle fracture and presence of the lower third molar

A meta-analysis by Giovacchini et al. (2018) revealed a statistically significant association between mandibular angle fracture and the presence of the lower third molar. When the Pell and Gregory classification is applied, Position C, Class II, and Class III are particularly related. De Sousa Ruela et al. (2018) found that an impacted lower third molar increases the chance of mandibular angle fracture 3.16-fold, with the highest risk in Class III/Position C.

Guidelines

Indications and contraindication for surgical removal

Indications and non-indications for lower third molar extraction are shown in Table 1. The active use of medications such as intravenous therapy with antiresorptive agents should be considered a contraindication (Diz et al., 2013; De Bruyn et al., 2020). Also, systemic conditions in the patient's medical history could be related to an increased risk of surgical complications (Bui et al., 2003).

Although not all lower third molars require surgical removal, all patients should be evaluated by an expert in lower third molar management (AAOMS, 2016) given the documented high incidence of issues related to lower third molars. All these recommendations agree on the need to remove a symptomatic tooth with pathology (National Institute for Health and Clinical Excellence, 2000; Stordeur et al., 2012). However, there has been no consensus on how to manage an asymptomatic lower molar tooth (Scottish Intercollegiate Guidelines Network, 2000).

Diagnosis and treatment planning

Panoramic sign and Classification system

Rood's signs

Rood and Shehab (1990) suggested seven radiographic signs of a relationship between the lower third molar and the MC in a panoramic radiograph. Four of these signs were tooth-related (a bifid apex, root narrowing, root deflection, and darkening), and the other three were MC-related (narrowing, diversion, and interruption of the white line in the MC) (Rood and Shehab, 1990; Huang et al., 2015) (Fig. 1 and Table 2).

Winter classification

The Winter classification is based on the inclination (mesioangular, distoangular, horizontal, vertical, buccal/lingual obliquity, transverse, inverse) of the impacted third molar tooth to the long axis of the second molar tooth (Fig. 2 and Table 3).

Pell and Gregory classification

The Pell and Gregory system classifies lower third molars into Classes I, II, and III on the basis of the distance from the distal to the second molar to the anterior border of the ramus of the mandible. This classification also considers Positions A, B, and C based on the depth of the impacted third molar tooth in the bone in relation to the occlusal plane (Fig. 3 and Table 4).

CBCT findings

Indication for CBCT

3D imaging can provide additional useful information on the relationship between the MC and the lower third molar, can give the operator confidence, and can consequently prevent a disruptive approach during surgery that could cause neurosensory disturbance of the IAN (Araujo et al., 2019). However, the reported radiation dose levels for CBCT are much higher than in a panoramic radiograph (ranges from 10μSv to 1200μSv, which is 2-240 times as much as a panoramic radiograph) (Jacobs, 2011). However, it is considered that the radiation dose level in CBCT for the wisdom tooth on one side ranges from 10-20 μSv when the field of view

(FOV) is appropriately adjusted, which is also much less than the worldwide average natural radiation dose to humans per year (2.4mSv) (Thorne, 2003). Thus, CBCT should be indicated and, at the same time, might be recommended in cases where there is a high risk of injury to the MC, as suggested by signs on panoramic radiography, and/or to cope with intraoperative complications as the anatomy is better depicted than with panoramic imaging (Ghaeminia et al., 2011; Roeder et al., 2012; Yabroudi and Sindet-Pedersen, 2012; Ghaeminia et al., 2015; Kursun et al., 2015).

Positional relationship of mandibular canal and lower third molar on CBCT

Using CBCT images, differences in position (buccal, inferior, lingual, inter-radicular), shape (round/oval, teardrop, dumbbell), and contact (none, single, double) have been reported (Ueda et al., 2012; Wang et al., 2018; Kubota et al., 2020). Some of these are associated with IAN injury (Figs. 4-6). According to Shujaat et al. (2014), the root of the third molar was positioned buccal to the MC in most cases (74%) followed by middle (apex of root) (18%) and lingual (8%). Al Ali and Jaber (2020) reported that the root of the third molar was positioned lingual, buccal, and inferior to the MC in 45 (57%), 18 (22.8%), and 14 (17.7%) cases, respectively. In most subjects, impacted lower third molars were in the lingual position (74%) without perforation of the lingual cortical plate. The bone around lingually positioned teeth was more likely to be thinner than that around centrally or buccally positioned third molars (Khojastepour et al., 2019). Other studies showed that the most prevalent position of the third molar root was above the MC, followed by the side lingual to the MC (Maglione et al., 2015; Chen et al., 2018; Quirino de Almeida Barros et al., 2018). Yabroudi et al. (2012) showed that most third molars were superior and buccal to the MC. Thus, the positional relationship between the root of the lower third molar and the MC can differ among cohorts, so it is difficult to determine the tendency.

Comparison of panoramic radiograph and CBCT

Detection of anatomical risk factors

There were statistically significant differences between panoramic radiograph and CBCT examinations for detecting anatomical risk factors. CBCT provided a better understanding of the anatomical relationship between lower third molar roots and the MC (Baqain et al., 2020). The "intersecting" relationship on CBCT is more frequent in mesioangular third molars than in other angulations in the Winter classification. The frequency of an "intersecting" relationship also increased as the space for accommodation of the third molar decreased (Class III) and the depth of impaction increased (Position C) in the Pell and Gregory system (Khojastepour et al., 2019). Lingually-positioned and impacted third molars were the most deeply impacted, followed by the central and buccal positions (Ge et al., 2016). A dumbbell-shaped or teardrop-shaped MC usually indicates direct contact with the root (Ueda et al., 2012). The incidence of an "intersecting" position of the root apex into the MC was greater for a mesioangular third molar (65.9%), which is the major type of impaction in the Winter classification (Khojastepour et al., 2019). In contrast, a buccal position of the tooth was more frequent in mesioangular teeth than other angulations (Khojastepour et al., 2019).

Treatment planning

When surgical management is planned, assessment by panoramic radiographs provides sufficient information to determine whether to perform a full extraction or to choose an alternative, e.g., coronectomy (Matzen et al., 2013; Aravindaksha et al., 2015; Manor et al., 2017). It has been argued that experienced surgeons can decide the surgical approach without CBCT (Baqain et al., 2020). However, Ghaeminia et al. (2011) reported that 3D information from CBCT images contributes to a drastic change of surgical approach toward tooth removal by revealing the buccolingual relationship between the MC and the lower third molar. This enables surgeons to decide, if they remove buccal bone, where to place elevators and remove extra bone after coronectomy. Within the limits of the available data, de Toledo Telles-Araújo (2020) concluded in their systematic review that there is no strong evidence that the use of CBCT reduces the risk of IAN injury following lower molar surgery.

Overall benefit of CBCT

As CBCT can visualize the relevant anatomical structures more clearly than panoramic radiography, especially the lower third molar roots and MC, and gives dentists more information including risk factors. The 3D information provided by CBCT might not change either the surgical approach or the outcome, but it can be considered, especially by less experienced surgeons, when a panoramic radiograph reveals signs of a high risk for IAN injury.

Other considerations

Use of ultrasonic electric devices

A meta-analysis assessed the effect of piezosurgery (Badenoch-Jones et al., 2016); patients showed less facial swelling, trismus, and pain than a conventional burr group at postoperative day 1, less facial swelling at day 7, and lower risk of neurological complications. Trismus at postoperative day 7 and pain at day 5 showed no significant differences. Operation times were longer with the piezosurgery group.

Adjuvant laser therapy

A meta-analysis that assessed the effects of low-level laser therapy (LLLT) on reducing postoperative complications of lower third molar removal concluded that current evidence does not support the use of LLLT for this purpose (Dawdy et al., 2017).

Operation time and flap design

A meta-analysis by Zhu et al. (2020) showed that the operation time using an envelope flap was 1.23 minutes faster than using a triangular flap (including the modified triangular flap). This time difference could be attributed to the additional suturing time.

Time off

We found only one study that investigated sick leave associated with third molar removal. According to Lopes et al. (1995), 81% of patients took time off of work after this surgery. The time off of work ranged from 0-10 days with a mean of three days.

Complications

Inferior alveolar nerve injury

Definition of permanent injury

In IAN injury, the degree of persistent deficit can be slight and in most cases will not greatly affect sensation (Alling, 1986). In general, there is a high likelihood of regeneration over time; most injuries healed after 3-4 months (Kjølle and Bjørnland, 2013). Postoperative neurosensory impairments such as numbness or paresthesia were considered temporary if they subsided within six months. If the symptoms remained unresolved for longer than six months, the injury was considered permanent (Gulicher and Gerlach, 2001; Jain et al., 2016; Korkmaz et al., 2017; Wang et al., 2018; Kubota et al., 2020). Recovery after nine months postoperatively is extremely rare, and it is unlikely that any recovery will occur after 18-24 months of follow-up (Robinson, 1988).

Incidence

The reported incidence of IAN injury ranged from 0.35% to 19% when the tooth roots were very close to the IAN (Carmichael and McGowan, 1992; Lopes et al., 1995; Haug et al., 2005; Cheung et al., 2010; Hasegawa et al., 2013; Kjølle and Bjørnland, 2013; Smith, 2013; Guerrero et al., 2014; Martin et al., 2015). A recent larger study reported that among 4338 lower third molar extractions performed by various levels of surgeons, IAN injury occurred in 0.35% (Cheung et al., 2010). In most cases, IAN paresthesia is temporary and recovers within six months; however, in fewer than 1% of cases, the injury persists for longer and often becomes permanent (Smith et al., 1997; Gulicher and Gerlach, 2001; Jerjes et al., 2010; Momin et al., 2013; Eshghpour et al., 2017).

IAN injury and sex

Some studies revealed no association between sex and IAN injury (Valmaseda-Castellón et al., 2001), but others indicated that female patients are more likely to have a higher incidence of IAN injury than males (Valmaseda-Castellon et al., 2001; Blondeau and Daniel, 2007; Kim et al., 2012).

IAN injury and age

Many studies agreed that patients with IAN injury are significantly older than those without injury (Bruce et al., 1980; Valmaseda-Castellon et al., 2001; Blondeau and Daniel, 2007; Kim et al., 2012; Korkmaz et al., 2017). According to Kubota et al. (2020) and Kjølle and Bjørnland (2013), IAN injury is more persistent in patients aged over 30 years. Another study reported that third molars in 50-70 year old females were closer to the IAN significantly more frequently than those in patients younger than 30 years (De Bruyn et al., 2020). Decreased bone elasticity, narrowed periodontal space, enhanced tooth hypercementosis, sclerotic changes in the surrounding bone, and delayed regeneration of the injured nerve were all considered disadvantageous factors in older people (Nakamori et al., 2014; Nguyen et al., 2014). The authors agreed that patient age increases the risk of IAN injury exponentially, but only if there are anatomical risk factors such as close proximity of the third molar roots to the MC (Valmaseda-Castellón et al., 2001). Otherwise, IAN regeneration seems generally more rapid and complete in patients under 30 years of age (Kjølle and Bjørnland, 2013), although some studies found no association between IAN injury and the patient's age (Kipp et al., 1980).

IAN injury and signs in images

Some studies have concluded that three of the seven signs in panoramic radiographs are significantly more related to IAN injury, i.e., diversion of the MC, interruption of the white line, and darkening of the root (Rood and Shehab, 1990; Atieh, 2010; Wenzel, 2010). Position C was a non-significant variable (Wang et al., 2018; Kubota et al., 2020). The IAN is more vulnerable to injury when it courses on the lingual side (Kim and Lee., 2014). Class III, teardrop, and dumbbell-shaped MC features in panoramic radiographs, lingual/inter-radicular MC positions, and multiple roots with perforated MCs in CBCT images, are probably associated with IAN injury. Perforation of the MC wall by the lower third molar is a major risk factor for IAN injury (Ueda et al., 2012).

IAN injury and intraoperative nerve exposure/hemorrhage

According to Jhamb et al. (2009), IAN exposure is higher when the MC courses lingual to the third molar. Jain et al. (2016) reported intraoperative findings showing that out of 11 patients who had hemorrhage with or without IAN exposure, nine (81.81 %) had nerve injury. This could indicate that intraoperative hemorrhage with or without nerve exposure could increase the chances of IAN injury. Wang et al. (2018) reported that out of 62 IAN exposures observed intraoperatively, 24 (38.7%) resulted in permanent IAN injury.

IAN injury and tooth sectioning

Besides the anatomical risk factors, surgical techniques such as crown sectioning can significantly reduce the incidence of IAN injury (Jain et al., 2016), though some have reported that crown sectioning is related to IAN injury. Vertical sectioning of the root did not significantly increase the incidence of IAN injury, although there was a trend toward it (Valmaseda-Castellón et al., 2001). It seems that tooth sectioning is not a critical factor for IAN injury.

Lingual nerve injury

LN injury and anatomy

Lingual nerve (LN) injury during wisdom tooth removal could result in loss of general sensation and taste of the anterior two-thirds of the tongue. The LN runs anteromedial to the IAN at the level of the mandibular foramen, passes under the inferior border of the superior pharyngeal constrictor muscle, and finally enters the floor of the oral cavity (Iwanaga et al., 2018a; Iwanaga et al., 2018b; Kikuta et al., 2019). The course of the LN in the retromolar area is medial to the lingual plate, with a distance of 2 mm and 3 mm from the lingual plate horizontally and lingual alveolar crest vertically, respectively (Behnia et al., 2000). Some researchers reported an atypical course of the LN as “passing through the retromolar pad” and “in the retromolar pad just on the surface of mandible,” although these are rare (Kiesselbach and Chamberlain, 1984; Behnia et al., 2000). However, previous descriptions of the variant course was not based on precise anatomy of the retromolar pad and could have led to a reader misunderstanding. In 2017, Iwanaga et al. showed that the LN course could change due to tongue movement, and then same author group clearly showed anatomical evidence that “the LN does not pass through the retromolar pad” and clarified the anatomical structure of the retromolar pad (Iwanaga et al., 2018b; Iwanaga et al., 2020d). To avoid LN injury during lower third molar surgery, the initial incision into the mucosa distal to the second molar has to be made posterolaterally on the bone, and the periosteum of the lingual flap has to be protected from damage as the LN could run next to the periosteum.

LN injury and incidence

Permanent alterations of the lingual nerve (LN) were more discernible by patients (Kjølle and Bjørnland, 2013). The risk of LN injury associated with the lower third molar ranges from 0.5 to 6.6% (Tolstunov et al., 2016). A recent larger study reported that of the 4338 lower third molar extractions performed by various levels of surgeons, LN injury occurred in 0.69% (Cheung et al., 2010). Some studies agreed that the recovery rate was lower for LN injury than IAN injury, little improvement in tongue sensation being seen from the first 12 months up to five years (Alling, 1986; Kjølle and Bjørnland, 2013), though other studies have failed to support this (Carmichael and McGowan, 1992).

LN injury and anesthesia

Both retrospective (Blackburn and Bramley, 1989) and prospective (Brann et al., 1999) clinical studies have found a much higher rate of LN injury with patients under general anesthesia than with local anesthesia. There were some differences among studies, probably because of different surgical techniques and interoperator variability.

LN injury and depth of the lower third molar

Some studies concluded that the depth of impaction was not clearly related to LN injury. In contrast, two studies found that the deeper the third molar, the higher the rate of LN injury

(Mason, 1988; Carmichael and McGowan, 1992). Vertical impactions had a significantly lower incidence, whereas those classified as horizontal or “other” impactions had a significantly higher incidence of LN injury (Carmichael and McGowan, 1992). Paradoxically, fully erupted third molars had the highest rate of LN injury (5.4%). Indeed, erupted lower third molars subjected to surgical removal were often difficult cases requiring such procedures as ostectomy, lingual flap retraction, and tooth sectioning. The erupted tooth has no protection by the tongue from surgical invasion of e.g., lingual bone, which the impacted tooth usually has. These surgical maneuvers seem to be the true cause of nerve injury, not the depth of impaction (Valmaseda-Castellón et al., 2000).

LN injury and lingual plate perforation and exposure

Lingual plate perforation and LN exposure are the main risk factors for LN injury during lower third molar extraction (Renton and McGurk, 2001). Thinning and perforation of the lingual plate can reduce the distance between the tooth and the LN and therefore increase the chance of LN injury during the surgical procedure (Renton and McGurk, 2001; Tolstunov et al., 2016). The possibility of perforation or fracture of the lingual cortical plate was greater for vertical, distoangular, and horizontal angulations (Khojastepour et al., 2019).

Other complications

Bleeding

In adults, the incidence of persistent bleeding during lower third molar tooth surgery ranged from 0.6-5.8% (Burce et al., 1980). A high incidence of hemorrhage or excessive bleeding has been described in relation to distally-angled lower third molars with deep impaction and in patients older than 25 years (Chiapasco et al., 1993). Potential sources of bleeding include the inferior alveolar artery, sublingual artery (or its branch), lingual branch of the inferior alveolar artery, buccal artery (or its branch), facial artery (or its branch), and the artery in the retromolar foramen (Standring, 2015; Kikuta et al., 2018; Iwanaga et al., 2020e).

Drainage and pain, swelling, and trismus

Third molar removal is often related to pain, swelling, and trismus, and how to minimize the postoperative discomfort remains controversial. A meta-analysis by Liu et al. (2018) evaluated the effectiveness of surgical drainage for managing postoperative pain, facial swelling, and trismus 2-3 days (early stage) and 5-7 days (late stage) after lower third molar removal. They concluded that the pain during the early stage could be reduced by surgical drainage, but not in the late stage. Facial swelling was statistically significantly different between the surgical drainage and control groups in both the early and late stages, and surgical drainage seemed more effective for improving opening of the mouth. Liu et al.'s study also mentioned the types of drainage, i.e., tube, rubber, and gauze drains. For facial swelling, tube drainage showed better results than rubber and gauze drainage. In terms of pain, the rubber drain resulted in a better outcome than tube and gauze drains that have to be sutured to the mucosa (Liu et al., 2018).

Flap design and pain, swelling, and trismus

Menziletoglu et al. (2019) compared postoperative morbidity between two flap designs: the buccal-based triangular flap and the lingual-based triangular flap (Fig. 7). There was a statistically significant difference between the two groups in both pain and swelling at both days 1 and 7, postoperatively. The authors concluded that patient quality of life is low in the lingual-based triangular flap and considered the buccal flap preferable for lower third molar removal. Şimşek et al. (2019) compared the modified triangular flap and envelope flap (Szmyd, 1971; Jakse et al., 2002) (Fig. 8). In agreement with previous studies, Şimşek et al. found the modified triangular flap led to lower pain levels than the envelope flap design (Sandhu et al., 2010; Rabi et al., 2017). A meta-analysis by Zhu et al. (2019) showed no statistically significant difference in pain or trismus between the envelope and triangular flaps (including the modified triangular flap). Several studies concluded that the triangular flap is associated with increased swelling on days 2-5, but meta-analysis was not used owing to the heterogeneity in measurements among studies (Kirk et al., 2007; Briguglio et al., 2011; Erdogan et al., 2011; Baqain et al., 2012; Koyuncu and Cetingul, 2013; Coulthard et al., 2014; Tareen et al., 2015; Alqahtani et al., 2017; Korkmaz et al., 2017; Zhu et al., 2019).

Wound closure and pain, swelling, and trismus

The idea of the classic primary wound closure technique originates from basic surgical principles. Researchers suggested that a fully-covered wound would decrease the chances of postoperative infection (Archer, 1975; Killey et al., 1975). Secondary closure is believed to allow drainage as the socket still remains in communication with the oral cavity (Cerqueira et al., 2004; Pasqualini et al., 2005). Whether primary or secondary wound closure results in better outcomes has been controversial. A systematic review of randomized control trials by Carrasco-Labra et al. (2012) found no evidence of treatment effect in terms of pain, swelling, and trismus. A more recent meta-analysis found that secondary closure had a favorable effect on pain, swelling, and trismus in both early and late stages after lower third molar removal (Ma et al., 2019). The inclusion and exclusion criteria in the two foregoing analyses were different so the previous studies included were also different. Another randomized control trial by Pachipulusu and Manjula (2018) concluded that secondary closure was better than primary closure regarding postoperative pain, swelling and trismus, but there was no difference in periodontal healing. The authors did not recommend secondary closure for patients with poor oral hygiene as the risk of the food impaction and infection would be greater. Finally, a clinical study by Balamurugan and Zachariah (2020) reported secondary closure with a buccal mucosal-advancement flap to compare with primary and secondary closure after third molar removal. There was less pain, swelling, and trismus with this technique than with primary or secondary closure.

Extraction-related mandibular fracture

Fracture of the mandible is one of the most severe complications associated with tooth extraction and the reported incidence ranges from 0.0034 to 0.0075%, more specifically 0.0046-0.0075% for lower third molar removal (Nyul, 1959; Alling et al., 1993; Perry et al., 2000; Libersa et al., 2002; Wagner et al., 2005; Wagner et al., 2007). A meta-analysis of 47 reports found 200 cases of iatrogenic fracture of the mandible associated with tooth extraction during the period 1953-2015. Out of those 200 cases, 136 (78%) were related to lower third molar extraction. Interestingly, intraoperative and postoperative fractures (including not only the third molar but also other teeth) were reported as 25% and 75 %, respectively (Joshi et al., 2016). More than 75% of postoperative fractures occurred two weeks after extraction or later. The age distribution peaked at 40-49 years (29%) and the male/female ratio was 2.2:1 (including all fractures) (Joshi et al., 2016).

Oral contraceptive use and dry socket

A meta-analysis of 16 studies found that oral contraceptive use could increase the incidence of postoperative dry sockets in females after impacted lower third molar removal (1.8 times greater than control group). Another retrospective study by Almeida et al. (2016) concluded that there was about 3.5 times greater risk of developing dry socket in females who are taking oral contraceptive at the time of surgery. The authors recommended a cautious attitude to impacted lower third molar removal procedures for females who are taking oral contraceptives (Xu et al., 2015; Almeida et al., 2016).

Antibiotics and postoperative infection

Use of amoxicillin either pre- or post-operatively did not reduce the risk of infection in healthy patients who had third molar extractions (Isiordia-Espinoza et al., 2015). A systematic review of eight articles by Menon et al. (2019) revealed that both amoxicillin and amoxicillin-clavulanic acid are effective for preventing postoperative infection and complications after third molar surgery. Similarly, a meta-analysis by Ramos et al. (2016) reviewed 3304 extractions and concluded that the use of penicillins (amoxicillin, amoxicillin-clavulanic acid, azidocillin) and nitroimidazoles (metronidazole, tinidazole) to prevent dry socket reduced the risk of infection by 57%. Ren et al. (2007) found that patients who received systemic antibiotics were 2.2 times less likely to develop alveolar osteitis and 1.8 times less likely to develop infection. Another study supported antibiotic use to help prevent dry socket and other infections (Lodi et al., 2012). However, other studies gave different results and found no effect of antibiotics in preventing postoperative dry socket and infections (Isiordia-Espinoza et al., 2015; Arteagoitia et al., 2016).

Anti-inflammatory drugs and postoperative pain

Bailey et al. (2013) enrolled a total of 2241 participants to compare the effects of ibuprofen and paracetamol (acetaminophen) for postoperative pain relief. Most studies indicated that 400mg of ibuprofen was superior to 1000mg of acetaminophen, those being the most frequently prescribed doses in clinical practice.

Corticosteroids and postoperative pain

Use of corticosteroids (mostly dexamethasone) had a positive outcome on the control of pain, trismus, and edema. The choice of route other than submucosal (oral administration, intramuscular, intravenous, intra-alveolar, pterygomandibular space) did not affect the results, so oral administration was a good and easy option. To control trismus, preoperative use was superior to postoperative use (Almeida et al., 2019).

Effect of neurosensory deficit on quality of life

One of the most distressing complications of lower third molar removal is injury to the IAN and LN, leading to neurosensory impairments in the lower lip, chin, and the anterior two-thirds of the tongue. Leung et al. (2013a; 2013b) investigated patients with and without neurosensory deficit following lower third molar surgery. The results suggested that patients with permanent neurosensory deficits of the IAN and LN would have a worse quality of life and more depressive symptoms than the group with no postoperative complications (Leung and Cheung, 2016). In addition, older patients (over 40 years) were more likely to develop depression. Another study concluded that patients with IAN neurosensory deficit can have a poorer quality of life than those without (Çakır et al., 2018). However, De Toledo Telles-Araújo et al. (2020) stated that neurosensory disturbance can affect the patient's quality of life negatively. The former papers were published by groups from Hong Kong and Turkey, and the latter from Brazil. We hypothesized that different races or cultures could have different perceptions of sensory deficit. Leung (2019) partially supported this perspective by stating that “in the Asian population the effect of the taste loss appears to impact more on the individual’s quality of life than in people in western countries.” Multinational studies are required to address this speculation.

Other treatment options

Germectomy

Wisdom tooth germectomy aims to remove germs before they form the roots. As its nature, germectomy does not require a specific technique other than a general technique for wisdom tooth removal.

Benefit of germectomy

In general, the roots of the lower third molar are not fully formed until 21 years (Bagheri et al., 2007). In any case, preventive extraction is indicated up to the age of 25 years because the bone is less mineralized (elasticity and resilience) and the periodontal ligament is not yet fully formed (Chaparro-Avendaño et al., 2005). Lytle (1993) advocates early extraction of the germs of the lower third molars impacted against the second molars, since the younger the patient, the faster the osteogenesis within the defect caused by extraction. Germectomy thereby helps to reduce the risk of formation of a periodontal pouch distal to the second molar after third molar extraction (Kugelberg, 1990; Lytle, 1993).

Germectomy and postoperative complications

Some authors have found no differences in pain, swelling or mouth opening difficulties related to patient age (Fisher et al., 1998). In contrast, others have shown that as patient age increases, those three postoperative complications increase (Bruce et al., 1980; Chiapasco et al., 1993). One study reported complications in 6.4% of cases after lower third molar removal in a patient group aged 13-16 years (Pons-Slvadó et al., 2000). Another study found that complications were observed in 17.4% of patients aged 12-14 years, 19% aged 15-16, and 13.7% aged 17-18 (Chaparro-Avendaño et al., 2005). Chaparro-Avendaño et al. (2005) found that pain, infection, swelling, ecchymosis, and mouth opening difficulties can be more problematic at younger ages, while increasing patient age is more likely to be associated with an increased risk of IAN and /or LN injuries. Chiapasco et al. (1995) observed a complications rate of 2.6% in patients aged 9-16 years, versus 2.8% in patients aged 17-24 years, and 7.4% among those older than 24 years. A clinical study demonstrated that germectomy is related to a lower incidence of complications than extractions in adults (Bjørnland et al., 1987; Chiapasco et al., 1995; Zhang and Zhang, 2012). One advantage of germenectomy of the lower third molar is that it is less likely to cause IAN paresthesias, since the roots of the tooth are not yet fully formed, so the relationship to IAN is non-existent or much less evident than in adults (Chiapasco et al., 1995). The incidence of

IAN injury after lower third molar extraction ranges from 0.3% to 8% (Bruce et al., 1980; Sisk et al., 1986; Capuzzi et al., 1994; Valmaseda-Castellón et al., 2001; Chaparro-Avendaño et al., 2005). The incidence of LN injury ranges from 0-10% (Sisk et al., 1986; Blackburn and Bramley, 1989; Valmaseda-Castellón et al., 2000; Chaparro-Avendaño et al., 2005). Overall, the risk of serious complications such as IAN or LN injury seems to be lower with germectomy at younger ages.

Germectomy and dry socket

In adults, the incidence of dry socket after third molar extraction ranges from 0.5 to 30% (Bruce et al., 1980; Sisk et al., 1986), and secondary infection ranges from 1.5 to 5.8% (Sisk et al., 1986). Bjornland et al. (1987), following 172 germectomies, reported a 1.8% incidence of dry socket and a secondary infection rate of 1.7%. This result was supported by Chaparro-Avendaño et al. (2005), with a 1.8% rate of secondary infections that recovered after 7-15 days.

Indication and best timing for germectomy

The best time for preventive lower third molar extraction is when one-half to two-thirds of the molar roots are formed, usually between 16 and 18 years of age (Chaparro-Avendaño et al., 2005). Lower third molar germectomy consists of extraction of the developing dental germ included within the mandible. This procedure is usually carried out after the age of 12-13 years, which is when the lower third molar tooth is generally in its initial calcification stages

(Chaparro-Avendaño et al., 2005). Third molar extractions during the germ phase afford several advantages: surgical access is much easier, impaction of the second molar by the third molar is prevented, pericoronitis of the third molar can be avoided, and postoperative healing shows better outcome in the adolescent than in adults (Chaparro-Avendaño et al., 2005). According to Cassetta and Altieri (2017), lower third molar germectomy does not significantly reduce the treatment time for lower second molar uprighting, and the presence of the lower third molar germ does not impede orthodontic uprighting. Therefore, lower third molar germectomy is not recommended until considered necessary.

Coronectomy

Coronectomy was first introduced in France by Ecuyer and Debien (1984) and in the English literature by Knutsson et al. (1989) as an alternative to complete removal of an impacted lower third molar. Usually, crown is resected on or below the cemento-enamel junction. The resected surface is placed 3-4 mm from the alveolar bone crest. The dental pulp is left untouched at all times. Then the wound is irrigated using saline and closed primarily (Hatano et al., 2009; Pitros et al., 2019).

IAN injury and coronectomy

Coronectomy is indicated when the lower third molar is in contact with the IAN, so complete removal could injure the nerve (Cervera-Espert et al., 2016; Kang et al., 2020). The incidence of

IAN injury, one of the most significant complications related to third molar extraction, appears to be lower with coronectomy, as reported in many studies (O'Riordan, 2004; Dolanmaz et al., 2009; Hatano et al., 2009; Leung and Cheung, 2009; Martin et al., 2015; Cervera-Espert et al., 2016). The incidence of IAN injury with coronectomy is in the range 0-4.3% (Hatano et al., 2009; Leung and Cheung, 2012; Pitros et al., 2019). However, some studies state that the entire teeth were removed if the roots were mobile (Leung and Cheung, 2012; Pitros et al., 2019). This means that even after resection of the crown, some force could be applied to the MC by an elevator that could result in IAN paresthesia. Different study protocols could be one reason for the different results. Another potential reason could be differences in skill levels of the surgeons (Pitros et al., 2019).

LN injury and coronectomy

LN injury after coronectomy has been reported in previous studies. Two studies with relatively small samples (102 cases and 155 cases) resulted in no LN injury by coronectomy, while another larger study showed 0.3% (6/2119) of the patients experienced the LN injury (Hatano et al., 2009; Leung and Cheung, 2012; Omran et al., 2020).

Coronectomy and other complications

High-risk radiographic signs such as a relationship between the MC and the root of the lower third molar tooth have not been related to the incidence of post-coronectomy complications

(Pitros et al., 2019). Dry socket associated with the coronectomy has been reported at 0.86-14.6% (Monaco et al., 2012; Frenkel et al., 2015; Kohara et al., 2015; Pitros et al., 2019). Thus, coronectomy could reduce the incidence of dry socket (Martin et al., 2015; Cervera-Espert et al., 2016)

Coronectomy, age and sex

According to retrospective study by Pitros et al (2019), older patients are more likely to present with both short-term (e.g., pain, dry socket, infection, IAN injury, bleeding) and long-term (root migration, chronic inflammation, IAN injury, eruption of root) complications after coronectomy, but sex is not a good predictor of complications.

Coronectomy and migration of the root

Pitros et al. (2019) reviewed long-term complications of 22 teeth with an average of 4.8 years, and found one case of erupted root (1.7%) at seven years follow-up, which is supported by previous studies indicating 0.6–1.8% root eruption (Patel et al., 2014; Frenkel et al., 2015; Kohara et al., 2015). Leung and Cheung (2009) and Monaco et al. (2012) gave the highest percentages (62.2% and 75%, respectively) of root fragment migration of the lower third molar three months after coronectomy (with average distances of 1.90 mm and 1.60 mm, respectively).

Frenkel et al. (2015) reported significantly greater migration in younger patients. At six-months follow-up, the migration group had a lower mean age than the non-migration group (24.5 years vs 39.6 years, respectively). Similar significant results were obtained after the 12-month evaluation (24.5 years for migration group vs 37.5 years for non-migration group) (Frenkel et al., 2015). Pogrel et al. (2004) compared the radiographs at the time of surgery and six months after the coronectomy and recorded 2-3 mm fragment root migrations from the initial position in 30% of cases. Dolanmaz et al. (2009) and Leung and Cheung (2012) registered maximum root fragment migration two years after coronectomy, with average distances of 4.0 mm and 2.9 mm, respectively. After the second year the degree of migration was greatly reduced. Kohara et al. (2015) recorded greater root migration during the first two years (average 1.84 mm in three months, 2.88 mm in one year, and 3.41 mm and 3.51 mm after two years). From the second year after surgery, 82.2% of the roots did not move. Goto et al. (2012) and Leung and Cheung (2012) reported significantly greater root migration in female patients. Direction of migrated roots varied between cases and might still be difficult to predict. Coronectomy still requires clinical and radiographic follow-up for the remaining root, including secondary root retrieval, because there are fewer long-term outcome studies (Monaco et al., 2019; Shokouchi et al., 2019).

Conclusions

We have analyzed systematic reviews, randomized clinical trials, and related articles in this paper. Although some of the clinical questions have answers agreed upon by many researchers, several still need to be addressed by meta-analysis and the randomized clinical trials that will build up high-quality systematic reviews. In particular, coronectomy of the lower third molar tooth is a relatively new procedure so there is less evidence regarding it. We hope this survey will help dentists in giving appropriate informed consent guidance to patients who might be considering lower third molar treatment.

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Figure legends

Figure 1

The relationship of the lower third molar to the mandibular canal in a panoramic radiograph

Figure 2

Winter's classification based on the angulation of the lower third molar

Figure 3

Pell and Gregory classification. Class defines the mesio-distal position of the impacted third molar, depending on the space between the anterior border of the ramus and the distal border of the second molar (shown in red lines). Position defines the vertical position of the impacted third molar, depending on the occlusal plane and cervical line of the second molar (blue lines)

Figure 4

Different shapes of the mandibular canal in CBCT

Figure 5

Different position of the mandibular canal to the root of the lower third molar

Figure 6

Contact of the mandibular canal and root(s) of the lower third molar

Figure 7

a: Buccal-based flap

b: Lingual-based flap

Figure 8

a: Modified triangular flap

b: Envelope flap

Review

Comprehensive review of lower third molar management: a guide for improved informed consent

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Running title:

Lower third molar management

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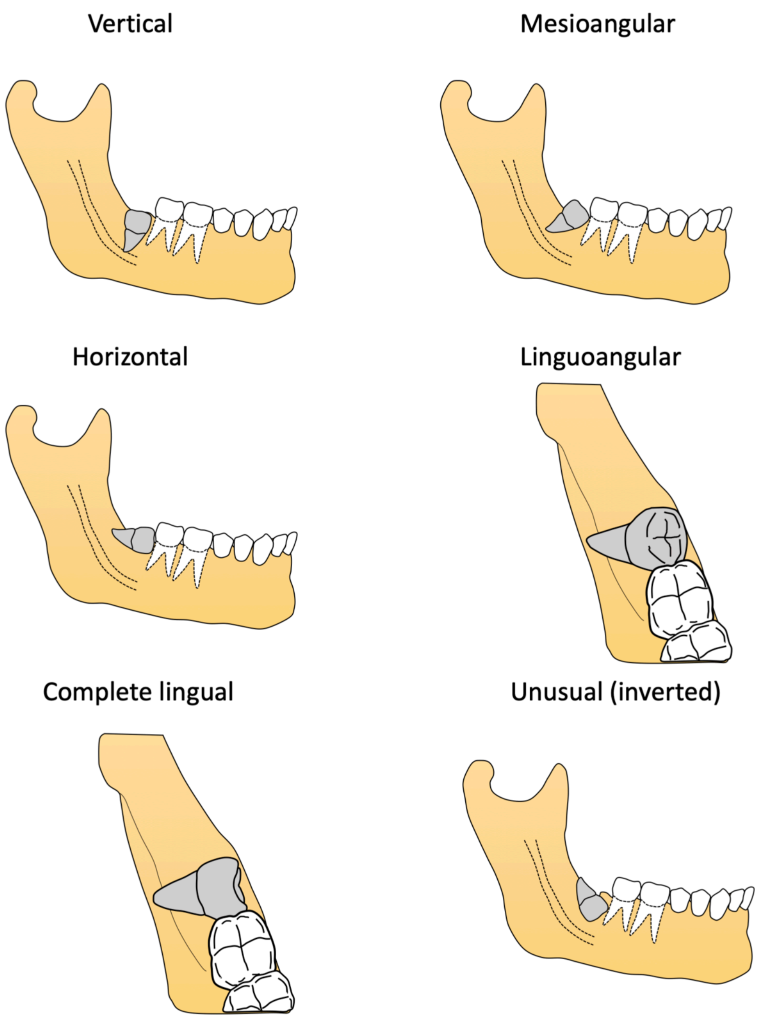
The authors have nothing to disclose.



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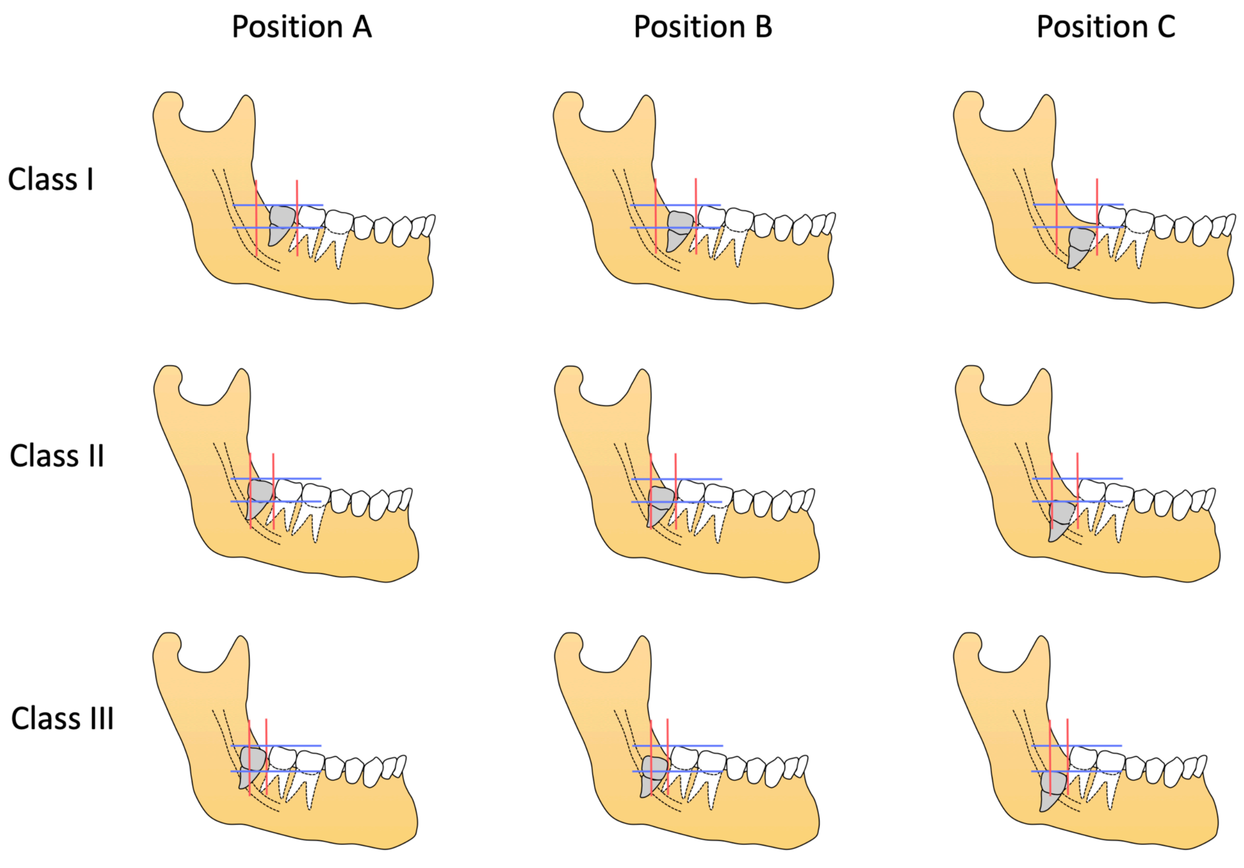

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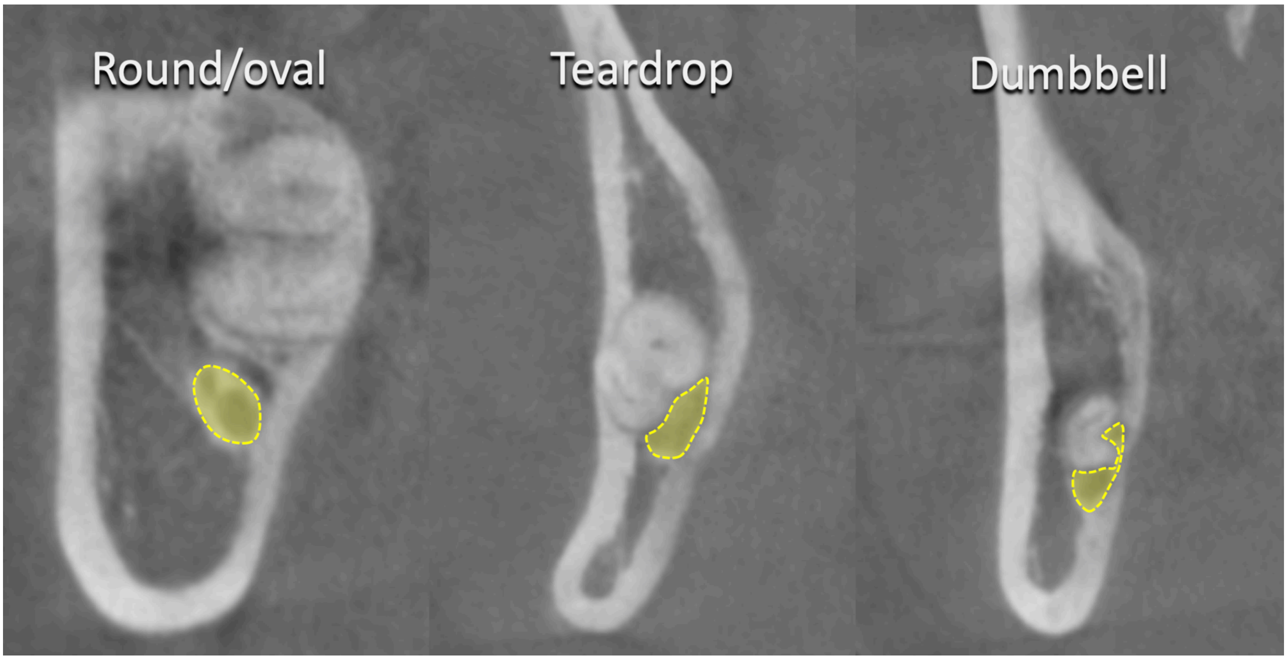

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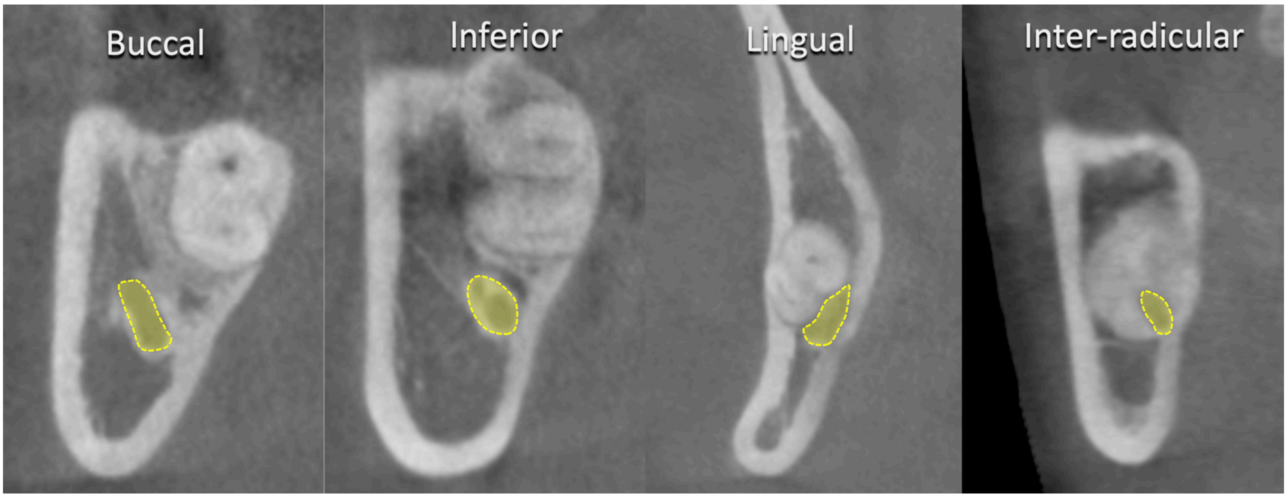

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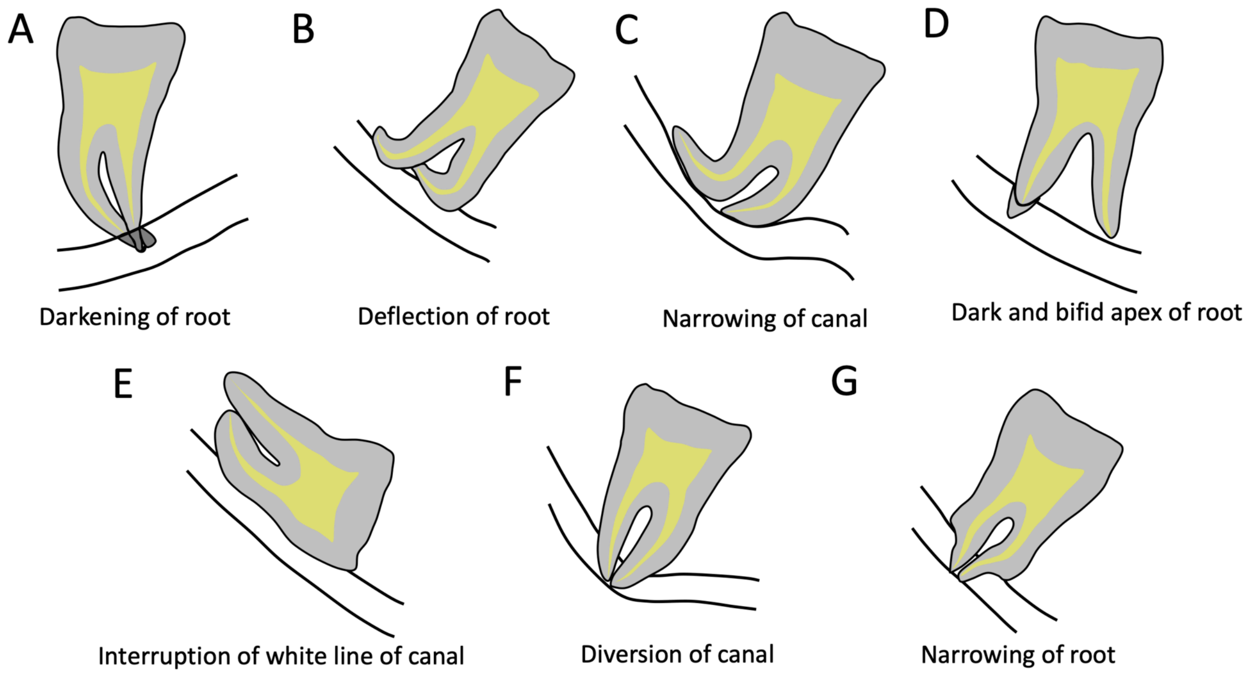

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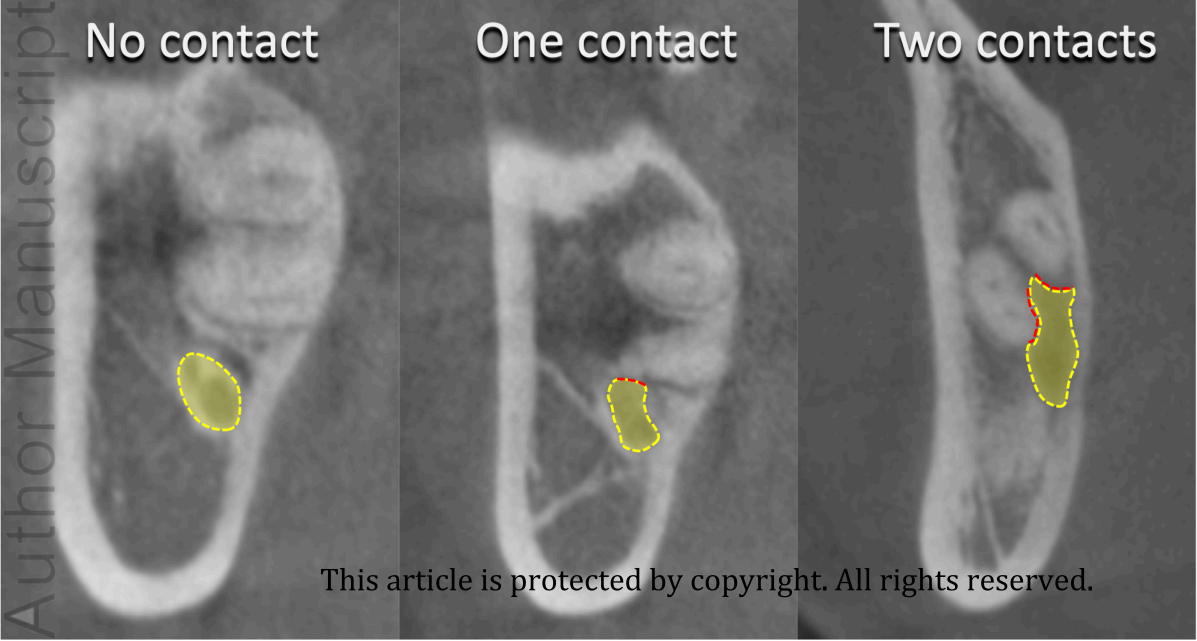
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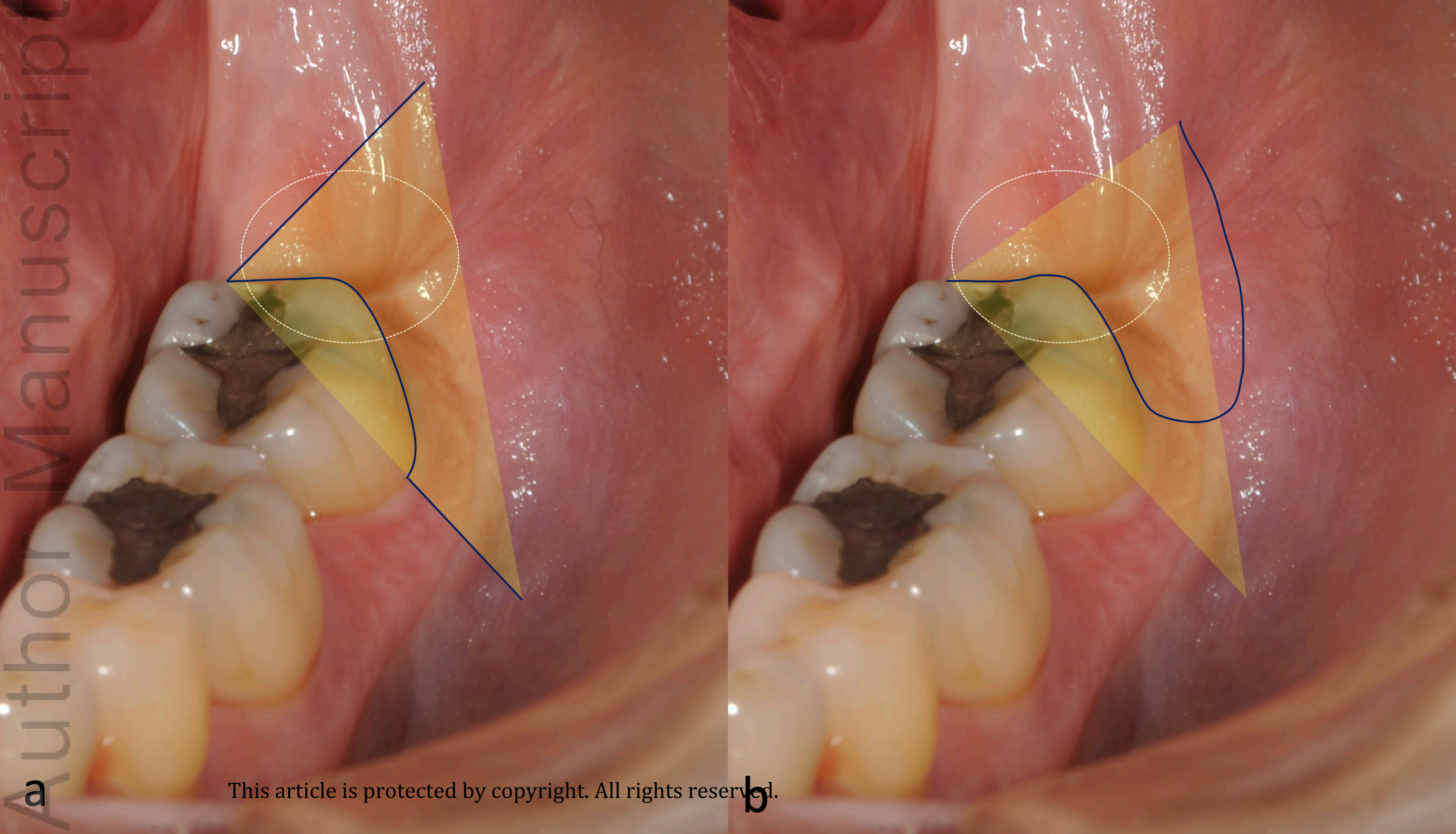
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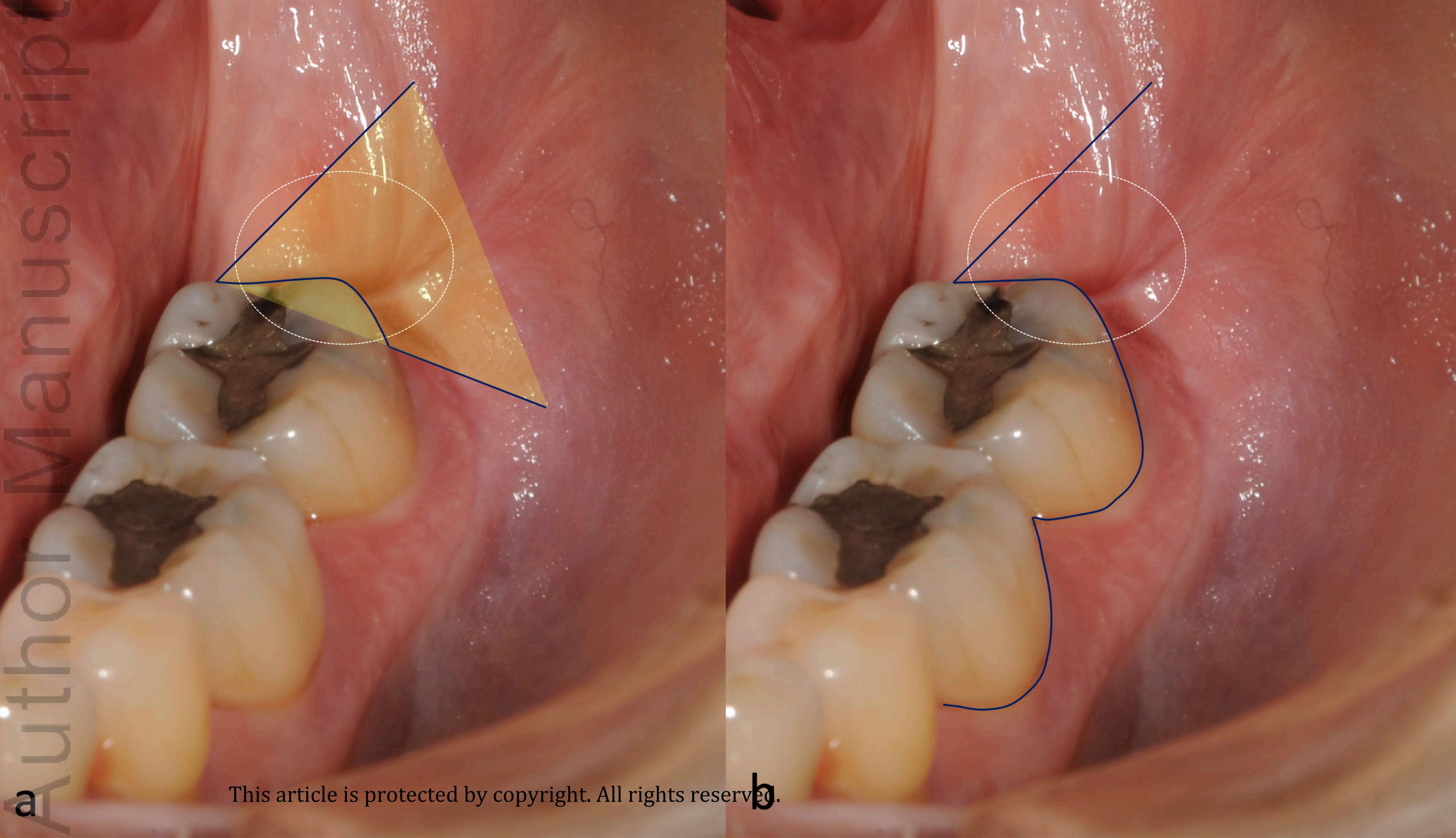
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Table 1

This decision table is based on existing guidelines and gives indications and non-indications for M3 extraction: M3 removal depending on its being symptomatic or asymptomatic, and pathological or not (after French good practice guidelines regarding third molar removal: Indications, techniques, methods, 2020).

	Indications for M3 extraction	
	Pathological M3	Non-pathological M3
Symptomatic M3	M3 symptomatic caries with no long-term restoration prognosis Non-treatable symptomatic pulp/periapical pathology (granuloma, cyst) M3-related cellulitis, abscess, osteomyelitis M3-related periodontopathy M3 symptomatic fracture	Recurrent or conservative treatment – resistant pericoronitis Internal/external resorption of adjacent tooth M3 altering dynamic occlusion
Asymptomatic M3	M3 asymptomatic caries with no long-term restoration prognosis Non-treatable asymptomatic pulp/periapical pathology (granuloma, cyst) M3 asymptomatic fracture M3 associated with a cyst or malignant tumor M3 associated with a possibly malignant pathology M3 positioned in line of bony fracture (reduction and optimisation of osteosynthesis)	Anticipation of difficulties or potential complications associated with M3 root development and likely proximity with alveolar nerve Health condition: incoming radiotherapy, potential diabetes, heart condition and/or immunosuppressant-related infection area M3 positioned in surgical field and/or jaw reconstruction Transplanted M3 Placement of an implant near a non-erupted M3 Assessment of specific, inappropriate life condition in order to prevent M3-related troubles [pregnancy, physical/emotional stress, (air) travel, sports activity, military deployment, etc.] Prevention of resorption of adjacent tooth crown or root

Non-functional M3 (no antagonist, with risk of elongation)

Optimisation/planning of a prosthesis: likeliness of secondary eruption or impacted tooth in a tissue-borne prosthesis area

Evaluation of orthognathic surgery in case of surgical difficulty (M3 an obstacle to osteotomy)

Orthodontic need if an easier distal displacement 2nd molar

Table 2

Radiographic signs of the intimate relationship between the mandibular third molar root and inferior alveolar nerve canal (Rood, 1990).

Radiographic signs	Description
Darkening of the mandibular third molar root	Radiolucency of the mandibular third molar root area, where mandibular third molar root and mandibular canal are superimposed
Deflection of the root	Dilacerations root morphology of mandibular third molar, where mandibular canal is contact or superimposed to it
Narrowing of the mandibular canal	Narrowing of the mandibular canal dimension where the canal and mandibular third molar root are contact or superimposed
Dark and bifid apex	Bifid and darkening of the mandibular third molar root, where mandibular canal is superimposed to it
Interruption of the radiopaque line	Absence of continuity of mandibular canal cortex
Diversion of the mandibular canal	Obviously, direction change of the mandibular canal in passage of the mandibular third molar root
Narrowing of the root	Narrowing of the mandibular third molar root, where the mandibular canal and mandibular third molar root are contact or superimposed

Table 3

Winter classification for impacted lower third molar teeth (Winter, 1926)

Impaction type	Definition
Vertical impaction	Long axis of the third molar is parallel to the long axis of the second molar
Mesioangular impaction	Impacted tooth is tilted toward the second molar in a mesial direction
Distoangular impaction	Long axis of the third molar is angled distally or posteriorly away from the second molar
Horizontal impaction	Long axis of the third molar is horizontal
Linguoangular impaction	Combined with the previous factors, the tooth can be lingually (tilted toward the tongue) impacted
Buccoangular impaction	Combined with the previous factors, the tooth can be buccally (tilted toward the cheek) impacted
Complete lingual impaction	The tooth is, in effect, horizontally impacted but in a cheek-tongue direction
Unusual (inverted) impaction	The tooth is reversed and positioned upside down

Table 4. Pell and Gregory classification for impacted third molar teeth (*Pell and Gregory, 1926*)

Variable	Description
Available space	
Class Ⅰ	Sufficient space between the anterior border of the ascending ramus and the distal aspect of the second molar for eruption of the third molar
Class Ⅱ	The space available between the anterior border of the ramus and distal aspect of the second molar is less than the mesiodistal diameter of the third molar
Class Ⅲ	The third molar is totally embedded in the bone of the anterior border of the ascending ramus because of the absolute lack of space
Depth	
Position A	Highest portion of the impacted third molar is level with or above the occlusal plane
Position B	Highest portion of the impacted third molar is below the occlusal plane but above the cervical line of the second molar
Position C	Highest portion of the impacted third molar is below the cervical line of the second molar