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REVIEW

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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 article 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
complications, iatrogenic, nerve injury, oral surgery, tooth extraction, wisdom tooth

1 | INTRODUCTION

Removal of the lower third molar is the most common dental surgical procedure (Kunkel, Morbach, Kleis, & Wagner, 2006; Shepherd & Brickley, 1994). 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 (Guerrero, Botetano, Beltran, Horner, & Jacobs, 2014; Iwanaga, Anand, et al., 2020; Iwanaga, Katafuchi, et al., 2020; Iwanaga, Shiromoto, et al., 2020; Kawai, Asaumi, Sato, Kumazawa, & Yosue, 2011; Naitoh, Hiraiwa, Aimiya, & Ariji, 2009; Ngeow & 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 article, published reports are reviewed to provide such a guide for dentists involved with the management of lower third molar removal.

2 | GENERAL INFORMATION

2.1 | Epidemiology and pathology

2.1.1 | Pericoronitis and caries

The prevalence of third molar impaction is estimated to be 24% worldwide (Carter & Worthington, 2016; Vandeplas, Vranckx, Hekner, Politis, & Jacobs, 2020). A number of studies suggests that third molar impaction rates increase up to approximately 30 years of age (Venta, 2012; Yamaoka, Furusawa, & Yamamoto, 1995). Most clinicians view the lower third molar teeth as “ticking time bombs” that can eventually become impacted if they are not removed (Carter & 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 (Fisher, Moss, Offenbacher, Beck, & White Jr., 2010; Garaas et al., 2012; Shugars et al., 2004; Venta, Kylatie, & Hiltunen, 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, Devlin, Tickle, & O'Malley, 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 & 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), 2,064 out of 6,793 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 2,064 subjects were free of caries and periodontal pathology.

2.1.2 | 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, de Almeida, Lima-Rivera, 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.

2.2 | Guidelines

2.2.1 | Indications and contraindication for surgical removal

Indications and nonindications 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 (De Bruyn, Vranckx, Jacobs, & Politis, 2020; Diz, Scully, & Sanz, 2013). Also, systemic conditions in the patient's medical history could be related to an increased risk of surgical complications (Bui, Seldin, & Dodson, 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 & Eyssen, 2012). However, there has been no consensus on how to manage an asymptomatic lower molar tooth (Scottish Intercollegiate Guidelines Network, 2000).

TABLE 1 This decision table is based on existing guidelines and gives indications and nonindications 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	**Nonpathological M3**
Symptomatic M3	M3 symptomatic caries with no long-term restoration prognosis Nontreatable 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 Nontreatable 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 optimization 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 nonerupted 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 Nonfunctional 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 second molar

3 | DIAGNOSIS AND TREATMENT PLANNING

3.1 | Panoramic sign and classification system

3.1.1 | 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) (Huang, Lui, & Cheng, 2015; Rood & Shehab, 1990) (Figure 1 and Table 2).

3.1.2 | 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 (Figure 2 and Table 3).

3.1.3 | 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

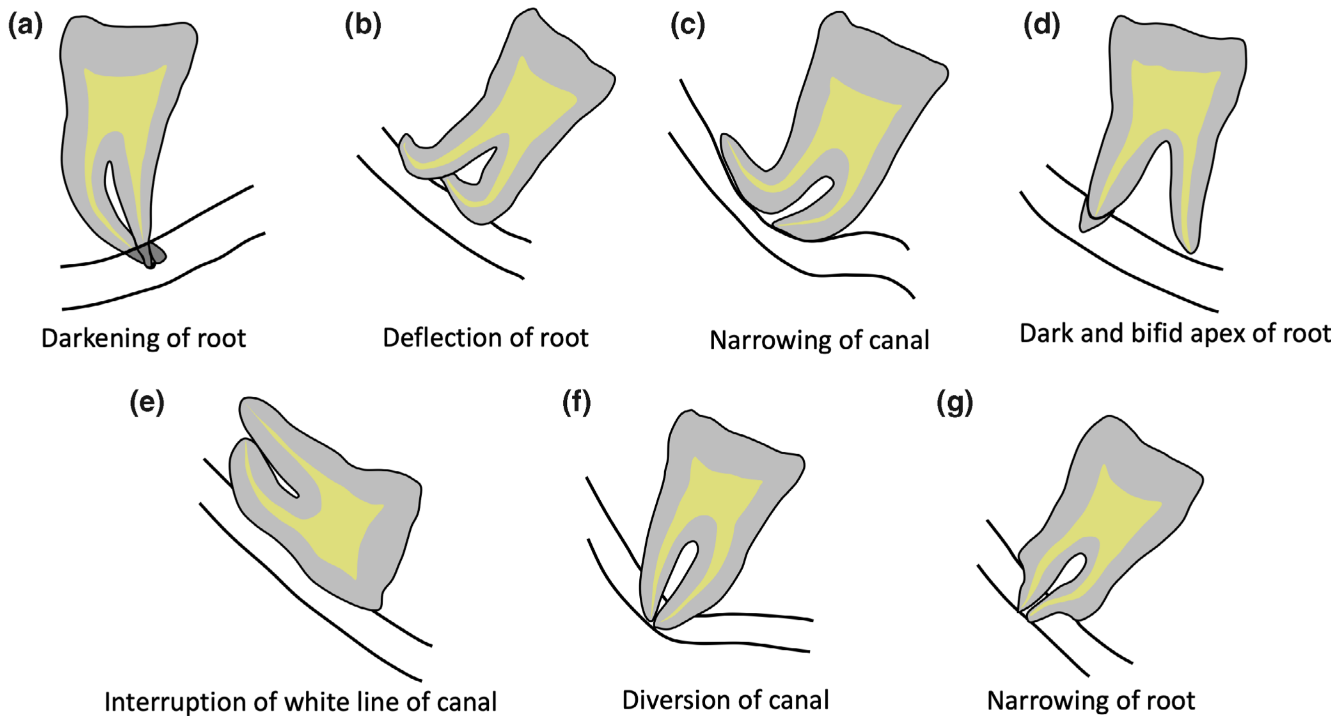

FIGURE 1 The relationship of the lower third molar to the mandibular canal in a panoramic radiograph [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 2 Radiographic signs of the intimate relationship between the mandibular third molar root and inferior alveolar nerve canal (Rood & Shehab, 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

depth of the impacted third molar tooth in the bone in relation to the occlusal plane (Figure 3 and Table 4).

3.2 | CBCT findings

3.2.1 | 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 10 to 1,200 μSv, 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 to 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 (2.4 mSv) (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; Ghaeminia et al., 2015; Kursun, Hakan, Bengi, & Nihat, 2015; Roeder, Wachtlin, & Schulze, 2012; Yabroudi & Sindet-Pedersen, 2012).

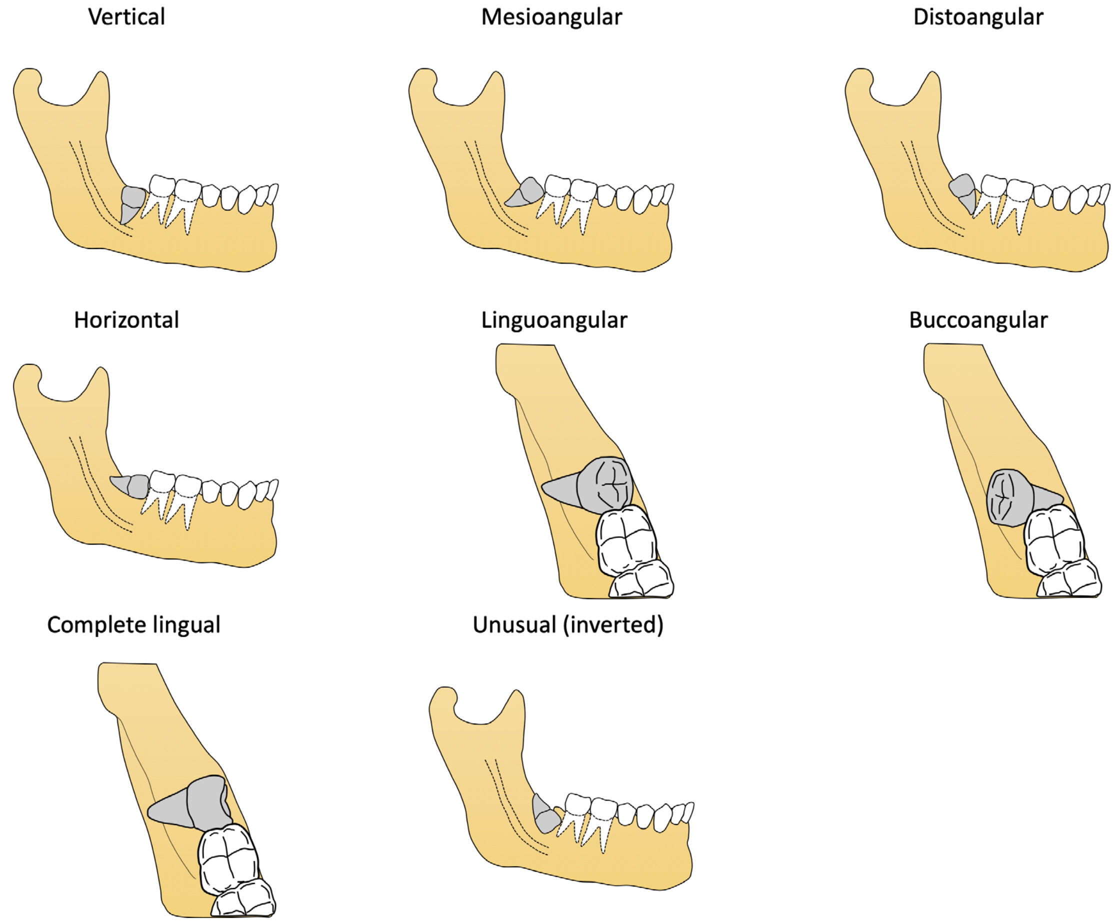

FIGURE 2 Winter's classification based on the angulation of the lower third molar [Color figure can be viewed at wileyonlinelibrary.com]

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

3.2.2 | Positional relationship of MC 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 (Kubota, Imai, Nakazawa, & Uzawa, 2020; Ueda et al., 2012; Wang et al., 2018). Some of these are associated with IAN injury (Figures 4–6). According to Shujaat, Abouelkheir, Al-Khalifa, Al-Jandan, and Marei (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, Khaghaninejad, Hasanshahi, Forghani, & Ahrari, 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 (Chen, Liu, Pei, Liu, & Pan, 2018; Maglione, Costantinides, & Bazzocchi, 2015; Quirino de Almeida Barros, Bezerra

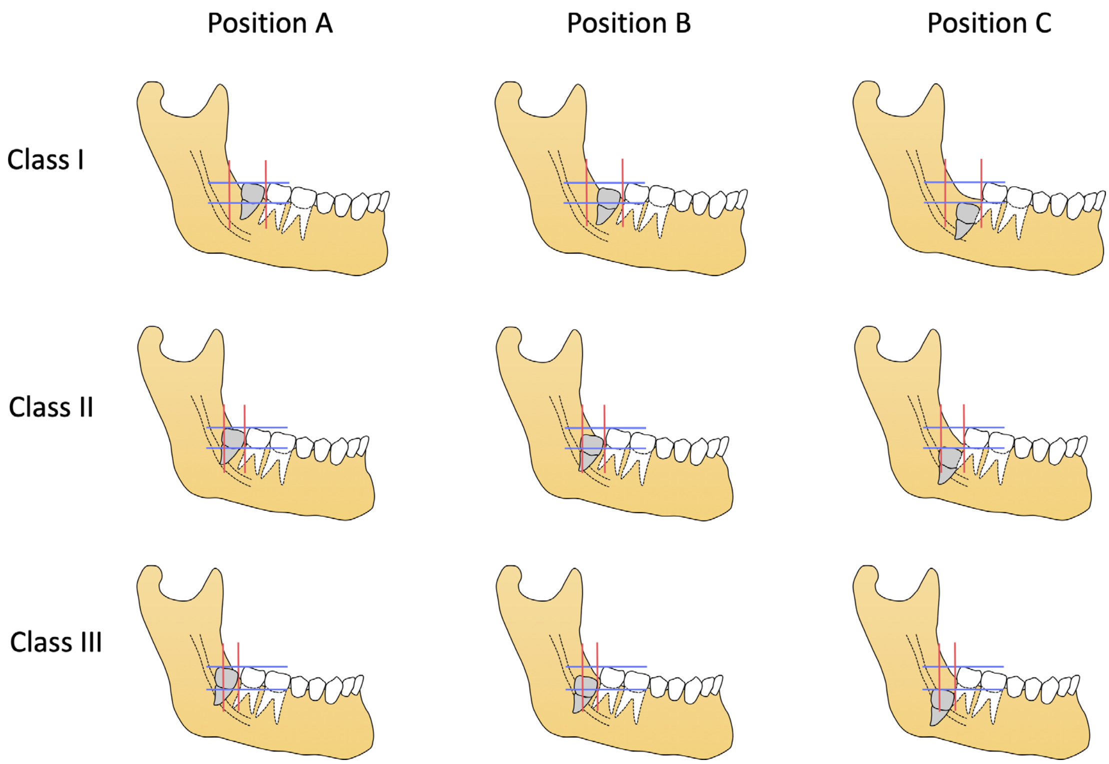

FIGURE 3 Pell and Gregory classification. Class defines the mesiodistal position of the impacted third molar, depending on the space between the anterior border of the ramus and the distal border of the second molar (shown in red lines). Position defines the vertical position of the impacted third molar, depending on the occlusal plane and cervical line of the second molar (blue lines) [Color figure can be viewed at wileyonlinelibrary.com]

TABLE 4 Pell and Gregory classification for impacted third molar teeth (Pell & Gregory, 1993)

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

de Melo, de Macedo Bernardino, Area Leao Lopes Araujo Arruda, & Meira Bento, 2018). Yabroudi and Sindet-Pedersen (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.

3.3 | Comparison of panoramic radiograph and CBCT

3.3.1 | 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, AlHadidi, AbuKaraky, & Khader, 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, Zheng, Yang, & Qian, 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

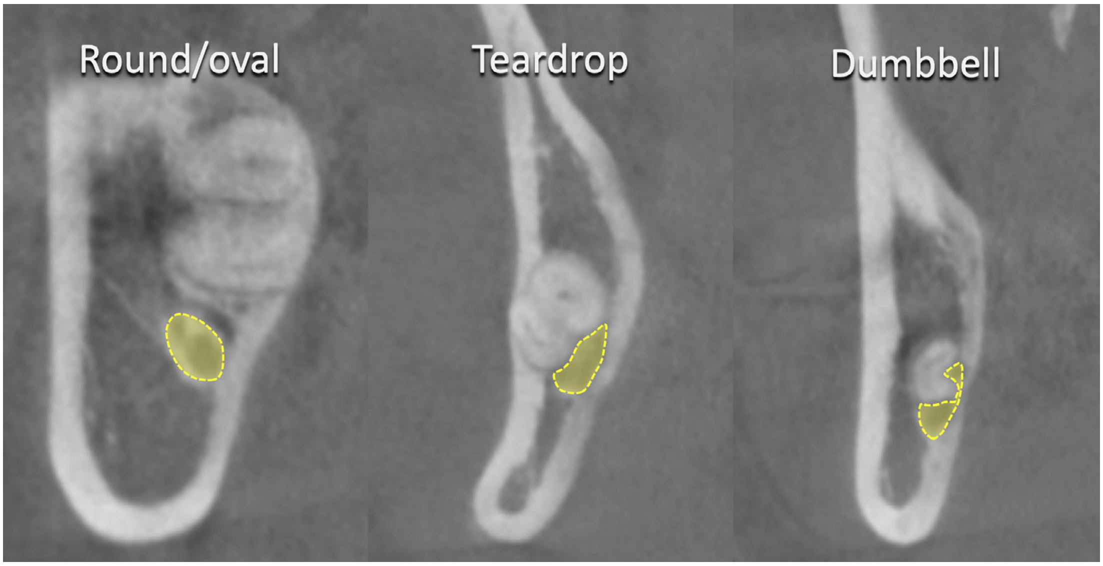

FIGURE 4 Different shapes of the mandibular canal in cone beam computed tomography [Color figure can be viewed at wileyonlinelibrary.com]

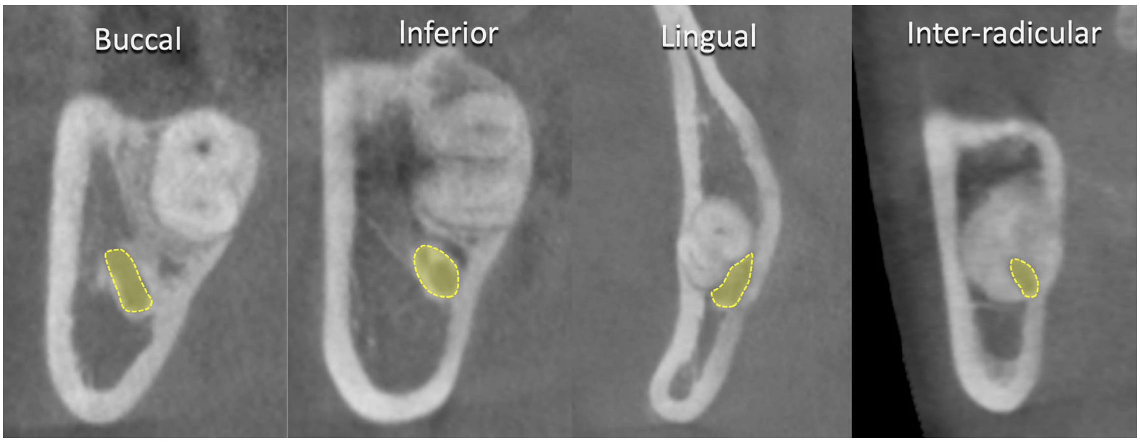

FIGURE 5 Different position of the mandibular canal to the root of the lower third molar [Color figure can be viewed at wileyonlinelibrary.com]

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).

3.3.2 | 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, for example, coronectomy (Aravindaksha et al., 2015; Manor, Abir, Manor, & Kaffe, 2017; Matzen, Christensen, Hintze, Schou, & Wenzel, 2013). 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-Araujo et al. (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.

3.3.3 | 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.

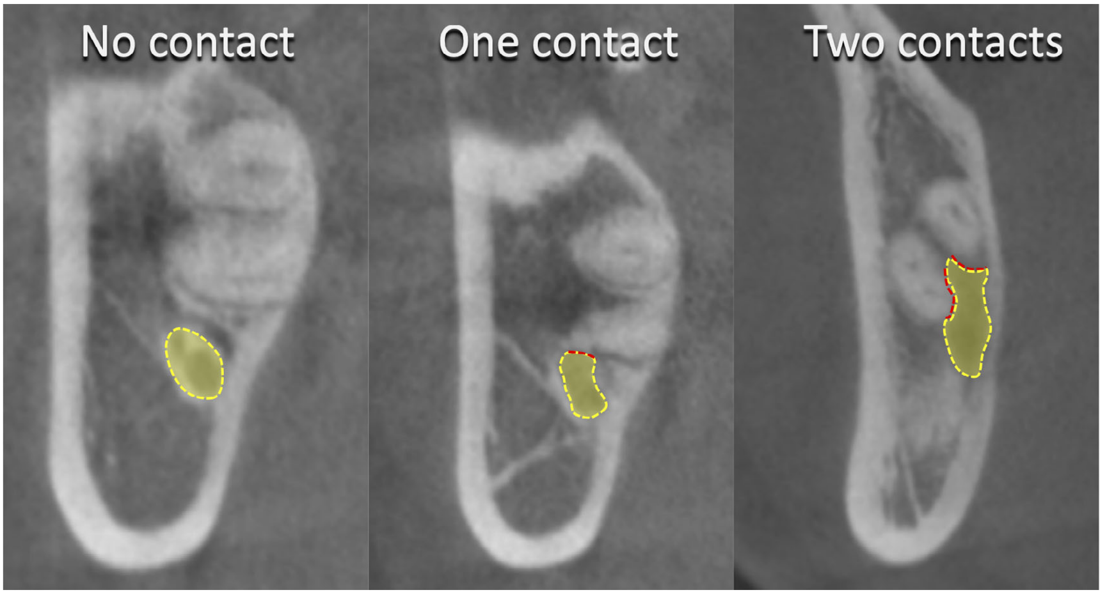

FIGURE 6 Contact of the mandibular canal and root(s) of the lower third molar [Color figure can be viewed at wileyonlinelibrary.com]

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.

3.4 | Other considerations

3.4.1 | Use of ultrasonic electric devices

A meta-analysis assessed the effect of piezosurgery (Badenoch-Jones, David, & Lincoln, 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.

3.4.2 | 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).

3.4.3 | 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.

3.4.4 | Time off

We found only one study that investigated sick leave associated with third molar removal. According to Lopes, Mumenya, Feinmann, and Harris (1995), 81% of patients took time off of work after this surgery. The time off of work ranged from 0 to 10 days with a mean of 3 days.

4 | COMPLICATIONS

4.1 | Inferior alveolar nerve injury

4.1.1 | 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 3rd., 1986). In general, there is a high likelihood of regeneration over time; most injuries healed after 3–4 months (Kjølle & Bjørnland, 2013). Postoperative neurosensory impairments such as numbness or paresthesia were considered temporary if they subsided within 6 months. If the symptoms remained unresolved for longer than 6 months, the injury was considered permanent (Gulicher & Gerlach, 2001; Jain et al., 2016; Korkmaz, Kayipmaz, Senel, Atasoy, & Gumrukcu, 2017; Kubota et al., 2020; Wang et al., 2018). Recovery after 9 months postoperatively is extremely rare, and it is unlikely that any recovery will occur after 18–24 months of follow-up (Robinson, 1988).

4.1.2 | Incidence

The reported incidence of IAN injury ranged from 0.35 to 19% when the tooth roots were very close to the IAN (Carmichael & McGowan, 1992; Cheung et al., 2010; Guerrero et al., 2014; Hasegawa et al., 2013; Haug, Perrott, Gonzalez, & Talwar, 2005; Kjølle & Bjørnland, 2013; Lopes et al., 1995; Martin, Perinetti, Costantinides, & Maglione, 2015; Smith, 2013). A recent larger study reported that among 4,338 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 6 months; however, in fewer than 1% of cases, the injury persists for longer and often becomes permanent (Eshghpour, Shaban, Ahrari, Erfanian, & Shadkam, 2017; Gulicher & Gerlach, 2001; Jerjes et al., 2010; Momin et al., 2013; Smith et al., 1997).

4.1.3 | IAN injury and sex

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

4.1.4 | IAN injury and age

Many studies agreed that patients with IAN injury are significantly older than those without injury (Blondeau & Daniel, 2007; Bruce, Frederickson, & Small, 1980; Kim et al., 2012; Korkmaz et al., 2017; Valmaseda-Castellón et al., 2001). 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, Tomihara, & Noguchi, 2014; Nguyen, Grubor, & Chandu, 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 & Bjørnland, 2013), although some studies found no association between IAN injury and the patient's age (Kipp, Goldstein, & Weiss Jr., 1980).

4.1.5 | 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, that is, diversion of the MC, interruption of the white line, and darkening of the root (Atieh, 2010; Rood & Shehab, 1990; Wenzel, 2010). Position C was a nonsignificant variable (Kubota et al., 2020; Wang et al., 2018). The IAN is more vulnerable to injury when it courses on the lingual side (Kim & 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).

4.1.6 | IAN injury and intraoperative nerve exposure/hemorrhage

According to Jhamb, Dolas, Pandilwar, and Mohanty (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.

4.1.7 | 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.

4.2 | Lingual nerve injury

4.2.1 | 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, Choi, et al., 2018; Iwanaga, Nakamura, et al., 2018; Kikuta, Iwanaga, Kusukawa, & Tubbs, 2019). The course of the LN in the retromolar area is medial to the lingual plate, with a distance of 2 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 (Behnia et al., 2000; Kiesselbach & Chamberlain, 1984). 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, one anatomical study showed that the LN course could change due to tongue movement (Iwanaga, 2017), 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, Cleveland, Wada, & Tubbs, 2020; Iwanaga, Nakamura, et al., 2018). 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.

4.2.2 | LN injury and incidence

Permanent alterations of the lingual nerve (LN) were more discernible by patients (Kjølle & Bjørnland, 2013). The risk of LN injury associated with the lower third molar ranges from 0.5 to 6.6% (Tolstunov, Brickeen, Kamanin, Susarla, & Selvi, 2016). A recent larger study reported that of the 4,338 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 5 years (Alling 3rd., 1986; Kjølle & Bjørnland, 2013), though other studies have failed to support this (Carmichael & McGowan, 1992).

4.2.3 | LN injury and anesthesia

Both retrospective (Blackburn & Bramley, 1989) and prospective (Brann, Brickley, & Shepherd, 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.

4.2.4 | 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 (Carmichael & McGowan, 1992; Mason, 1988). Vertical impactions had a significantly lower incidence, whereas those classified as horizontal or "other" impactions had a significantly higher incidence of LN injury (Carmichael & 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 for example, 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, Berini-Aytes, & Gay-Escoda, 2000).

4.2.5 | 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 & 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 & 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).

4.3 | Other complications

4.3.1 | Bleeding

In adults, the incidence of persistent bleeding during lower third molar tooth surgery ranged from 0.6 to 5.8% (Bruce 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, De Cicco, & Marrone, 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 (Iwanaga, Shiromoto, & Tubbs, 2020; Kikuta et al., 2018; Standring, 2015).

4.3.2 | 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, You, Ma, Wang, and Zhao (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, that is, 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).

4.3.3 | Flap design and pain, swelling, and trismus

Menziletoglu, Guler, Basturk, Isik, and Erdur (2019) compared postoperative morbidity between two flap designs: the buccal-based triangular flap and the lingual-based triangular flap (Figure 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 Kaya, Yapici Yavuz, and Saruhan (2019) compared the modified triangular flap and envelope flap (Jakse, Bankaoglu, Wimmer, Eskici, & Pertl, 2002; Szmyd, 1971) (Figure 8). In agreement with previous studies, Şimşek et al. found the modified triangular flap led to lower pain levels than the envelope flap design (Rabi et al., 2017; Sandhu, Sandhu, & Kaur, 2010). A meta-analysis by Zhu et al. (2020) 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, Liston, Tong, & Love, 2007; Briguglio et al., 2011; Erdogan, Tatli, Ustun, & Damlar, 2011; Baqain, Al-Shafii, Hamdan, & Sawair, 2012; Koyuncu & Cetingul, 2013; Coulthard et al., 2014; Tareen, Hamad, Saleem, & Ahmad, 2015; Alqahtani, Khaleelahmed, & Desai, 2017; Korkmaz et al., 2017; Zhu et al., 2019).

4.3.4 | 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 & Kay, 1975). Secondary closure is believed to allow drainage as the socket still remains in communication with the oral cavity (Cerqueira, Vasconcelos, & Bessa-Nogueira, 2004; Pasqualini, Cocero, Castella, Mela, & Bracco, 2005). Whether primary or secondary wound closure results in better outcomes has been controversial. A systematic review of randomized control trials by Carrasco-Labra, Brignardello-Petersen, Yanine, Araya, and Guyatt (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.

4.3.5 | 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 (Alling & Alling, 1993; Libersa, Roze, Cachart, & Libersa, 2002; Nyul, 1959; Perry & Goldberg, 2000; Wagner, Otten, Schoen, & Schmelzeisen, 2005; Wagner, Schoen, Wongchuensoontorn, &

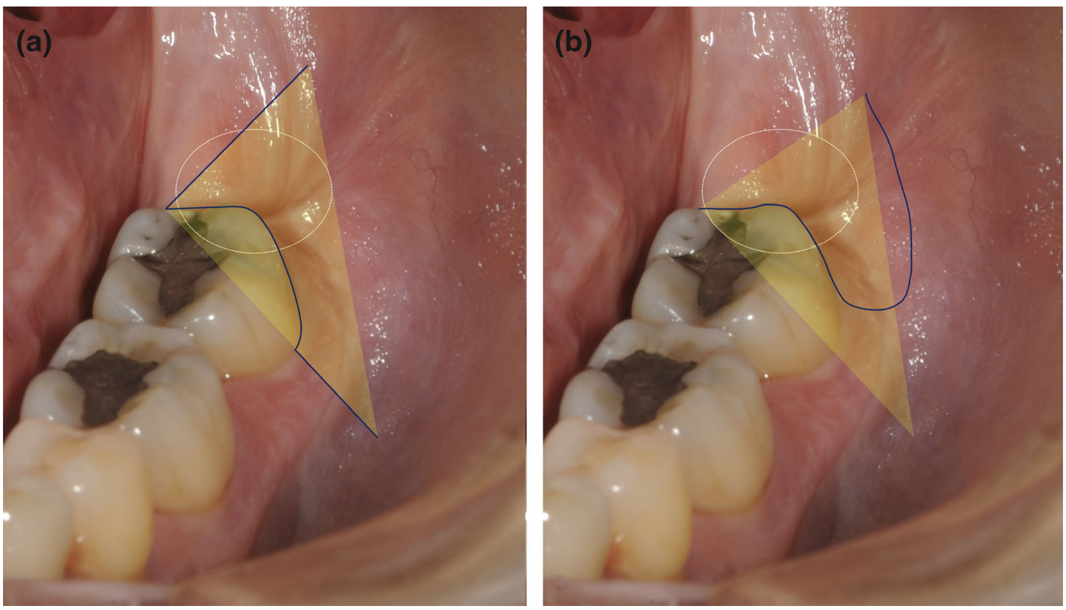

FIGURE 7 (a) Buccal-based flap. (b) Lingual-based flap [Color figure can be viewed at wileyonlinelibrary.com]

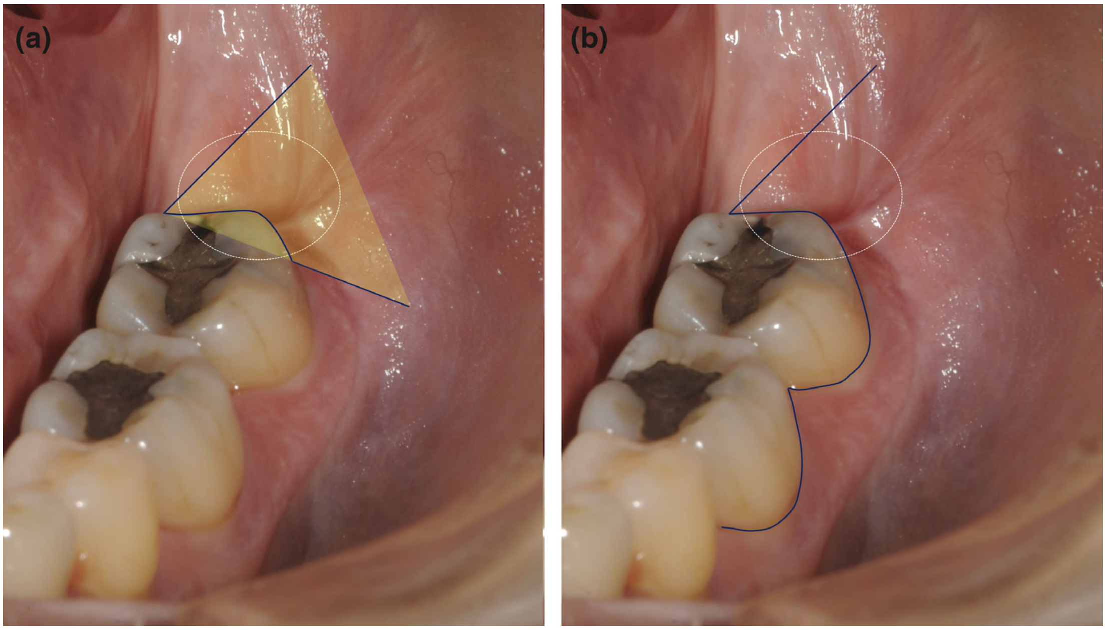

FIGURE 8 (a) Modified triangular flap. (b) Envelope flap [Color figure can be viewed at wileyonlinelibrary.com]

Schmelzeisen, 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, Goel, & Thorat, 2016). More than 75% of postoperative fractures occurred 2 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).

4.3.6 | 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, Pierce, Klar, and Sherman (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 (Almeida et al., 2016; Xu et al., 2015).

4.3.7 | Antibiotics and postoperative infection

Use of amoxicillin either pre- or postoperatively did not reduce the risk of infection in healthy patients who had third molar extractions (Isiordia-Espinoza, Aragon-Martinez, Martinez-Morales, & Zapata-Morales, 2015). A systematic review of eight articles by Menon, Gopinath, Li, Leung, and Botelho (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, Santamaria, Santamaria, Barbier, and Arteagoitia (2016) reviewed 3,304 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 and Malmstrom (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 (Arteagoitia, Barbier, Santamaria, Santamaria, & Ramos, 2016; Isiordia-Espinoza et al., 2015).

4.3.8 | Anti-inflammatory drugs and postoperative pain

Bailey et al. (2013) enrolled a total of 2,241 participants to compare the effects of ibuprofen and paracetamol (acetaminophen) for postoperative pain relief. Most studies indicated that 400 mg of ibuprofen was superior to 1,000 mg of acetaminophen, those being the most frequently prescribed doses in clinical practice.

4.3.9 | 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, Lemos, de Moraes, Pellizzer, & Vasconcelos, 2019).

4.3.10 | 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, Lee, Ho, and Cheung (2013); Leung, McGrath, and Cheung (2013) 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 & 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, Karaca, Peker, & Ogutlu, 2018). However, de Toledo Telles-Araujo 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.

5 | OTHER TREATMENT OPTIONS

5.1 | 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.

5.1.1 | Benefit of germectomy

In general, the roots of the lower third molar are not fully formed until 21 years (Bagheri & Khan, 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-Avendano, Perez-Garcia, Valmaseda-Castellon, Berini-Aytes, & Gay-Escoda, 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).

5.1.2 | Germectomy and postoperative complications

Some authors have found no differences in pain, swelling or mouth opening difficulties related to patient age (Fisher, Frame, Rout, & McEntegart, 1988). 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-Salvadó, Berini Aytés, & Gay, 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-Avendano et al., 2005). Chaparro-Avendano 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, Crescentini, and Romanoni (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 (Bjornland, Haanaes, Lind, & Zachrisson, 1987; Chiapasco et al., 1995; Zhang & 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 nonexistent 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; Capuzzi, Montebugnoli, & Vaccaro, 1994; Chaparro-Avendano et al., 2005; Sisk, Hammer, Shelton, & Joy Jr., 1986; Valmaseda-Castellón et al., 2001). The incidence of LN injury ranges from 0 to 10% (Blackburn & Bramley, 1989; Chaparro-Avendano et al., 2005; Sisk et al., 1986; Valmaseda-Castellón et al., 2000). Overall, the risk of serious complications such as IAN or LN injury seems to be lower with germectomy at younger ages.

5.1.3 | 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-Avendano et al. (2005), with a 1.8% rate of secondary infections that recovered after 7–15 days.

5.1.4 | 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-Avendano 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-Avendano 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-Avendano 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.

5.2 | Coronectomy

Coronectomy was first introduced in France by Ecuyer and Debien (1984) and in the English literature by Knutsson, Lysell, and Rohlin (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, Kurita, Kuroiwa, Yuasa, & Ariji, 2009; Pitros, Jackson, & O'Connor, 2019).

5.2.1 | 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, Perez-Martinez, Cervera-Ballester, Penarrocha-Oltra, & Penarrocha-Diago, 2016; Kang, Sah, & Fei, 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 (Cervera-Espert et al., 2016; Dolanmaz, Yildirim, Isik, Kucuk, & Ozturk, 2009; Hatano et al., 2009; Leung & Cheung, 2009; Martin et al., 2015; O'Riordan, 2004). The incidence of IAN injury with coronectomy is in the range 0–4.3% (Hatano et al., 2009;Leung & Cheung, 2012; Pitros et al., 2019). However, some studies state that the entire teeth were removed if the roots were mobile (Leung & 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).

5.2.2 | 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% (6/2,119) of the patients experienced the LN injury (Hatano et al., 2009; Leung & Cheung, 2012; Omran et al., 2020).

5.2.3 | 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 postcoronectomy complications (Pitros et al., 2019). Dry socket associated with the coronectomy has been reported at 0.86–14.6% (Frenkel, Givol, & Shoshani, 2015; Kohara, Kurita, Kuroiwa, Goto, & Umemura, 2015; Monaco, de Santis, Gatto, Corinaldesi, & Marchetti, 2012; Pitros et al., 2019). Thus, coronectomy could reduce the incidence of dry socket (Cervera-Espert et al., 2016; Martin et al., 2015).

5.2.4 | 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.

5.2.5 | 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 7 years follow-up, which is supported by previous studies indicating 0.6–1.8% root eruption (Frenkel et al., 2015; Kohara et al., 2015; Patel et al., 2014). 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 3 months after coronectomy (with average distances of 1.90 and 1.60 mm, respectively).

Frenkel et al. (2015) reported significantly greater migration in younger patients. At 6-months follow-up, the migration group had a lower mean age than the nonmigration group (24.5 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 nonmigration group) (Frenkel et al., 2015). Pogrel, Lee, and Muff (2004) compared the radiographs at the time of surgery and 6 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 2 years after coronectomy, with average distances of 4.0 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 2 years (average 1.84 mm in 3 months, 2.88 mm in 1 year, and 3.41 mm and 3.51 mm after 2 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; Shokouhi et al., 2019).

6 | CONCLUSIONS

We have analyzed systematic reviews, randomized clinical trials, and related articles in this article. 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.

DISCLOSURE OF INTERESTS

The authors have nothing to disclose.

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REFERENCES

Agency for Quality in Dentistry (2006). Surgical removal of third molars. In *Guideline*. Berlin, Germany: ZZQ Retrieved from http://www3.kzbv.de/zzqpubl.nsf/7549c7b9ec54d2dfc1257018002ad508/5f184e5d59df47ebc125714d004890fa/$FILE/Leitlinie_Weish_EN.pdf

Al Ali, S., & Jaber, M. (2020). Correlation of panoramic high-risk markers with the cone beam CT findings in the preoperative assessment of the mandibular third molars. *Journal of Dental Sciences*, *15*, 75–83.

Alling, C. C., 3rd. (1986). Dysesthesia of the lingual and inferior alveolar nerves following third molar surgery. *Journal of Oral and Maxillofacial Surgery*, *44*, 454–457.

Alling, C. C., & Alling, R. D. (1993). Indications for management of impacted teeth. In C. C. Alling, J. F. Helfrick, & R. D. Alling (Eds.), *Impacted teeth*. Philadelphia, PA: WB Saunders.

Almeida, L. E., Pierce, S., Klar, K., & Sherman, K. (2016). Effects of oral contraceptives on the prevalence of alveolar osteitis after mandibular third molar surgery: A retrospective study. *International Journal of Oral and Maxillofacial Surgery*, *45*, 1299–1302.

Almeida, R. d. A. C., Lemos, C. A. A., de Moraes, S. L. D., Pellizzer, E. P., & Vasconcelos, B. C. (2019). Efficacy of corticosteroids versus placebo in impacted third molar surgery: Systematic review and meta-analysis of randomized controlled trials. *International Journal of Oral and Maxillofacial Surgery*, *48*, 118–131.

Alqahtani, N. A., Khaleelahmed, S., & Desai, F. (2017). Evaluation of two flap designs on the mandibular second molar after third molar extractions. *Journal of Oral and Maxillofacial Pathology*, *21*, 317–318.

American Association of Oral and Maxillofacial Surgeons. (2016). *Management of third molar teeth*. Rosemont, IL: AAOMS Retrieved from http://www.aaoms.org/docs/govt_affairs/advocacy_white_papers/management_third_molar_white_paper.pdf

Araujo, G. T. T., Peralta-Mamani, M., Silva, A., Rubira, C. M. F., Honorio, H. M., & Rubira-Bullen, I. R. F. (2019). Influence of cone beam computed tomography versus panoramic radiography on the surgical technique of third molar removal: A systematic review. *International Journal of Oral and Maxillofacial Surgery*, *48*, 1340–1347.

Aravindaksha, S. P., Balasundaram, A., Gauthier, B., Pervolarakis, T., Boss, H., Dhawan, A., & Wheater, M. (2015). Does the use of cone beam CT for the removal of wisdom teeth change the surgical approach compared with panoramic radiography? *Journal of Oral and Maxillofacial Surgery*, *73*, e12.

Archer, W. H. (1975). *Oral and maxillofacial surgery* (5th ed.). Philadelphia, PA: WB Saunders.

Arteagoitia, M. I., Barbier, L., Santamaria, J., Santamaria, G., & Ramos, E. (2016). Efficacy of amoxicillin and amoxicillin/clavulanic acid in the prevention of infection and dry socket after third molar extraction. A systematic review and meta-analysis. *Medicina Oral, Patología Oral y Cirugía Bucal*, *21*, e494–e504.

Atieh, M. A. (2010). Diagnostic accuracy of panoramic radiography in determining relationship between inferior alveolar nerve and mandibular third molar. *Journal of Oral and Maxillofacial Surgery*, *68*, 74–82.

Badenoch-Jones, E. K., David, M., & Lincoln, T. (2016). Piezoelectric compared with conventional rotary osteotomy for the prevention of postoperative sequelae and complications after surgical extraction of mandibular third molars: A systematic review and meta-analysis. *The British Journal of Oral & Maxillofacial Surgery*, *54*, 1066–1079.

Bagheri, S. C., & Khan, H. A. (2007). Extraction versus nonextraction management of third molars. *Oral and Maxillofacial Surgery Clinics of North America*, *19*, 15–21.

Bailey, E., Worthington, H. V., van Wijk, A., Yates, J. M., Coulthard, P., & Afzal, Z. (2013). Ibuprofen and/or paracetamol (acetaminophen) for pain relief after surgical removal of lower wisdom teeth. *Cochrane Database of Systematic Reviews*, *12*, CD004624.

Balamurugan, R., & Zachariah, T. (2020). Comparison of primary and secondary closure with a buccal mucosal-advancement flap on postoperative course after mandibular impacted third molar surgery. *Oral and Maxillofacial Surgery*, *24*, 37–43.

Baqain, Z. H., AlHadidi, A., AbuKaraky, A., & Khader, Y. (2020). Does the use of cone-beam computed tomography before mandibular third molar surgery impact treatment planning? *Journal of Oral and Maxillofacial Surgery*, *78*, 1071–1077.

Baqain, Z. H., Al-Shafii, A., Hamdan, A. A., & Sawair, F. A. (2012). Flap design and mandibular third molar surgery: A split mouth randomized clinical study. *International Journal of Oral and Maxillofacial Surgery*, *41*, 1020–1024.

Behnia H., Kheradvar A., & Shahrokhi M. (2000). An anatomic study of the lingual nerve in the third molar region. *Journal of Oral and Maxillofacial Surgery*, *58*(6), 649–651. http://dx.doi.org/10.1016/s0278-2391(00)90159-9.

Bjornland, T., Haanaes, H. R., Lind, P. O., & Zachrisson, B. (1987). Removal of third molar germs. Study of complications. *International Journal of Oral and Maxillofacial Surgery*, *16*, 385–390.

Blackburn, C. W., & Bramley, P. A. (1989). Lingual nerve damage associated with the removal of lower third molars. *British Dental Journal*, *167*, 103–107.

Blakey, G. H., Marciani, R. D., Haug, R. H., Phillips, C., Offenbacher, S., Pabla, T., & White, R. P., Jr. (2002). Periodontal pathology associated with asymptomatic third molars. *Journal of Oral and Maxillofacial Surgery*, *60*, 1227–1233.

Blondeau, F., & Daniel, N. G. (2007). Extraction of impacted mandibular third molars: Postoperative complications and their risk factors. *Journal of the Canadian Dental Association*, *73*, 325.

Brann, C. R., Brickley, M. R., & Shepherd, J. P. (1999). Factors influencing nerve damage during lower third molar surgery. *British Dental Journal*, *186*, 514–516.

Briguglio, F., Zenobio, E. G., Isola, G., Briguglio, R., Briguglio, E., Farronato, D., & Shibli, J. A. (2011). Complications in surgical removal of impacted mandibular third molars in relation to flap design: Clinical and statistical evaluations. *Quintessence International*, *42*, 445–453.

Bruce, R. A., Frederickson, G. C., & Small, G. S. (1980). Age of patients and morbidity associated with mandibular third molar surgery. *Journal of the American Dental Association (1939)*, *101*, 240–245.

Bui, C. H., Seldin, E. B., & Dodson, T. B. (2003). Types, frequencies, and risk factors for complications after third molar extraction. *Journal of Oral and Maxillofacial Surgery*, *61*, 1379–1389.

Çakır, M., Karaca, I. R., Peker, E., & Ogutlu, F. (2018). Effects of inferior alveolar nerve neurosensory deficits on quality of life. *Nigerian Journal of Clinical Practice*, *21*, 206–211.

Capuzzi, P., Montebugnoli, L., & Vaccaro, M. A. (1994). Extraction of impacted third molars. A longitudinal prospective study on factors that affect postoperative recovery. *Oral Surgery, Oral Medicine, and Oral Pathology*, *77*, 341–343.

Carmichael, F. A., & McGowan, D. A. (1992). Incidence of nerve damage following third molar removal: A West of Scotland Oral Surgery Research Group study. *The British Journal of Oral & Maxillofacial Surgery*, *30*, 78–82.

Carrasco-Labra, A., Brignardello-Petersen, R., Yanine, N., Araya, I., & Guyatt, G. (2012). Secondary versus primary closure techniques for the prevention of postoperative complications following removal of impacted mandibular third molars: A systematic review and meta-analysis of randomized controlled trials. *Journal of Oral and Maxillofacial Surgery*, *70*, e441–e457.

Carter, K., & Worthington, S. (2016). Predictors of third molar impaction: A systematic review and meta-analysis. *Journal of Dental Research*, *95*, 267–276.

Cassetta, M., & Altieri, F. (2017). The influence of mandibular third molar germectomy on the treatment time of impacted mandibular second molars using brass wire: A prospective clinical pilot study. *International Journal of Oral and Maxillofacial Surgery*, *46*, 905–911.

Cerqueira, P. R., Vasconcelos, B. C., & Bessa-Nogueira, R. V. (2004). Comparative study of the effect of a tube drain in impacted lower third molar surgery. *Journal of Oral and Maxillofacial Surgery*, *62*, 57–61.

Cervera-Espert, J., Perez-Martinez, S., Cervera-Ballester, J., Penarrocha-Oltra, D., & Penarrocha-Diago, M. (2016). Coronectomy of impacted mandibular third molars: A meta-analysis and systematic review of the literature. *Medicina Oral, Patología Oral y Cirugía Bucal*, *21*, e505–e513.

Chaparro-Avendano, A. V., Perez-Garcia, S., Valmaseda-Castellon, E., Berini-Aytes, L., & Gay-Escoda, C. (2005). Morbidity of third molar extraction in patients between 12 and 18 years of age. *Medicina Oral, Patología Oral y Cirugía Bucal*, *10*, 422–431.

Chen, Y., Liu, J., Pei, J., Liu, Y., & Pan, J. (2018). The risk factors that can increase possibility of mandibular canal wall damage in adult: A cone-beam computed tomography (CBCT) study in a Chinese population. *Medical Science Monitor*, *24*, 26–36.

Cheung, L. K., Leung, Y. Y., Chow, L. K., Wong, M. C., Chan, E. K., & Fok, Y. H. (2010). Incidence of neurosensory deficits and recovery after lower third molar surgery: A prospective clinical study of 4338 cases. *International Journal of Oral and Maxillofacial Surgery*, *39*, 320–326.

Chiapasco, M., Crescentini, M., & Romanoni, G. (1995). Germectomy or delayed removal of mandibular impacted third molars: The relationship between age and incidence of complications. *Journal of Oral and Maxillofacial Surgery*, *53*, 418–422 discussion 422–413.

Chiapasco, M., De Cicco, L., & Marrone, G. (1993). Side effects and complications associated with third molar surgery. *Oral Surgery, Oral Medicine, and Oral Pathology*, *76*, 412–420.

Coulthard, P., Bailey, E., Esposito, M., Furness, S., Renton, T. F., & Worthington, H. V. (2014). Surgical techniques for the removal of mandibular wisdom teeth. *Cochrane Database of Systematic Reviews*, *29*(7), CD004345.

Dawdy, J., Halladay, J., Carrasco-Labra, A., Araya, I., Yanine, N., & Brignardello-Petersen, R. (2017). Efficacy of adjuvant laser therapy in reducing postsurgical complications after the removal of impacted mandibular third molars: A systematic review update and meta-analysis. *Journal of the American Dental Association (1939)*, *148*(887–902), e884.

De Bruyn, L., Vranckx, M., Jacobs, R., & Politis, C. (2020). A retrospective cohort study on reasons to retain third molars. *International Journal of Oral and Maxillofacial Surgery*, *49*, 816–821.

De Sousa Ruela, W., de Almeida, V. L., Lima-Rivera, L. M., Santos, P. L., Porporatti, A. L., de Freitas, P. H. L., & Paranhos, L. R. (2018). Does an association exist between the presence of lower third molar and mandibular angle fractures?: A meta-analysis. *Journal of Oral and Maxillofacial Surgery*, *76*(1), 34–45.

de Toledo Telles-Araujo, G., Peralta-Mamani, M., Caminha, R. D. G., de Fatima, M.-d.-S. A., Rubira, C. M. F., Honorio, H. M., & Rubira-Bullen, I. R. F. (2020). CBCT does not reduce neurosensory disturbances after third molar removal compared to panoramic radiography: A systematic review and meta-analysis. *Clinical Oral Investigations*, *24*, 1137–1149.

Diz, P., Scully, C., & Sanz, M. (2013). Dental implants in the medically compromised patient. *Journal of Dentistry*, *41*, 195–206.

Dolanmaz, D., Yildirim, G., Isik, K., Kucuk, K., & Ozturk, A. (2009). A preferable technique for protecting the inferior alveolar nerve: Coronectomy. *Journal of Oral and Maxillofacial Surgery*, *67*, 1234–1238.

Ecuyer, J., & Debien, J. (1984). Surgical deductions. *Actual Odontostomatol (Paris)*, *38*, 695–702.

Erdogan, O., Tatli, U., Ustun, Y., & Damlar, I. (2011). Influence of two different flap designs on the sequelae of mandibular third molar surgery. *Oral and Maxillofacial Surgery*, *15*, 147–152.

Eshghpour, M., Shaban, B., Ahrari, F., Erfanian, M., & Shadkam, E. (2017). Is low-level laser therapy effective for treatment of neurosensory deficits arising from sagittal split ramus osteotomy? *Journal of Oral and Maxillofacial Surgery*, *75*, 2085–2090.

Fisher, E. L., Moss, K. L., Offenbacher, S., Beck, J. D., & White, R. P., Jr. (2010). Third molar caries experience in middle-aged and older Americans: A prevalence study. *Journal of Oral and Maxillofacial Surgery*, *68*, 634–640.

Fisher, S. E., Frame, J. W., Rout, P. G., & McEntegart, D. J. (1988). Factors affecting the onset and severity of pain following the surgical removal of unilateral impacted mandibular third molar teeth. *British Dental Journal*, *164*, 351–354.

French Society of Stomatology, Maxillo-Facial Surgery and Oral Surgery. (2020). French good practice guidelines regarding third molar removal: Indications, techniques, methods. *Journal of Stomatology Oral and Maxillofacial Surgery*, *121*(4), 418–429. https://doi.org/10.1016/j.jormas.2020.05.026

Frenkel, B., Givol, N., & Shoshani, Y. (2015). Coronectomy of the mandibular third molar: A retrospective study of 185 procedures and the decision to repeat the coronectomy in cases of failure. *Journal of Oral and Maxillofacial Surgery*, *73*, 587–594.

Garaas, R., Moss, K. L., Fisher, E. L., Wilson, G., Offenbacher, S., Beck, J. D., & White, R. P., Jr. (2011). Prevalence of visible third molars with caries experience or periodontal pathology in middle-aged and older Americans. *Journal of Oral and Maxillofacial Surgery*, *69*, 463–470.

Garaas, R. N., Fisher, E. L., Wilson, G. H., Phillips, C., Shugars, D. A., Blakey, G. H., … White, R. P., Jr. (2012). Prevalence of third molars with caries experience or periodontal pathology in young adults. *Journal of Oral and Maxillofacial Surgery*, *70*, 507–513.

Ge, J., Zheng, J. W., Yang, C., & Qian, W. T. (2016). Variations in the buccal-lingual alveolar bone thickness of impacted mandibular third molar: Our classification and treatment perspectives. *Scientific Reports*, *6*, 16375.

Ghaeminia, H., Gerlach, N. L., Hoppenreijs, T. J., Kicken, M., Dings, J. P., Borstlap, W. A., … Maal, T. J. (2015). Clinical relevance of cone beam computed tomography in mandibular third molar removal: A multicentre, randomised, controlled trial. *Journal of Cranio-Maxillo-Facial Surgery*, *43*, 2158–2167.

Ghaeminia, H., Meijer, G. J., Soehardi, A., Borstlap, W. A., Mulder, J., Vlijmen, O. J., … Maal, T. J. (2011). The use of cone beam CT for the removal of wisdom teeth changes the surgical approach compared with panoramic radiography: A pilot study. *International Journal of Oral and Maxillofacial Surgery*, *40*, 834–839.

Giovacchini, F., Paradiso, D., Bensi, C., Belli, S., Lomurno, G., & Tullio, A. (2018). Association between third molar and mandibular angle fracture: A systematic review and meta-analysis. *Journal of Cranio-Maxillo-Facial Surgery*, *46*, 558–565.

Goto, S., Kurita, K., Kuroiwa, Y., Hatano, Y., Kohara, K., Izumi, M., & Ariji, E. (2012). Clinical and dental computed tomographic evaluation 1 year after coronectomy. *Journal of Oral and Maxillofacial Surgery*, *70*, 1023–1029.

Guerrero, M. E., Botetano, R., Beltran, J., Horner, K., & Jacobs, R. (2014). Can preoperative imaging help to predict postoperative outcome after wisdom tooth removal? A randomized controlled trial using panoramic radiography versus cone-beam CT. *Clinical Oral Investigations*, *18*, 335–342.

Gulicher, D., & Gerlach, K. L. (2001). Sensory impairment of the lingual and inferior alveolar nerves following removal of impacted mandibular third molars. *International Journal of Oral and Maxillofacial Surgery*, *30*, 306–312.

Hasegawa, T., Ri, S., Shigeta, T., Akashi, M., Imai, Y., Kakei, Y., … Komori, T. (2013). Risk factors associated with inferior alveolar nerve injury after extraction of the mandibular third molar—A comparative study of preoperative images by panoramic radiography and computed tomography. *International Journal of Oral and Maxillofacial Surgery*, *42*, 843–851.

Hatano, Y., Kurita, K., Kuroiwa, Y., Yuasa, H., & Ariji, E. (2009). Clinical evaluations of coronectomy (intentional partial odontectomy) for mandibular third molars using dental computed tomography: A case-control study. *Journal of Oral and Maxillofacial Surgery*, *67*, 1806–1814.

Haug, R. H., Perrott, D. H., Gonzalez, M. L., & Talwar, R. M. (2005). The American Association of Oral and Maxillofacial Surgeons Age-Related Third Molar Study. *Journal of Oral and Maxillofacial Surgery*, *63*, 1106–1114.

Huang, C. K., Lui, M. T., & Cheng, D. H. (2015). Use of panoramic radiography to predict postsurgical sensory impairment following extraction of impacted mandibular third molars. *Journal of the Chinese Medical Association*, *78*, 617–622.

Isiordia-Espinoza, M. A., Aragon-Martinez, O. H., Martinez-Morales, J. F., & Zapata-Morales, J. R. (2015). Risk of wound infection and safety profile of amoxicillin in healthy patients which required third molar surgery: A systematic review and meta-analysis. *The British Journal of Oral & Maxillofacial Surgery*, *53*, 796–804.

Iwanaga, J. (2017). The clinical view for dissection of the lingual nerve with application to minimizing iatrogenic injury. *Clinical Anatomy*, *30*, 467–469.

Iwanaga, J., Anand, M. K., Jain, M. N., Nagata, M., Matsushita, Y., Ibaragi, S., … Tubbs, R. S. (2020). Microsurgical anatomy of the superior wall of the mandibular canal and surrounding structures: Suggestion for new classifications for dental Implantology. *Clinical Anatomy*, *33*, 223–231.

Iwanaga, J., Choi, P. J., Vetter, M., Patel, M., Kikuta, S., Oskouian, R. J., & Tubbs, R. S. (2018). Anatomical study of the lingual nerve and inferior alveolar nerve in the pterygomandibular space: Complications of the inferior alveolar nerve block. *Cureus*, *10*(8), e3109.

Iwanaga, J., Cleveland, M. K., Wada, J., & Tubbs, R. S. (2020). How to avoid iatrogenic lingual nerve injury in the retromolar area: An anatomical study of retromolar pad and lingual nerve. *Surgical and Radiologic Anatomy*, *42*, 523–528.

Iwanaga, J., Katafuchi, M., Matsushita, Y., Kato, T., Horner, K., & Tubbs, R. S. (2020). Anatomy of the mandibular canal and surrounding structures: Part I: Morphology of the superior wall of the mandibular canal. *Annals of Anatomy*, *232*, 151580.

Iwanaga, J., Nakamura, K., Alonso, F., Kirkpatrick, C., Oskouian, R. J., Watanabe, K., & Tubbs, R. S. (2018). Anatomical study of the so-called "retromolar gland": Distinguishing normal anatomy from oral cavity pathology. *Clinical Anatomy*, *31*, 462–465.

Iwanaga, J., Shiromoto, K., Kato, T., Tanaka, T., Ibaragi, S., & Tubbs, R. S. (2020). Anatomy of the mandibular canal and surrounding structures part II: Cancellous pattern of the mandible. *Annals of Anatomy*, 151583. https://doi.org/10.1016/j.aanat.2020.151583.

Iwanaga, J., Shiromoto, K., & Tubbs, R. S. (2020). Releasing incisions of the buccal periosteum adjacent to the lower molar teeth can injure the facial artery: An anatomical study. *Surgical and Radiologic Anatomy*, *42*, 31–34.

Jacobs, R. (2011). Dental cone beam CT and its justified use in oral health care. *JBR-BTR*, *94*, 254–265.

Jain, N., Thomas, S., Prabhu, S., Jain, S., Pathak, A. D., Pillai, A., & Satpathy, M. (2016). Influence of tooth sectioning technique and various risk factors in reducing the IAN injury following surgical removal of an impacted mandibular third molar. *Oral and Maxillofacial Surgery*, *20*, 149–156.

Jakse, N., Bankaoglu, V., Wimmer, G., Eskici, A., & Pertl, C. (2002). Primary wound healing after lower third molar surgery: Evaluation of 2 different flap designs. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics*, *93*, 7–12.

Jerjes, W., Upile, T., Shah, P., Nhembe, F., Gudka, D., Kafas, P., … Hopper, C. (2010). Risk factors associated with injury to the inferior alveolar and lingual nerves following third molar surgery-revisited. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics*, *109*, 335–345.

Jhamb, A., Dolas, R. S., Pandilwar, P. K., & Mohanty, S. (2009). Comparative efficacy of spiral computed tomography and orthopantomography in preoperative detection of relation of inferior alveolar neurovascular bundle to the impacted mandibular third molar. *Journal of Oral and Maxillofacial Surgery*, *67*, 58–66.

Joshi, A., Goel, M., & Thorat, A. (2016). Identifying the risk factors causing iatrogenic mandibular fractures associated with exodontia: A systemic meta-analysis of 200 cases from 1953 to 2015. *Oral and Maxillofacial Surgery*, *20*, 391–396.

Kang, F., Sah, M. K., & Fei, G. (2020). Determining the risk relationship associated with inferior alveolar nerve injury following removal of mandibular third molar teeth: A systematic review. *Journal of Stomatology Oral and Maxillofacial Surgery*, *121*, 63–69.

Kawai, T., Asaumi, R., Sato, I., Kumazawa, Y., & Yosue, T. (2011). Observation of the retromolar foramen and canal of the mandible: A CBCT and macroscopic study. *Oral Radiology*, *28*, 10–14.

Khojastepour, L., Khaghaninejad, M. S., Hasanshahi, R., Forghani, M., & Ahrari, F. (2019). Does the Winter or Pell and Gregory classification system indicate the apical position of impacted mandibular third molars? *Journal of Oral and Maxillofacial Surgery*, *77*, 2222.e1–2222.e9.

Kiesselbach, J. E., & Chamberlain, J. G. (1984). Clinical and anatomic observations on the relationship of the lingual nerve to the mandibular third molar region. *Journal of Oral and Maxillofacial Surgery*, *42*, 565–567.

Kikuta, S., Iwanaga, J., Kusukawa, J., & Tubbs, R. S. (2019). An anatomical study of the lingual nerve in the lower third molar area. *Anatomy and Cell Biology*, *52*(2), 140–142.

Kikuta, S., Iwanaga, J., Nakamura, K., Hino, K., Nakamura, M., & Kusukawa, J. (2018). The retromolar canals and foramina: Radiographic observation and application to oral surgery. *Surgical and Radiologic Anatomy*, *40*, 647–652.

Killey, H. C., & Kay, L. W. (1975). *The impacted wisdom tooth* (2nd ed.). London, England: Churchill Livingstone.

Kim, H. G., & Lee, J. H. (2014). Analysis and evaluation of relative positions of mandibular third molar and mandibular canal impacts. *Journal of the Korean Association of Oral and Maxillofacial Surgeons*, *40*, 278–284.

Kim, J. W., Cha, I. H., Kim, S. J., & Kim, M. R. (2012). Which risk factors are associated with neurosensory deficits of inferior alveolar nerve after mandibular third molar extraction? *Journal of Oral and Maxillofacial Surgery*, *70*, 2508–2514.

Kipp, D. P., Goldstein, B. H., & Weiss, W. W., Jr. (1980). Dysesthesia after mandibular third molar surgery: A retrospective study and analysis of 1,377 surgical procedures. *Journal of the American Dental Association (1939)*, *100*, 185–192.

Kirk, D. G., Liston, P. N., Tong, D. C., & Love, R. M. (2007). Influence of two different flap designs on incidence of pain, swelling, trismus, and alveolar osteitis in the week following third molar surgery. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics*, *104*, e1–e6.

Kjølle, G. K., & Bjørnland, T. (2013). Low risk of neurosensory dysfunction after mandibular third molar surgery in patients less than 30 years of age. A prospective study following removal of 1220 mandibular third molars. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology*, *116*, 411–417.

Knutsson, K., Lysell, L., & Rohlin, M. (1989). Postoperative status after partial removal of the mandibular third molar. *Swedish Dental Journal*, *13*, 15–22.

Kohara, K., Kurita, K., Kuroiwa, Y., Goto, S., & Umemura, E. (2015). Usefulness of mandibular third molar coronectomy assessed through clinical evaluation over three years of follow-up. *International Journal of Oral and Maxillofacial Surgery*, *44*, 259–266.

Korkmaz, Y. T., Kayipmaz, S., Senel, F. C., Atasoy, K. T., & Gumrukcu, Z. (2017). Does additional cone beam computed tomography decrease the risk of inferior alveolar nerve injury in high-risk cases undergoing third molar surgery?Does CBCT decrease the risk of IAN injury? *International Journal of Oral and Maxillofacial Surgery*, *46*, 628–635.

Koyuncu, B. O., & Cetingul, E. (2013). Short-term clinical outcomes of two different flap techniques in impacted mandibular third molar surgery. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology*, *116*, e179–e184.

Kubota, S., Imai, T., Nakazawa, M., & Uzawa, N. (2020). Risk stratification against inferior alveolar nerve injury after lower third molar extraction by scoring on cone-beam computed tomography image. *Odontology*, *108*, 124–132.

Kugelberg, C. F. (1990). Periodontal healing two and four years after impacted lower third molar surgery. A comparative retrospective study. *International Journal of Oral and Maxillofacial Surgery*, *19*, 341–345.

Kunkel, M., Morbach, T., Kleis, W., & Wagner, W. (2006). Third molar complications requiring hospitalization. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics*, *102*, 300–306.

Kursun, S., Hakan, K. M., Bengi, O., & Nihat, A. (2015). Use of cone beam computed tomography to determine the accuracy of panoramic radiological markers: A pilot study. *Journal of Dental Sciences*, *10*, 167–171.

Leung, Y. Y. (2019). Management and prevention of third molar surgery-related trigeminal nerve injury: Time for a rethink. *Journal of the Korean Association of Oral and Maxillofacial Surgeons*, *45*, 233–240.

Leung, Y. Y., & Cheung, L. K. (2009). Safety of coronectomy versus excision of wisdom teeth: A randomized controlled trial. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics*, *108*, 821–827.

Leung, Y. Y., & Cheung, L. K. (2012). Coronectomy of the lower third molar is safe within the first 3 years. *Journal of Oral and Maxillofacial Surgery*, *70*, 1515–1522.

Leung, Y. Y., & Cheung, L. K. (2016). Longitudinal treatment outcomes of microsurgical treatment of neurosensory deficit after lower third molar surgery: A prospective case series. *PLoS One*, *11*, e0150149.

Leung, Y. Y., Lee, T. C., Ho, S. M., & Cheung, L. K. (2013). Trigeminal neurosensory deficit and patient reported outcome measures: The effect on life satisfaction and depression symptoms. *PLoS One*, *8*, e72891.

Leung, Y. Y., McGrath, C., & Cheung, L. K. (2013). Trigeminal neurosensory deficit and patient reported outcome measures: The effect on quality of life. *PLoS One*, *8*, e77391.

Libersa, P., Roze, D., Cachart, T., & Libersa, J. C. (2002). Immediate and late mandibular fractures after third molar removal. *Journal of Oral and Maxillofacial Surgery*, *60*, 163–165 discussion 165–166.

Liu, S., You, Z., Ma, C., Wang, Y., & Zhao, H. (2018). Effectiveness of drainage in mandibular third molar surgery: A systematic review and meta-analysis. *Journal of Oral and Maxillofacial Surgery*, *76*, 1640–1650.

Lodi, G., Figini, L., Sardella, A., Carrassi, A., Del Fabbro, M., & Furness, S. (2012). Antibiotics to prevent complications following tooth extractions. *Cochrane Database of Systematic Reviews*, *11*, CD003811.

Lopes, V., Mumenya, R., Feinmann, C., & Harris, M. (1995). Third molar surgery: An audit of the indications for surgery, post-operative complaints and patient satisfaction. *The British Journal of Oral & Maxillofacial Surgery*, *33*, 33–35.

Lytle, J. J. (1993). Etiology and indications for the management of impacted teeth. *Oral and Maxillofacial Surgery Clinics of North America*, *5*, 63–76.

Ma, S., Li, X., Zhang, A., Liu, S., Zhao, H., & Zhao, H. (2019). Efficacy of secondary closure technique after extraction of third molars: A meta-analysis. *The British Journal of Oral & Maxillofacial Surgery*, *57*, 977–984.

Maglione, M., Costantinides, F., & Bazzocchi, G. (2015). Classification of impacted mandibular third molars on cone-beam CT images. *Journal of Clinical and Experimental Dentistry*, *7*, e224–e231.

Manor, Y., Abir, R., Manor, A., & Kaffe, I. (2017). Are different imaging methods affecting the treatment decision of extractions of mandibular third molars? *Dento Maxillo Facial Radiology*, *46*, 20160233.

Martin, A., Perinetti, G., Costantinides, F., & Maglione, M. (2015). Coronectomy as a surgical approach to impacted mandibular third molars: A systematic review. *Head & Face Medicine*, *11*, 9.

Mason, D. A. (1988). Lingual nerve damage following lower third molar surgery. *International Journal of Oral and Maxillofacial Surgery*, *17*, 290–294.

Matzen, L. H., Christensen, J., Hintze, H., Schou, S., & Wenzel, A. (2013). Influence of cone beam CT on treatment plan before surgical intervention of mandibular third molars and impact of radiographic factors on deciding on coronectomy vs surgical removal. *Dento Maxillo Facial Radiology*, *42*, 98870341.

Menon, R. K., Gopinath, D., Li, K. Y., Leung, Y. Y., & Botelho, M. G. (2019). Does the use of amoxicillin/amoxicillin-clavulanic acid in third molar surgery reduce the risk of postoperative infection? A systematic review with meta-analysis. *International Journal of Oral and Maxillofacial Surgery*, *48*, 263–273.

Menziletoglu, D., Guler, A. Y., Basturk, F., Isik, B. K., & Erdur, E. A. (2019). Comparison of two different flap designs for bilateral impacted mandibular third molar surgery. *Journal of Stomatology Oral and Maxillofacial Surgery*. https://doi.org/10.1016/j.jormas.2019.08.006

Momin, M. A., Matsumoto, K., Ejima, K., Asaumi, R., Kawai, T., Arai, Y., … Yosue, T. (2013). Correlation of mandibular impacted tooth and bone morphology determined by cone beam computed topography on a premise of third molar operation. *Surgical and Radiologic Anatomy*, *35*, 311–318.

Monaco, G., D'Ambrosio, M., De Santis, G., Vignudelli, E., Gatto, M. R. A., & Corinaldesi, G. (2019). Coronectomy: A surgical option for impacted third molars in close proximity to the inferior alveolar nerve-a 5-year follow-up study. *Journal of Oral and Maxillofacial Surgery*, *77*, 1116–1124.

Monaco, G., de Santis, G., Gatto, M. R., Corinaldesi, G., & Marchetti, C. (2012). Coronectomy: A surgical option for impacted third molars in close proximity to the inferior alveolar nerve. *Journal of the American Dental Association (1939)*, *143*, 363–369.

Naitoh, M., Hiraiwa, Y., Aimiya, H., & Ariji, E. (2009). Observation of bifid mandibular canal using cone-beam computerized tomography. *The International Journal of Oral & Maxillofacial Implants*, *24*, 155–159.

Nakamori, K., Tomihara, K., & Noguchi, M. (2014). Clinical significance of computed tomography assessment for third molar surgery. *World Journal of Radiology*, *6*, 417–423.

National Institute for Health and Clinical Excellence. (2000). *Guidance on the extraction of wisdom teeth. Technology appraisal guidance*. Retrieved from https://www.nice.org.uk/guidance/ta1

Ngeow, W. C., & Chai, W. L. (2020). The clinical anatomy of accessory mandibular canal in dentistry. *Clinical Anatomy*. https://doi.org/10.1002/ca.23577.

Nguyen, E., Grubor, D., & Chandu, A. (2014). Risk factors for permanent injury of inferior alveolar and lingual nerves during third molar surgery. *Journal of Oral and Maxillofacial Surgery*, *72*, 2394–2401.

Nyul, L. (1959). Kieferfrakturen bei zahnextrationen. *Zahnärztliche Welt*, *60*, 1–5.

Omran, A., Hutchison, I., Ridout, F., Bose, A., Maroni, R., Dhanda, J., … Chiu, G. (2020). Current perspectives on the surgical management of mandibular third molars in the United Kingdom: The need for further research. *The British Journal of Oral & Maxillofacial Surgery*, *58*, 348–354.

O'Riordan, B. C. (2004). Coronectomy (intentional partial odontectomy of lower third molars). *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics*, *98*, 274–280.

Pachipulusu, P. K., & Manjula, S. (2018). Comparative study of primary and secondary closure of the surgical wound after removal of impacted mandibular third molars. *Oral and Maxillofacial Surgery*, *22*, 261–266.

Pasqualini, D., Cocero, N., Castella, A., Mela, L., & Bracco, P. (2005). Primary and secondary closure of the surgical wound after removal of impacted mandibular third molars: A comparative study. *International Journal of Oral and Maxillofacial Surgery*, *34*, 52–57.

Patel, V., Sproat, C., Kwok, J., Beneng, K., Thavaraj, S., & McGurk, M. (2014). Histological evaluation of mandibular third molar roots retrieved after coronectomy. *The British Journal of Oral & Maxillofacial Surgery*, *52*, 415–419.

Pell, G. J., & Gregory, B. T. (1993). Impacted mandibular third molars: Classification and modified techniques for removal. *Dental Digest*, *39*, 330–338.

Perry, P. A., & Goldberg, M. H. (2000). Late mandibular fracture after third molar surgery: A survey of Connecticut oral and maxillofacial surgeons. *Journal of Oral and Maxillofacial Surgery*, *58*, 858–861.

Pitros, P., Jackson, I., & O'Connor, N. (2019). Coronectomy: A retrospective outcome study. *Oral and Maxillofacial Surgery*, *23*, 453–458.

Pogrel, M. A., Lee, J. S., & Muff, D. F. (2004). Coronectomy: A technique to protect the inferior alveolar nerve. *Journal of Oral and Maxillofacial Surgery*, *62*, 1447–1452.

Pons-Salvadó, S., Berini Aytés, L., & Gay, E. C. (2000). Terceros molares inferiors incluidos. Revisión de 156 casos de germenectomías bilaterales. *Archivos de Odontoestomatología*, *16*, 41–50.

Quirino de Almeida Barros, R., Bezerra de Melo, N., de Macedo Bernardino, I., Area Leao Lopes Araujo Arruda, M. J., & Meira Bento, P. (2018). Association between impacted third molars and position of the mandibular canal: A morphological analysis using cone-beam computed tomography. *The British Journal of Oral & Maxillofacial Surgery*, *56*, 952–955.

Rabi, A., Haris, P. M. M., Panickal, D. M., Ahamed, S., Pulikkottil, V. J., & Haris, K. T. M. (2017). Comparative evaluation of two different flap designs and postoperative outcome in the surgical removal of impacted mandibular third molar. *The Journal of Contemporary Dental Practice*, *18*, 807–811.

Ramos, E., Santamaria, J., Santamaria, G., Barbier, L., & Arteagoitia, I. (2016). Do systemic antibiotics prevent dry socket and infection after third molar extraction? A systematic review and meta-analysis. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology*, *122*, 403–425.

Ren, Y. F., & Malmstrom, H. S. (2007). Effectiveness of antibiotic prophylaxis in third molar surgery: A meta-analysis of randomized controlled clinical trials. *Journal of Oral and Maxillofacial Surgery*, *65*, 1909–1921.

Renton, T., & McGurk, M. (2001). Evaluation of factors predictive of lingual nerve injury in third molar surgery. *The British Journal of Oral & Maxillofacial Surgery*, *39*, 423–428.

Robinson, P. P. (1988). Observations on the recovery of sensation following inferior alveolar nerve injuries. *The British Journal of Oral & Maxillofacial Surgery*, *26*, 177–189.

Roeder, F., Wachtlin, D., & Schulze, R. (2012). Necessity of 3D visualization for the removal of lower wisdom teeth: Required sample size to prove non-inferiority of panoramic radiography compared to CBCT. *Clinical Oral Investigations*, *16*, 699–706.

Rood, J. P., & Shehab, B. A. (1990). The radiological prediction of inferior alveolar nerve injury during third molar surgery. *The British Journal of Oral & Maxillofacial Surgery*, *28*, 20–25.

Sandhu, A., Sandhu, S., & Kaur, T. (2010). Comparison of two different flap designs in the surgical removal of bilateral impacted mandibular third molars. *International Journal of Oral and Maxillofacial Surgery*, *39*, 1091–1096.

Scottish Intercollegiate Guidelines Network. (2000). *Management of unerupted and impacted third molar teeth. A national clinical guideline*. Edinburgh, England: SIGN.

Shepherd, J. P., & Brickley, M. (1994). Surgical removal of third molars. *BMJ*, *309*, 620–621.

Shokouhi, B., Thavaraj, S., Sproat, C., Kwok, J., Beneng, K., & Patel, V. (2019). Coronectomy root retrievals: A review of 92 cases. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology*, *127*, 200–209.

Shugars, D. A., Jacks, M. T., White, R. P., Jr., Phillips, C., Haug, R. H., & Blakey, G. H. (2004). Occlusal caries experience in patients with asymptomatic third molars. *Journal of Oral and Maxillofacial Surgery*, *62*, 973–979.

Shujaat, S., Abouelkheir, H. M., Al-Khalifa, K. S., Al-Jandan, B., & Marei, H. F. (2014). Pre-operative assessment of relationship between inferior dental nerve canal and mandibular impacted third molar in Saudi population. *Saudi Dental Journal*, *26*, 103–107.

Şimşek Kaya, G., Yapici Yavuz, G., & Saruhan, N. (2019). The influence of flap design on sequelae and quality of life following surgical removal of impacted mandibular third molars: A split-mouth randomised clinical trial. *Journal of Oral Rehabilitation*, *46*, 828–835.

Sisk, A. L., Hammer, W. B., Shelton, D. W., & Joy, E. D., Jr. (1986). Complications following removal of impacted third molars: The role of the experience of the surgeon. *Journal of Oral and Maxillofacial Surgery*, *44*, 855–859.

Smith, A. C., Barry, S. E., Chiong, A. Y., Hadzakis, D., Kha, S. L., Mok, S. C., & Sable, D. L. (1997). Inferior alveolar nerve damage following removal of mandibular third molar teeth. A prospective study using panoramic radiography. *Australian Dental Journal*, *42*, 149–152.

Smith, W. P. (2013). The relative risk of neurosensory deficit following removal of mandibular third molar teeth: The influence of radiography and surgical technique. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology*, *115*, 18–24.

Standring, S. (2015). *Gray's anatomy: The anatomical basis of clinical practice*. London, England: Elsevier Health Sciences.

Stordeur, S., & Eyssen, M. (2012). Prophylactic removal of pathology-free wisdom teeth: Rapid assessment. Federaal Kenniscentrum voor Gezondheidszorg KCE Report 182A. Retrieved from https://kce.fgov.be/sites/default/files/atoms/files/KCE_182C_wisdom_teeth.pdf

Szmyd, L. (1971). Impacted teeth. *Dental Clinics of North America*, *15*, 299–318.

Tareen, M. K., Hamad, J., Saleem, S. M., & Ahmad, S. (2015). To compare the triangular flap to envelope flap for the removal of impacted mandibular last molar. *Pakistan Journal of Medical & Health Sciences*, *9*, 434–436.

Thorne, M. C. (2003). Background radiation: Natural and man-made. *Journal of Radiological Protection*, *23*, 29–42.

Toedtling, V., Devlin, H., Tickle, M., & O'Malley, L. (2019). Prevalence of distal surface caries in the second molar among referrals for assessment of third molars: A systematic review and meta-analysis. *The British Journal of Oral & Maxillofacial Surgery*, *57*, 505–514.

Tolstunov, L., Brickeen, M., Kamanin, V., Susarla, S. M., & Selvi, F. (2016). Is the angulation of mandibular third molars associated with the thickness of lingual bone? *The British Journal of Oral & Maxillofacial Surgery*, *54*, 914–919.

Ueda, M., Nakamori, K., Shiratori, K., Igarashi, T., Sasaki, T., Anbo, N., … Hiratsuka, H. (2012). Clinical significance of computed tomographic assessment and anatomic features of the inferior alveolar canal as risk factors for injury of the inferior alveolar nerve at third molar surgery. *Journal of Oral and Maxillofacial Surgery*, *70*, 514–520.

Valmaseda-Castellón, E., Berini-Aytes, L., & Gay-Escoda, C. (2000). Lingual nerve damage after third lower molar surgical extraction. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics*, *90*, 567–573.

Valmaseda-Castellón, E., Berini-Aytes, L., & Gay-Escoda, C. (2001). Inferior alveolar nerve damage after lower third molar surgical extraction: A prospective study of 1117 surgical extractions. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics*, *92*, 377–383.

Vandeplas, C., Vranckx, M., Hekner, D., Politis, C., & Jacobs, R. (2020). Does retaining third molars result in the development of pathology over time? A systematic review. *Journal of Oral and Maxillofacial Surgery*. https://doi.org/10.1016/j.joms.2020.06.014.

Venta, I. (2012). How often do asymptomatic, disease-free third molars need to be removed? *Journal of Oral and Maxillofacial Surgery*, *70*, S41–S47.

Venta, I., Kylatie, E., & Hiltunen, K. (2015). Pathology related to third molars in the elderly persons. *Clinical Oral Investigations*, *19*, 1785–1789.

Wagner, K. W., Otten, J. E., Schoen, R., & Schmelzeisen, R. (2005). Pathological mandibular fractures following third molar removal. *International Journal of Oral and Maxillofacial Surgery*, *34*, 722–726.

Wagner, K. W., Schoen, R., Wongchuensoontorn, C., & Schmelzeisen, R. (2007). Complicated late mandibular fracture following third molar removal. *Quintessence International*, *38*(1), 63–65.

Wang, D., Lin, T., Wang, Y., Sun, C., Yang, L., Jiang, H., & Cheng, J. (2018). Radiographic features of anatomic relationship between impacted third molar and inferior alveolar canal on coronal CBCT images: Risk factors for nerve injury after tooth extraction. *Archives of Medical Science*, *14*, 532–540.

Wenzel, A. (2010). It is not clear whether commonly used radiographic markers in panoramic images possess predictive ability for determining the relationship between the inferior alveolar nerve and the mandibular third molar. *The Journal of Evidence-Based Dental Practice*, *10*, 232–234.

Winter, G. B. (1926). *The principles of exodontia as applied to the impacted mandibular third molar*. St. Louis, MO: American Medical Book Company.

Xu, J. L., Sun, L., Liu, C., Sun, Z. H., Min, X., & Xia, R. (2015). Effect of oral contraceptive use on the incidence of dry socket in females following impacted mandibular third molar extraction: A meta-analysis. *International Journal of Oral and Maxillofacial Surgery*, *44*, 1160–1165.

Yabroudi, F., & Sindet-Pedersen, S. (2012). Cone beam tomography (CBCT) as a diagnostic tool to assess the relationship between the inferior alveolar nerve and roots of mandibular wisdom teeth. *Smile Dental Journal*, *7*, 12–17.

Yamaoka, M., Furusawa, K., & Yamamoto, M. (1995). Influence of adjacent teeth on impacted third molars in the upper and lower jaws. *Australian Dental Journal*, *40*, 233–235.

Zhang, Q. B., & Zhang, Z. Q. (2012). Early extraction: A silver bullet to avoid nerve injury in lower third molar removal? *International Journal of Oral and Maxillofacial Surgery*, *41*, 1280–1283.

Zhu, J., Yuan, X., Yan, L., Li, T., Guang, M., & Zhang, Y. (2020). Comparison of postoperative outcomes between envelope and triangular flaps after mandibular third molar surgery: A systematic review and meta-analysis. *Journal of Oral and Maxillofacial Surgery*, *78*, 515–527.

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