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Complications of exodontia versus coronectomy of mandibular third molars in close anatomical relation to the inferior alveolar nerve.

Célia Johanne Baudin

Dissertação conducente ao Grau de Mestre em Medicina Dentária (Ciclo Integrado)

Gandra, 27 de julho de 2021

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Trabalho realizado sob a Orientação de " Prof. Doutor Luis Manuel Duarte Martins da Silva"

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Agradecimentos

A mes parents,

Pour votre amour, votre soutien tout au long de mes études et pour les sacrifices que vous avez faits pour moi au fil des années, je ne pourrai jamais assez vous remercier.

A ma sœur,

Tu es une femme merveilleuse et je suis tellement reconnaissante de t'avoir à mes côtés.

Les Chicoteuses : Alice, Clara, Clara, Léa et Stéphanie

Bien plus que des amies, vous faites partie des personnes qui me sont les plus proches.
J'espère qu'on sera toujours là les unes pour les autres.
Pour toutes ces années avec vous qui resteront à jamais gravées dans ma mémoire, merci.

Nikolas,

J'ai su dès le premier jour de faculté que nous deviendrions amis. Ton avenance, ta gentillesse, ton écoute et constante bonne humeur font de toi un être formidable.
Merci pour tous ces moments passés et ceux à venir.

Joaquim,

As ligações românticas podem ser tão fortes e importantes como as ligações familiares.
Para mim tu és a família que eu escolhi e eu, simplesmente, amo-te.

Prof. Doutor Luis Manuel Duarte Martins da Silva,

Obrigado por ser o meu orientador de dissertação. Foi uma honra e um prazer ter a oportunidade de colaborarmos; aceite toda minha gratidão.

Resumo

A coronectomia é um procedimento cirúrgico relativamente recente (1989) que consiste na remoção da coroa do dente deixando as raízes *in situ* por forma a evitar complicações como lesão do nervo alveolar inferior.

O objetivo deste estudo foi realizar uma revisão integrativa da literatura comparando as complicações decorrentes da exodontia versus coronectomia dos terceiros molares inferiores em estreita relação anatómica com o nervo alveolar inferior.

A pesquisa foi conduzida na base de dados PUBMED utilizando uma combinação de palavras-chave.

Obtivemos 111 estudos, dos quais 21 foram selecionados. Tivemos em consideração os estudos que forneceram dados relevantes relacionados com a frequência e evolução ao longo do tempo das complicações de cada procedimento.

Nos resultados, as complicações mais frequentes estudadas foram: lesão nervosa, osteíte alveolar e infeção. Em menor grau, os autores também relataram edema, hemorragia e dor.

A exodontia demonstrou uma maior ocorrência de lesões do nervo alveolar inferior: 4,8% (temporária) e 0,3% (permanente) vs coronectomia: 0,5% (temporária) e 0,2%(permanente).

A osteíte alveolar foi mais prevalecente após a extracção: 14,2% vs 0,4% após a coronectomia.

Edema e hemorragia ocorreram, respetivamente, em 10,0% e 11,5% após a exodontia e 8,3% e 0,9% após coronectomia.

As complicações, inerentes à exodontia foram o trismo e a equimose, enquanto a migração das raízes, a mobilização das raízes, a coronectomia incompleta, a cicatrização de feridas e as bolsas periodontais foram específicas da coronectomia.

A coronectomia deve, portanto, fazer parte do armamentário das cirurgias dentárias, para situações clínicas específicas que são delineadas nesta revisão.

Palavras-chave:

"terceiro molar", "mandibular"," risco de exodontia", "complicação"," coronectomia".

Abstract

Coronectomy is a relatively recent (1989) surgical procedure, which consists in removing the tooth's crown and let the roots in situ in order to prevent certain complications like inferior alveolar nerve injury.

The objective of this study was to perform an integrative literature review comparing the complications arising from exodontia versus coronectomy of mandibular third molars in close anatomical relation to the inferior alveolar nerve.

The search was conducted on the PUBMED database using a combination of keywords.

The search retrieved 111 studies, among which 21 were selected. This selection took into consideration the studies that provided relevant data related to the frequency and evolution overtime of the complications of each procedure.

In terms of results, the most frequent complications studied were nerve injury, alveolar osteitis and infection. To a lesser extent the authors also reported on swelling, bleeding and pain.

Extraction demonstrated a higher occurrence of IAN injuries: 4,8% (temporary) and 0,3% (permanent) versus coronectomy: 0,5% (temporary) and 0,2% (permanent).

Alveolar osteitis was more prevalent after extraction: 14,2% versus 0,4% after coronectomy.

Swelling and bleeding occurred, respectively, in 10,0% and 11,5% after extraction and 8,3% and 0,9% after coronectomy.

Complications in the reviewed series, inherent to extraction were trismus and ecchymosis, while root migration, root mobilisation, incomplete coronectomy, wound healing and periodontal pockets were specific to coronectomy.

Coronectomy should therefore be part of the armamentarium of dental surgeries, for specific clinical situations which are outlined in this review.

Keywords:

"third molar", "mandibular", "extraction risk", "complication", "coronectomy".

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List of abbreviations, initials and acronyms

IAN: Inferior Alveolar Nerve

CBCT: Cone Beam Computed Tomography

OPG: Orthopantomography

3MM: Mandibular third molars

IDN: Inferior dental nerve

MDCT: Multidetector computed tomography

DS: Dental student

OS: Oral surgeon

1. Introduction

One might not be very wise, as young adults, but when it comes to deal with mandibular wisdom teeth, oral surgeons certainly need experience and wisdom to deal with them.

The mandibular third molars are highly susceptible to inclusion or misplacement within the arch. Last teeth to erupt and placed most distally on the mandible, they often evolve in a restricted anatomical space, which makes their hygienization difficult. These are therefore teeth that, during their evolution, are at risk of causing certain pathologies and/or symptoms requiring their extraction.

Avulsion of the mandibular third molars is one of the most common procedures performed in oral surgery, however, there are several risks of complications that need to be carefully evaluated. Due to their location, the mandibular third molars have an anatomical relationship with the inferior alveolar nerve, which in case of close proximity, or contact, increases the risk of iatrogenic injury.

It was in 1984 that Ecuyer & Debien first described a technic to prevent nerve damage following avulsion by separating the crown from the roots and avulsing only the crown: coronectomy, as mentioned in the article of Gady *et al.*.(1)

K. Knutsson, in 1989, reported on coronectomy, studying the postoperative status after a mandibular third molar coronectomy on patients whose apexes of these teeth were located very close to the mandibular canal or whose roots had a complicated anatomy, as promising with regard to the risk of nerve complications, as stipulated by Martin *et al.*. (2)

In 2005, in a randomised controlled clinical trial, T. Renton, compared the incidence of nerve complications after coronectomy or post exodontia of the mandibular third molars close to the lower alveolar nerve.(3)

Encouraging results were obtained, although these were nuanced by several factors that will be developed in the course of this work.

Leaving the roots within the mandible, coronectomy is not very popular to a part of oral surgeons who fear medium-term complications. It is necessary to weigh the pros and cons of each technique in order to offer the patient the most suitable procedure and to reduce the risk of complications arising from each of these two techniques.

By carrying out a systematic integrative review, the aim of this work is to find out and present which technique, between coronectomy and exodontia, is more favourable for mandibular third molars in close anatomical relation to the inferior alveolar nerve, through the study of their complications.

The first part of this paper will focus on the clinical aspect of mandibular third molars, and the challenge they represent.

We will then develop the indications and contraindications related to each procedure.

The third part will focus on the complications surrounding both techniques.

2. Objective and hypothesis

The objective of this review is to identify and compare the complications following exodontia and coronectomy of third mandibular molars in close anatomical relation to the inferior alveolar nerve, in order to appropriately select the least complications-inducing procedure.

We hypothesize that coronectomy could be the best suited procedure for third mandibular molars in close anatomical relation to the inferior alveolar nerve.

3. Materials and methods

Data for this search was obtained electronically through PubMed, in a comparative study of the literature.

Two different searches were carried out in order to obtain comparable data.

The first refers to complications related to the exodontia of mandibular third molars. PubMed was used as the search engine, using the following combination of keywords: "Molar, Third"[MeSHTerm] AND "Mandibular" "Extraction risk "AND "Complication" NOT "Odontosection" NOT "Coronectomy". The exclusion terms returned 181 articles.

The following inclusion criteria were established: English-language articles, full text, published within the last 10 years.

A total of 84 articles were obtained. 33 articles were retained for the pertinence of their title and abstract. Finally, after being read entirely, 13 articles will be included in this work for reporting on complications after mandibular third molars extractions.

The second research deals with the complications of coronectomy. Neither the term "coronectomy" [MeSHTerm] nor "odontosection" [MeSHTerm] was found using The MeSH library.

Using the terms “Coronectomy” AND “Third molars” AND “Complications” NOT “extraction”, 12 records appeared. Due to the small number of articles, it was decided to exclude the term “complications”, to broaden the search.

After searching with the terms "Coronectomy" AND "Third molars" NOT "extraction", 33 articles were obtained.

By adding the same inclusion criteria as mentioned above (English language articles, full text, published within the last 10 years), the number decreased to 27.

11 records were selected for their pertinence after reading the title and abstract. A qualitative text analysis was done to select pertinent scientific articles. 8 were found to be relevant on the subject under study, complications of mandibular third molar coronectomy.

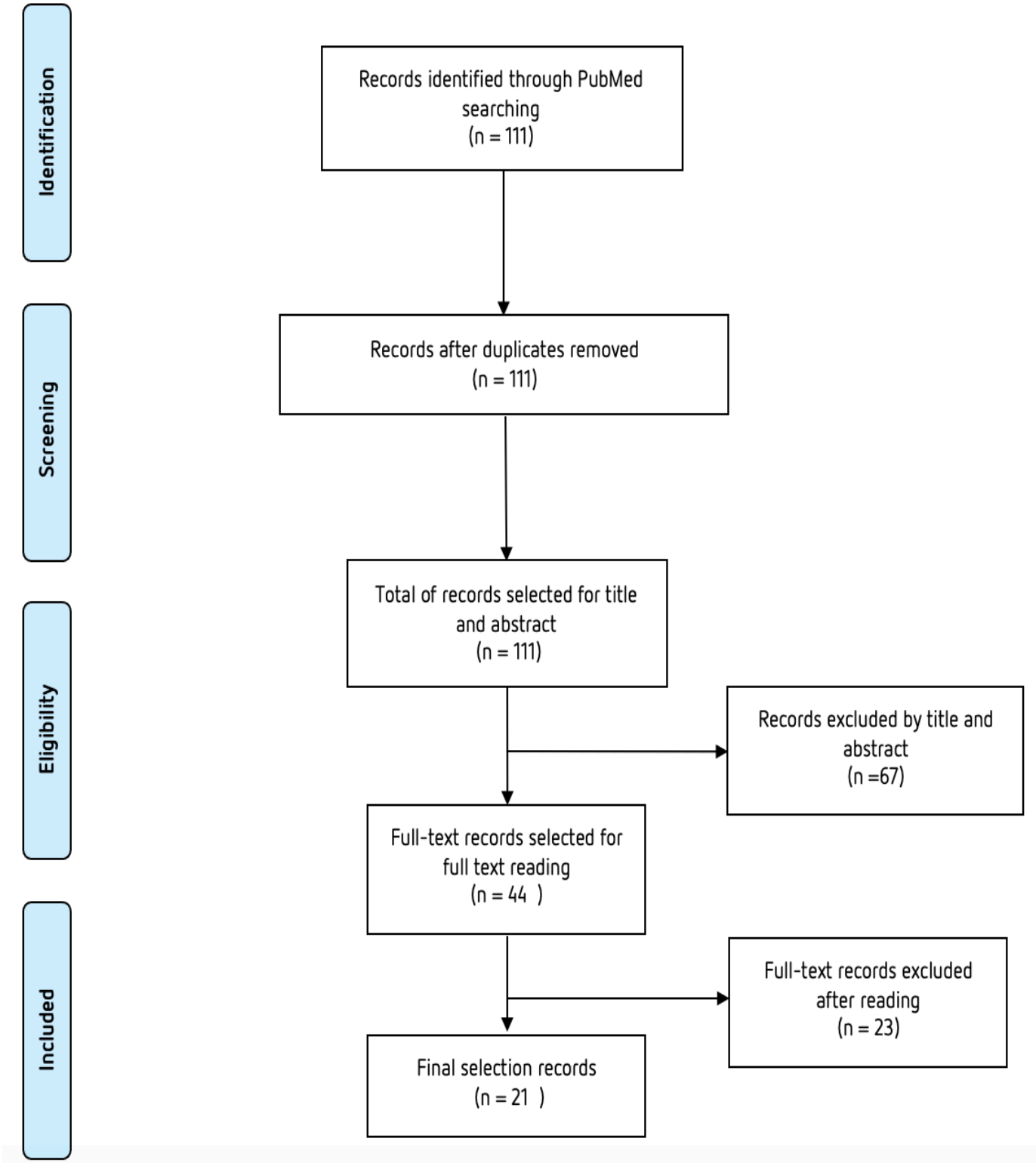

Figure 1. Relevant data selected (PRISMA Flow diagram)

4. Results

Among the 21 articles reviewed, 13 analysed the complications of exodontia and 8 of coronectomy. In total of the articles, 3233 teeth were extracted and 1773 underwent coronectomy.

• Inferior alveolar nerve injury was assessed by 17 authors. Impairment rates were higher among extractions: 4,8% (temporary) and 0,3% (permanent). With coronectomy these rates were 0,5%(temporary) and 0,2%(permanent).

• Lingual nerve injury was evaluated in 2 and 3 articles among extraction and coronectomy groups respectively. There, injury rates were greater following extraction: 4,3% (temporary) and 0,5% (permanent) than coronectomy: 0,4% (temporary) and 0,0% (permanent).

• Alveolar osteitis had a greater occurrence after extraction, with 14,2 % cases against 0,4% following coronectomy and was assessed by 6 authors.

• Infection was studied in 9 series, occurring after coronectomy more frequently than after extraction: 4,3% vs 1,6%.

• Swelling was being slightly more prone to develop after extraction than coronectomy: 10,0% of the cases against 8,3%. 2 authors from each group analysed this complication.

• Bleeding was evaluated in 3 extraction studies, while only 1 author from the coronectomy group studied it. Bleeding occurred significantly more during and/or after extraction: 11,5% of the cases than during and/or after coronectomy: 0,9% of the cases.

• Pain, because of its high subjectivity, was reported with the use of a visual analog scale (VAS) in order to quantify its intensity, but the data did not allow us to draw clear conclusions.

• 2 complications were found to be inherent to exodontia:

Trismus was assessed by Christensen *et al.* who reported it in 86,8% of the cases.(4)

Sayed *et al.* studied trismus together with swelling and pain and reported an overall incidence of 0,6% of cases among upper and lower third molars. Specific conclusions about the incidence of trismus in third mandibular molars could not therefore be determined.(5)

Ecchymosis was reported once, by Guerrero *et al.* with a rate of 2,7% at one week postoperative.(6)

• Relative to coronectomy, 5 complications were encountered.

Root migration, reported by 4 authors, was one of the most frequent complications. In the reviewed articles, root migration occurred in 80 to 97% of the cases, but only a few proportion required removal, 0,0% to 3,4% of the cases, due to their eruption in the oral cavity.

The presence of periodontal pockets on the distal site of the second mandibular molar, assessed in 4 studies, revealed a general trend towards pocket depth normalization. Frenkel *et al.* obtained mean values at 6 months and 12 months postoperative of 4mm and 3,8mm respectively.(7)

5 years after the procedure, Pedersen *et al.* observed a depth ≤ 3mm in 68% of the cases.(8) Finally, Yeung *et al.* reported after an average period of 7,3 years, 76,2% of pockets with a depth ≤ 3mm.(9)

Incomplete coronectomy, caused by enamel lipping was assessed by two authors. Leung *et al.* found 0,2% of incomplete coronectomy, and Pedersen *et al.* 2,2%.(8,10)

Non-closure of the wound was studied by two authors among who one reported up 3 years after the procedure. Frenkel *et al.* , 1 year after the coronectomy reported the presence of 2 cases with sinus opening, as failed healing, and Monaco *et al.*, in the period of one month to three years postoperative noted 9 cases.(7,11)

Finally, root mobilization during coronectomy, was quoted in two articles, but only Sureshkannan *et al.* reported a 7,7% incidence, which led to their retrieval.(12) Monaco *et al.* did not register any case of root mobilization during coronectomy.(11)

Author / Year	Study model	Objective	Sample	Inclusion criteria	Results
Eyrich *et al.* 2011 (13)	Retrospective study	Identify factors that lead to a higher risk of IAN impairment after extraction of mandibular third molar.	515 3MM	Impacted lower third molars, with projection of the tooth over the full width of the IAN on panoramic radiograph. 3D imaging before surgery, and complete follow-up, including documentation of pre- and postoperative IAN function.	•Overall IAN transient impairment : 9.4% (47/515 cases)
Leung *et al.* 2011 (14)	Prospective clinical cohort study	Identify the specific radiographic signs on OPG that are positive predictors of intraoperative inferior dental nerve (IDN) exposure and postoperative IDN deficit in lower third molar extraction.	178 3MM	Patients were included in the study under "study group" if their OPG showed 1 or more specific radiographic signs indicating a close relation between mandibular third molar root and inferior alveolar nerve.	•IAN deficit stratified by the depth of impaction was 0% (0 of 42), 4.6% (4 of 87), 6.7% (3 of 45), and 50% (2 of 4) at 0 to 4, 5 to 9, 10 to 14, and greater than 15 mm (Winter's line)respectively. •Prevalence of the IDN deficit when the IDN was exposed after third molar extraction was 20.8% (5 of 24), greater than the 2.6% (4 of 154) prevalence in the group without IDN exposure.
Freudlsperger *et al.* 2012 (15)	Retrospective study	Evaluate the influence of extraction difficulty according to anatomic variables on postoperative inflammatory complications.	585 3MM	Patients who underwent surgical removal of 585 lower third molars from January 1, 2002, to December 31, 2003. 3MM were classified using a combination of the Pell-Gregory and Winter classifications.	•Total rate of postoperative inflammatory complications was 22% (n=129), including 89% of alveolar osteitis (n=116), 7,8% of surgical site infection (n=10) and 2,3% (n=3) of abscess. • Rate of postoperative inflammatory complications in: -Non-complex 3MM: 7,3% -Moderate 3MM: 23,8% -Difficult 3MM: 29,6%
Neves *et al.* 2012 (16)	Clinical study	Assess the reliability of multidetector computed tomography (MDCT) in determining the surgical risk of the inferior alveolar nerve in extractions of third molars.	63 3MM	Impacted mandibular third molars.	•IAN neurosensory deficit: 6 cases(9,5%) •Haemorrhage occurred in 5 cases (7.9 %). •Most of the cases of haemorrhage (4 cases) and IAN neurosensory deficit (5 cases) occurred when the course of the mandibular canal was lingual to the third molar.
Christensen *et al.* 2012 (4)	Clinical study	Evaluate guidelines for selection of 3MM to be extracted by dental student (DS) or oral surgeon (OS), with regard to post-operative complications.	313 3MM	Cases distribution to DS or OS according to difficulty degree. "Complicated" molars were removed by OSs while "non-complicated" molars were removed by DSs.	•Dry socket: DS (9,5%), OS (1,8%), overall (6,7%). •Infection: DS(5,5%), OS (4,4%), overall (5,1%) •Sensory disturbance: DS (1,5%), OS (2,6%), overall (1,9%) •Swelling: DS (28,6%), OS (24,6%), overall (27,2%) •Bleeding: DS (61,8%), OS (60,5%), overall (61,3%) •Trismus: DS (83,9%), OS (86,8%), overall (85,0%)
Guerrero *et al.* 2012 (17)	Pilot study	Assess sensory disturbance of IAN after 3MM extraction, using CBCT and OPG for preoperative assessment.	86 3MM	Third mandibular molars judged as showing a "moderate" risk of IAN damage. 2 groups: •CBCT (43 teeth) •OPG (43 teeth)	•CBCT group: Temporary IAN sensory disturbance: 1/43 (2,3%) •OPG group: Temporary IAN sensory disturbance: 1/43 (2,3%) •Overall temporary IAN sensory disturbance: 2/86 (2,3%)

Eshghpour *et al.* 2013 (18)	Cross-sectional study	Evaluate the incidence of dry socket among surgical extraction of impacted third mandibular molar.	256 3MM	Patients who underwent removal of impacted third mandibular molar teeth between April 2009 and August 2010.	•Dry socket: 49/256 cases (19,1%)
Selvi *et al.* 2013 (19)	Retrospective study	Identify which factors are associated with postoperative neurosensory deficit after removal of 3rd molars among patients at high risk of injury to the IAN.	235 3MM	Patients at high risk of injury to the IAN who presented for management of 3rd molars between January 2005 and January 2012.	•25 IAN injury (11%)
Guerrero e*t al.* 2014 (6)	Randomised control trial	Comparison of postoperative complications following surgical extraction of impacted third molars using panoramic radiography and CBCT.	256 3MM	Patients referred for surgical removal of one or both impacted mandibular third molars with a moderate risk of potential damage to the IAN. 2 groups: •CBCT (126 teeth) •OPG (130 teeth)	•CBCT group (126 teeth) -Sensory disturbance: 2/126 (1,6%) -Hemorrhage:0 -Infection:5 -Swelling:4 -Trismus:1 -Dry socket:2 -Ecchymosis:3 •OPG group (130 teeth) -Sensory disturbance: 5/130 (3,8%) -Hemorrhage:0 -Infection:6 -Swelling:5 -Trismus:4 -Dry socket:3 -Ecchymosis:4 •Overall: -Sensory disturbance: 7/256 (2,7%) -Hemorrhage:0 -Infection:11 -Swelling:9 -Trismus:5 -Dry socket:5 -Ecchymosis:7
Huang *et al.* 2014 (20)	Clinical study	Use of panoramic radiographic findings to predict postsurgical sensory impairment following the extraction of impacted mandibular third molars.	120 3MM	Impacted mandibular third molars showing proximity between the inferior alveolar nerve (IAN) canal and the roots of the impacted third molar on panoramic radiograph.	•Transient IAN sensory impairment: 13/120 teeth (10,8%)
Frenkel *et al.* 2015 (7)	Retrospective study	Evaluate the success rate of coronectomy and, in the event of failure of the procedure, retreatment.	185 3MM	Patients who underwent coronectomy of the mandibular third molar from December 2008 to October 2012, when OPG indicated proximity of the roots of the molar to the IAN.	•4 weeks post-op: (102 teeth examined) →46 unsatisfactory healing (45,1%) →16 pain (15%) →1 hypoesthesia (0,99%) →15 inflammation (14%) →3 coronectomy failure (2,95%) →3 coronectomy was repeated (because of enamel retention) (2,95%) •6 months post-op: (64 teeth examined) →5 unsatisfactory healing (7%) →3 pain (5%) →66,7% residual roots migration (mean 2,2mm) →1 complete removal (1,6%)

					→1 coronectomy repeated (1,6%) •12 months post-op:(34 teeth examined) →2 unsatisfactory healing (5,9%) →1 pain (3%) →66,7% residual roots migration (mean 3,2mm) →2 complete removal (5,9%) (one because of root migration in the oral cavity and one because of unexplained pain).
Leung *et al.* 2015 (10)	Prospective study	Monitor the long-term morbidities of coronectomy on lower third molars.	612 3MM	Patients with impacted lower third molars that showed one or more of radiographic signs of proximity between the roots and the IAN.	•Neurosensory deficit of IAN: 0,16% (1 case) recovered within 12 months. •Infection: →1 week post-op: 2,9% (18/612 cases) →12 months post-op: 0,19% (1/529 cases) →24 months post-op: 0,24% (1/411 cases) →No incidences of infection at 6, 36 and 60 months post-op. •Pain: →1 week post-op: 31,2% (191/612 cases). Intensity in VAS: 3,2/10 →6 months post-op: 0,50% (3/596 cases). Intensity in VAS: 2,7/10 →12 months post-op: 0,38% (2/529cases). Intensity in VAS: 2,5/10 →24 months post-op: 0,49% (2/411 cases). Intensity in VAS: 2,0/10 •Dry socket: →1 week post-op: 0,16% (1/612 cases). •Root exposure: Overall root exposure: 2,3% (14/612 cases). •Reoperations and Removal of the retained roots: →3,3% (20 cases) required re-operation.
Monaco *et al.* 2015 (11)	Prospective cohort study	Investigate the immediate (up to 1 month) and late (between the 2nd and 36th months) postoperative complications after coronectomy.	116 3MM	•Mandibular molar needing extraction •Presence on OPG of at least one radiographic marker predictive of close contact between IAN and third molar roots •Direct contact between the roots and mandibular canal on CBCT.	•Immediate postoperative complications (up to 1 month after surgery): →Alveolitis: 4% (5 cases) →Swelling: 9% (10 cases) →Pain: 9% (10 cases) →Neurological damage: 0% •Late postoperative complications (1 month to 3 years after surgery): →Pulpitis: 1 case →Root eruption in oral cavity: 4 cases
Pippi *et al.* 2015 (21)	Retrospective study	Assess risks factors associated with IAN damage during extraction.	74 3MM	Patients who underwent extraction between March 2008 and June 2012, presenting on OPG a superimposition between the third molar roots and the upper half of the mandibular canal.	•6/74 (8,1%) of temporary IAN impairment •No intra-operational haemorrhage

Kouwenberg *et al.* 2016 (22)	Retrospective study	Evaluate the outcomes of coronectomy as an alternative to complete removal of the impacted mandibular third molar in patients with a suspected close relationship between the tooth root(s) and the mandibular canal.	151 3MM	Patients who underwent extraction between 2009 and 2013, and who were identified as" high-risk " with regard to inferior alveolar nerve injury on preoperative panoramic radiographs.	• 0% IAN and lingual nerve impairment • 11,3% (17 patients) required second procedure for removal of retained roots due to their eruption above bone level.
Yeung *et al.* 2018 (9)	Prospective study	Describe the long-term, three-dimensional changes of coronectomized lower third molar roots.	57 3MM	Patients who had received unilateral or bilateral lower third molar coronectomy two or more years ago, were asymptomatic at the site of coronectomy and had a preoperative CBCT.	•There was no case with partial eruption and exposure of the root remnant to the oral cavity (mean follow-up time of 7,3 years). •No sign of infection or inflammation in the third mandibular molar region. •Pocket depth at the adjacent lower second molar: distobuccal, distolingual and mid-distal sites ≤ 3 mm in 76.2% of the cases, 4- to 5-mm in 6.7%, and 6- to 9-mm in 7.1% cases. •Mean root migration distance: 2,82 mm
Pedersen *et al.* 2018 (8)	Clinical and radiological study	Examine the long-term morbidity after coronectomy,	231 3MM	Patients who consulted between 2005 and 2016, with a mandibular third molar indicated for removal, showing critical findings seen on cone beam computed tomography (CBCT), who underwent coronectomy.	•1 week post-operative: →IAN change in sensitivity: 8 (3,5%) →Lingual nerve change in sensitivity: 2 (0,9%) →Infection: 27 (11,7%) →Bleeding: 2 (0,9%) •12 months post-operative : → IAN change in sensitivity: 2 (→Lingual nerve change in sensitivity: 0 →Root migration: 191, 5 reaching the oral cavity. → Pocket depth at the adjacent lower second molar : 2mm in 54 cases, 3mm in 82 cases, 4mm in 47 cases, 5 mm in 15 cases, and 6 mm in 2 cases.
Bozkurt *et al.* 2019 (23)	Prospective study	Assess the association between post-extraction nerve injury and direct contact between IAN & 3MM, or canal decorticalization defined with CBCT.	126 3MM	Patients with indication for extraction of an impacted mandibular third molar and the presence of CBCT images confirming direct IAN contact.	•Temporary sensory impairment: 1 tooth (0,8%). •Permanent sensory impairment: 0
Leung *et al.* 2018 (24)	Prospective study	Investigate the long-term behaviour of retained root(s) after coronectomy	356 3MM	Patients with impacted lower third molars that showed one or more radiographic signs of proximity between the roots and the IAN.	•Mean total root migration: →At 6 months: 1,98mm → At 12 months: 2,67mm → At 24 months: 2,92mm → At 36 months: 2,96mm →At 60 months: 2,80mm •Occurrence of root migration post-operative: →At 6 months: 91,1% of the cases → At 12 months:61,4% of the cases → At 24 months: 24,3% of the cases → At 36 months: 2,5% of the cases →At 60 months: 4,2% of the cases.

Sayed *et al.* 2019 (5)	Retrospective study	Investigation of third molars complications after extraction.	625 3MM	Patients who underwent removal of molars between 2007 and 2017.	•Temporary IAN impairment: 9/625 (1,4%) •Permanent IAN impairment: 1/625 (0,2%) •Temporary lingual nerve impairment: 32/625 (5,1%) •Permanent lingual nerve impairment: 3/625 (0,5%)
Sureshkannan *et al.* 2020 (12)	Pilot study	Assess the efficacy of coronectomy to reduce nerve injury during lower third molars surgery.	65 3MM	Patients who reported to Raja Muthiah Dental College during between 2017 and 2019 for surgical removal of impacted 3MM, with a positive screening for nerve-root relationship on OPG.	•7,7% (5 patients) had a complete extraction as the roots were mobilized during procedure. •3,1% (2 patients) developed dry socket. •5,0% (3 patients) had root migration of >2mm in less than 1 year.

Table 1: Relevant data from the selected studies

5. Discussion

5.1 Challenges of mandibular third molars

5.12 Radiologic assessment

The orientation of the tooth is defined within the three planes of space. When still included, in the sagittal plane, the mandibular third molar most frequently has a mesioangular position: 53.8% of cases; but is also encountered in a vertical position to the extent of 23.3%, in a horizontal position in 20.6% of cases, and more rarely, the tooth is in a distoangular position (2.4% of cases). In the axial plane, the tooth may be aligned with the arch or oriented vestibularly or lingually. In the coronal plane, a majority are in position IA (Pell and Gregory's classification) (40.3%), closely followed by IIB (25.3%) and IIA (24%).(25)

Wang *et al.* investigated the relation of the inferior alveolar nerve in regard to mandibular third molar. The position of the mandibular canal was defined in four positions: apical, buccal, lingual or inter-radicular.(26)

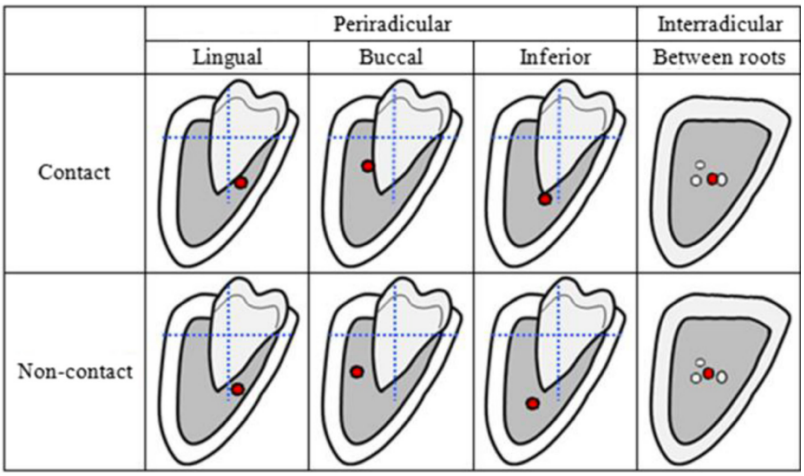

Figure 2 : Classification of the position and relationship of the IAC with the right mandibular third molars using the Cartesian coordinate system.(26)

The inferior position of the canal in regard to the third molar was mostly apical, in 78,8% of the cases. The lingual and buccal position were less frequently observed; respectively with a distribution of 11,7% and 8,8%. The inter-radicular location was met in 0,7% of the cases, which remain relatively infrequent.(26)

Eyrich *et al.* selected in their study mandibular third molars being projected over the entire width of the inferior alveolar nerve on ortopantomographs. The inferior position of the IAN could not be analysed, however, the same pattern of distribution of IAN position was observed, even though amplified. IAN had a buccal position to the molar in 52,8% of the cases, lingual and interradicular position in respectively 37,9% and 7,6% of the cases.(13)

Radiological anatomic relation between the mandibular canal (or inferior alveolar canal) through cone beam computed tomography (CBCT) and 2-dimension radiographs define the canal as two white lines, which delimit it superiorly and inferiorly. Depending on whether it is in contact with the mandibular third molar or not, alterations are to be observed, most of the time, in the upper white line.(27)

Radiologic imaging is so far the only tool capable to reveal a close relation between the roots apexes and the inferior alveolar canal. Orthopantomography and intra-oral radiographs bestow 2-dimensional images.(14)

Among mandibular third molars examined through orthopantomography, most articles focused on 5 specific markers indicating close relation between mandibular third molar root and inferior alveolar nerve:

"Darkening of the third molar root , abrupt narrowing of the third molar root, Interruption and loss of the white line representing the IDC, displacement of the IDC by the third molar root, abrupt narrowing of 1 or both of the white lines representing the IDC" Leung *et al.*.(14)

In the presence of one of these signs, advise to not undergo extraction and opt for coronectomy, or investigate further and realise a cone beam computed tomography can be done.(14)

Since 2015, the European guidelines on radiation protection in dental radiology do not recommend CBCT imaging outside cases where the surgeon needs specific anatomical details, not obtainable through orthopantomography.(28)

Few dental offices are equipped with cone beam computed tomography devices (which offer a 3-dimensional image), and CBCT is more expensive than 2- dimensional images, which is a fact to take into account for the patient.(14)

In the study made by Guerreo *et al.*, which compared the postoperative complications after extraction of mandibular third molars using orthopantomography and cone beam computer tomography, one patient of each group demonstrated temporary impairment of the inferior alveolar nerve.(17)

Guerrero's study was led further, with an increased number of extraction. The CBCT group revealed a slightly lower IAN sensory impairment (1,6%) vs the orthopantomography one (3,8%), after extraction.(17)

Nevertheless, the actual knowledge taken up by a systematic review and meta-analysis by Toledo *et al.*, shows that CBCT does not reduces the incidence of inferior alveolar nerve lesion after such extraction compared to orthopantomography.(29)

5.2 Indications & Contraindications

5.21 Exodontia

The eruption process of the mandibular third molar results in two distinct situations. While most erupt in a non-impacted and functional position, an impaction rate ranging from 9.5 to 68% is observed in different populations, leading to an increased risk of pathologies, requiring tooth extraction.(30)

The most common indications for avulsion are pericoronitis (49% of cases, including 58% of impacted and 3% of non-impacted cases), caries and associated pathologies (27% of cases), development of pathologies in the mandibular second molar, such as distal cervical caries or external root resorption induced by the third molar (14% of cases) and the presence of periodontal disease (5% of cases) often correlated to a lack of oral hygiene, linked to the difficulty of access.(31)

These indications are frequently encountered in impacted teeth, a pathological condition although sometimes devoid of symptoms, in which eruption into a normal and functional position does not occur, mainly due to lack of space or obstruction of another tooth.(32)

Dentigerous or odontogenic cysts (2% of avulsion cases) are most often associated with the impacted third molar, and entirely unerupted, that is, when the tooth is completely covered by bone, soft tissue or both.(31)

In lesser proportions, avulsion is indicated in the absence of pathology and symptoms, such as prior to certain orthognathic treatments (0.80%), orthodontic treatments (0.20%), radiotherapy (0.10%) or implant surgery (0.10%).(31)

Contraindications for exodontia are generally temporary and have to do with the general medical aptitude of the patient for the procedure such as bleeding propensity, immunosuppression, bisphosphonates intake or recent myocardial infarction.(33,34)

5.22 Coronectomy

Coronectomy is mostly studied among third mandibular molars, with precise indications and specific clinical frame. It is indicated when the tooth is vital, fully formed, impacted or erupted, free of periodontal disease, (with an exception for periodontal disease distal to the second molar) of physiological mobility, with indication for extraction and at high risk of iatrogenic inferior alveolar nerve injury.(11,35)

Opinions of whether this intervention can be realized finely on impacted third molars, no matter their classification differ.

Gleeson *et al.* concludes that coronectomy can be safely performed on all types of impacted third molars, noting that the mesioangular impacted one is among the easiest since it offers direct visual access to the root's surface once the crown is removed.(36)

On the other hand, Gady *et al.* advise against performing coronectomy horizontally impacted teeth(1), where difficulties can arise when decoronating. The recommendation goes to fragment the crown in order to avoid a possible iatrogenic injury of the IAN, using the elevator.(36)

In third mandibular molars affected by taurodontism, coronectomy appears to bring a great benefit compared to conventional extraction, preventing inferior alveolar nerve impairment, mandibular fracture and decreasing peri-tecidual morbidity.(37)

Molars associated with dentigerous cysts in closeness to the inferior alveolar nerve also qualify for coronectomy. Not only easing the cyst lining removal, it eliminates the cementoenamel junction and therefore prevents a recurrence, while presenting great both short and long terms outcomes.(38) However, teeth associated with tumours or large cysts should be excluded.(1)

Relatively to pregnancy, invasive, long and non-urgent procedures are better reported, however, if the surgical treatment of the third mandibular tooth at high risk of iatrogenic nervous lesion is necessary, coronectomy remains a plausible solution, that must be adopted on a case-by-case basis.(39)

Local contraindications include non-vital third molars, tumour, caries with pulpal involvement, unphysiological tooth mobility, apical abnormality, association with cystic tissue with poor prognostic to resolve if the root is left in situ or patients scheduled for an osteotomy later on.(1,40)

Coronectomy is not indicated in immature teeth. The apexes' formation not being complete, these are englobed by rests of the follicular sac and therefore, the risk of iatrogenic nervous lesion remains very low.(11)

Systemically, patients at risk of infective endocarditis, poorly control diabetes, undergoing treatments such as immunomodulation, immunocompromised, radiotherapy to the head and neck (previous or planned in the near future), bone disorders of the mandible (osteosclerosis, osteopetrosis) must not undergo the procedure.(40)

5.3 Complications

5.31 Limits of the study

The findings of this study are constrained by the quality of the series and the nature of the variables analysed.

Several articles among the extraction group did not have the purpose of fully reporting all possible complications of the procedure, but only to study particular variables associated with specific complications. (6,13,17,19,21,24)

Christensen *et al.* (2012) and Sayed *et al.* (2019) both included among their study teeth that were not in proximity of the inferior alveolar nerve. (4,5)

Regarding Christensen *et al.*, dental students were attributed non-complicated teeth. Oral surgeons were given the ones in close proximity with the nerve and only these teeth were included in the review.(4)

Sayed *et al.* reported on both upper and lower third molars. Specific data on mandibular third molars were only available regarding inferior alveolar nerve and lingual nerve. However, even if the author mentioned a close relation with the IAN concerning some molars, the proportion is unknown and therefore results from this article might be biased.(5)

Most studies only reported on a few complications, therefore the comparison of complications between exodontia and coronectomy comes from a very limited number of articles.

Among the studies who performed several follow-ups, the number of patients coming back for consultation gradually decreased. Some authors considered the no-show patients as not experiencing any complications. Considering this fact, it is hard to obtain precise rates of late-onset complications.

5.32 Complications encountered in both procedures

Trigeminal Nerve injury

Iatrogenic injury of the trigeminal nerve, in our case its third division, is one of the most common complication following extraction.

The risk factors associated with nerve injury during third mandibular molar surgery involve the age, sex (ration of 5:1 for women) and ethnicity of the patient, the degree of difficulty of the surgery -including the localisation of the tooth in regard to the nerve-, the operator's experience and a lingual access surgery.(19,41)

In 2 studies, nerve injuries recovered within 12 months. Both authors did not classified them as permanent injuries.(10,20) They were therefore included in tables n°1 and 2 in the temporary impairment column.

Some authors did not specify the type of inferior alveolar nerve lesion (temporary or permanent) since the outcome patient follow-up was not in the purpose of their study. (6,14,16,17,19)

Inferior alveolar nerve injury

Injury of the inferior alveolar nerve is the most encountered during third mandibular molar surgery and results in a sensitive impairment ranging from temporary to permanent, causing disfunctions such as anaesthesia or hypoesthesia and often associated with neurogenic disorders being paraesthesia, allodynia or even dysesthesia.(42)

Author	Number of teeth (n)	Incidence of temporary IAN injury (n (%))	Incidence of permanent IAN injury (n (%))	Reported overall Incidence/Teeth (n, (%))
Leung et al. 2011	178	9 (5%)	n/a	Temporary: 125/2392 (5,2%) Permanent: 3/1660 (0,2%)
Eyrich et al. 2011	515	47 (9,1%)	0 (0,0%)	
Guerrero et al. 2012	86	2 (2,3%)	0 (0,0%)	
Neves et al. 2012	63	6 (9,5%)	n/a	
Christensen et al. 2012	114	0 (0,0%)	2 (1,8%)	
Selvi et al. 2013	235	25 (10,6%)	n/a	
Guerrero et al. 2014	256	7 (2,7%)	n/a	
Huang et al. 2015	120	13 (10,8%)	0 (0,0%)	
Pippi et al. 2015	74	6 (8,1%)	0 (0,0%)	
Sayed et al. 2019	625	9 (1,4%)	1 (0,2%)	
Bozkurt et al. 2019	126	1 (0,8%)	0 (0,0%)	

Table 2 : Reported data of each pertinent study on the incidence of inferior alveolar injury after extraction (temporary, permanent, overall)

The temporary IAN impairment rate collected from extractions studies is 5,2%. (125/2392)

Selecting the articles reporting permanent IAN impairment among extractions, an incidence of 0,2% is observed (3/1660).

Eyrich *et al.* reported that a lingual course of the IAN, independently from perforation or not of the lingual cortical plate was increasing the risk of IAN injury.(13) Ghaeminia *et al.* suggests, that when such a situation is of the surgeon's knowledge, to luxate the crown lingually in order for the roots to rotate away from the mandibular canal.(43)

Leung *et al.* reported that "darkening of the third molar root" and "displacement of the IAC by the third molar root" are specific findings correlated with inferior alveolar canal exposure, which can lead to dysesthesia.(17)

A prevalence of 20,8% of IAN impairment - when IAC exposure occurred during the extraction - was observed, in comparison of 2,6% when it was not exposed.(14)

The study observed another marker: "darkening of the third molar root" as a higher risk of inferior alveolar nerve impairment.(14) This last marker has a negative predictive value of 97,7%, sensitivity of 66,7% and a specificity of 74%.(14)

Huang *et al.* on the contrary, did not find any statistical association between darkening of the root and IAN sensory lesion ($p>0,05$), but did find an association with the interruption and loss of the white line representing the IAC and IAN impairment ($p<0,05$).(20)

A correlation between the impaction's depth and inferior alveolar nerve impairment prevalence was also observed : 0% at 0 to 4 mm, 4.6% at 5 to 9 mm, 6.7% at 10 to 14 mm and 50% when superior to 15mm mm(2 of 4) at 0 to 4, 5 to 9, 10 to 14, and greater than 15 mm (Winter's line). The deeper the tooth was impacted, the higher was the prevalence of IAN impairment.(14)

When a superimposition of the IAN on the third mandibular molar root visible on orthopantomography, performing a CBCT is advised to define the difficulty of the procedure, any modification in the IAN course regarding the molar roots and the number of roots as they indicate a risk of nerve injury.(21)

Neves *et al.* investigated the relationship between the presence of haemorrhage caused by inferior alveolar artery and/or vein injury and IAN neurosensory impairment, but no statistically significant association was found.(16)

Author	Number of teeth (n)	Incidence of temporary IAN injury (n (%))	Incidence of permanent IAN injury (n (%))	Reported overall Incidence/Teeth (n, (%))
Leung et al. 2015	612	1 (0,2%)	0 (0,0%)	Temporary: 7/1360 (0,5%) Permanent: 2/1360 (0,1%)
Frenkel et al. 2015	185	1 (0,5%)	0 (0,0%)	
Monaco et al. 2015	116	0 (0,0%)	0 (0,0%)	
Kouwenberg et al. 2016	151	0 (0,0%)	0 (0,0%)	
Pedersen et al. 2018	231	5 (2,2%)	2 (0,9%)	
Sureshkannan et al. 2020	65	0 (0,0%)	0 (0,0%)	

Table 3 : Reported data of each pertinent study on the incidence of inferior alveolar injury after coronectomy (temporary, permanent, overall)

When results of the two tables are observed, coronectomy has much lower rates of temporary IAN impairment: 4,8% after extraction versus 0,5% after coronectomy.

Relatively to permanent injury of the IAN, both procedures reveal low rates (0,3% vs 0,2%). Pedersen *et al.* was the only one to report cases of permanent IAN injury among the reviewed coronectomy studies. The two patients with permanent IAN injury scored 7/10 and 9/10 in the subjective sensitivity scale in the aggrieved area.(8)

IAN impairment could be the result of crown sectioning, when the cementoenamel junction and IAN are very close.(10)

Lingual nerve injury

Encountered as the second most frequent iatrogenic induced injury during third mandibular molar surgery for extraction, and despite precautions to protect it like the standard Terence wards incision, some cases develop lingual nerve impairment such as paraesthesia one day after surgery, which will take nearly six months to completely resolve.(41)

Among the articles reviewed, 5 authors reported on the state of lingual nerve post procedure.

Author	Number of teeth (n)	Incidence of temporary lingual nerve injury (n (%))	Incidence of permanent lingual nerve injury (n (%))	Reported overall Incidence/Teeth (n, (%))
Christensen et al. 2012	114	0 (0,0%)	1 (0,3%)	Temporary: 32/739(4,3%) Permanent: 4/739(0,5%)
Sayed et al. 2019	625	32 (5,1%)	3 (0,5%)	

Table 4 : Reported data of each pertinent study on the incidence of lingual nerve injury after extraction (temporary, permanent overall)

Author	Number of teeth (n)	Incidence of temporary lingual nerve injury (n (%))	Incidence of permanent lingual nerve injury (n (%))	Reported overall Incidence/Teeth (n, (%))
Monaco et al. 2015	116	0 (0,0%)	0 (0,0%)	Temporary: 2/498 (0,4%) Permanent: 0/498 (0,0%)
Kouwenberg et al. 2016	151	0(0,0%)	0 (0,0%)	
Pedersen et al. 2018	231	2 (0,9%)	0 (0,0%)	

Table 5 : Reported data of each pertinent study on the incidence of lingual nerve injury after coronectomy (temporary, permanent, overall).

Sayed *et al.* obtained a much higher rate of temporary lingual nerve impairment than Christensen *et al.* (5,1% versus 0,0%).(4,5)

Both extraction techniques were similar, apart from Sayed *et al.* who performed a lingual flap retraction when raising a buccal mucoperiosteal flap.(4,5)

Anshul *et al.* states that lingual flap retraction is a great adjuvant in the reducing the risk of lingual nerve injury since it improves visibility to the surgical site and eases in performing the surgery.(44)

Furthermore, Sayed *et al.* did not find any statistically significant association between lingual flap retraction and lingual nerve injury.(5)

In a cadaveric study from Al-Amery *et al.*, the course of the lingual nerve was found to be highly variable in the molar region.(45)

The anatomical variations are the plausible causes of nerve damage during the procedure (i.e., during local anaesthesia, incision, flap elevation, flap retraction, during odontosection, extraction and suturing).(45)

Alveolar osteitis

Also termed dry socket or fibrinolytic osteitis, it is a common non-permanent post-surgical complication, but also the most frequent following extraction of mandibular molars(46), and to a lesser extent observed after coronectomy.(10)

After tooth extraction, the formation of a blood clot stabilized by fibrin will induce the formation of bone, but due to the failure of a blood clot to form or remain within the socket, it lets bone exposed to the oral cavity and induce inflammation of the alveolar bone, limited to the lamina dura.(18,47)

Lysis of the blood clot occurs by two pathways activation, the plasminogen direct (physiologic) pathway and the plasminogen indirect (unphysiological) pathway. Direct activators are liberated subsequently to a trauma to the alveolar bone cells, and the indirect', by bacteria. The liver's synthesized substance, plasminogen, is liberated in the blood circulation where it turns into plasmin under the influence of the activators. Plasmin acts upon fibrinogen and fibrin, leading to disintegration of the clot.(48)

The precise pathogenesis of alveolar osteitis remains a subject of study, however, several factors can increase its occurrence.

Third mandibular molars are the site of predilection for dry socket due to thick cortical bone begetting weak perforation of blood supply in the mandible.(49)

Women are more affected than men, in ratio 5:1, due to hormonal fluctuations in endogenous oestrogens occurring during the menstrual cycle. These activate indirectly the fibrinolytic system.(50)

Oral contraceptives, also elevate the fibrinolytic activity of plasma through increasing factors II, VII, VIII, X and plasminogen, thus affecting the clot formation and sustainability through blood lysis.(51)

Nicotine, a component of tobacco and a vasoconstrictor, reduces tissue oxygenation and predisposes smokers to micro-vessels thrombosis through increased platelet adhesion and endothelial cell damage.(51)

Surgical trauma plays a significant part in the development of dry socket.(48)

When high compressive forces are applied on the alveolar bone surrounding the tooth, the necrosis of the osteoblasts lining the socket's surface may start demonstrating fibrinolytic activity, responsible for the blood clot disintegration. The loss of ability for the necrotic osteoblasts to metabolically integrate with the blood clot, also could lead to its dislodgment.(46)

The presence of systemic diseases, like diabetes or immunocompromisation, shows an increased tendency to develop dry socket, owing to altered healing process.(48)

From a microbiological aspect, a specific pattern consisting of the abundant presence of Peptostreptococcus, Parvimonas, Prevotella and Fusobacterium species distinguishes itself in the development and prolongation of dry socket.(46,52)

Bacteria release proteolytic enzymes, destroying the blood clot. The occurrence of dry socket increases among patients with poor oral hygiene and periodontal diseases or infections.(48)

Iatrogenic causes, like inappropriate irrigation among others, seem to play a role in its incidence as well.(18)

However, young patients appear to be less at risk of developing dry socket due to a greater potential of the jaw in term of elasticity and healing through neovascularization.(15)

Symptomatology appears normally two to four days post-procedure and englobes moderate to severe dull and throbbing pain which can irradiate to other parts of the head, halitosis, moderate swelling and redness of the surrounding gum.(53)

Special attention should be paid when using post-extraction medication in the alveolus. If the inferior alveolar nerve is exposed and comes in contact with the drug components, the likelihood of chemically induced neuritis emerges. Without removal of the causative factor, irreversible neuropathy associated with neuropathic pain may develop.(41)

Author	Number of teeth (n)	Incidence of dry socket (n (%))	Reported overall Incidence/Teeth (n, (%))
Christensen et al. 2012	114	2 (1,8%)	172/1211 (14,2%)
Guerrero et al. 2012	256	5 (2.0%)	
Freudlsperger et al. 2012	585	116 (19,8%)	
Eshghpour et al. 2013	256	49 (19,1%)	

Table 6 : Reported data of each pertinent study on the incidence of Alveolar Osteitis after extraction.

Author	Number of teeth (n)	Incidence of dry socket (n (%))	Reported overall Incidence/Teeth (n, (%))
Leung et al. 2015	612	1 (0,2%)	3/677 (0,4%)
Sureshkannan et al. 2020	65	2 (3,1%)	

Table 7 : Reported data of each pertinent study on the incidence of Alveolar Osteitis after coronectomy.

4 authors in the extraction group studied the incidence of dry socket.

In the studies of Christensen *et al.*, Guerrero *et al.* and Freudlsperger *et al.*, the factors of risk increasing rates of dry socket were not considered relevant to enrol patients in the study.(4,6,15)

Christensen *et al.*, through a clinical examination, carried out an anamnesis about the patient health condition including the use of oral contraceptive. The latter was however not relevant for the patient's inclusion in the study.(4)

Eshghpour *et al.* on the other hand collected data on systemic disease, smoking habits, use of oral contraceptive and approximate time in menstruation cycle, among others.(18)

Among the 189 patients of the study, 27 suffered systemic disorders, which revealed posteriorly having no significant difference in incidence of dry socket.(18)

However, smokers and oral contraceptive users were significantly more prone to dry socket, which corroborates the actual knowledge related to risk factors.(18,46,48)

Furthermore, women in the 2nd and 3rd quarters of their cycle had a significantly greater incidence of dry socket, independently from the use of oral contraceptives.(18)

This result coincides with the progressive release of estradiol (endogenous estrogen) in the exact same quarters, during a normal menstruation cycle, being an inevitable risk factor linked with dry socket.(54)

Dry socket among the coronectomy articles was examined by 2 authors. All of them excluded from the study patients with systemic diseases.(10,12)

Assembling the data collected in the studies, the rate of dry socket incidence among the coronectomy records was low: 0,4% and much higher among extraction records: 14,2%.

Coronectomy has a lower risk of developing alveolar osteitis than extraction. It could possibly be improved removing risk factors, when possible.

Infection

Infection following either extraction or coronectomy may occur because of several factors.

Bone retention, important depth of impaction as well as complex anatomical position of the tooth, haemostatic treatment during surgery, and inexperience of the surgeon are the main causes leading to early onset infection.(55,56)

Concerning late-onset infection, literature reports surgical techniques, like ostectomy and tooth sectioning, as risk factors. Furthermore, late-onset infections are more likely to happen following surgical site closure. Through remnants of food entering the osteotomy and odontosection space or extraction created cavity, bacterial invasion cannot be totally prevented. Subsequently, closure of the cavity due to fast healing of the oral mucosa, growth of anaerobic microorganisms is establish within one month.(56)

The simultaneous extraction of both mandibular third molars in the study of Sukegawa *et al.* was statistically related to a higher risk in developing a late-onset infection as it may cause inflammation and trismus, making hygienisation difficult in the molar regions.(56)

Author	Number of teeth (n)	Incidence of infection (n (%))	Reported overall Incidence/Teeth (n, (%))
Christensen et al. 2012	114	5 (4,4%)	26/1580 (1,6%)
Freudlsperger et al. 2012	585	10 (1,7%)	
Guerrero et al. 2014	256	11 (4,3%)	
Sayed et al. 2019	625	0 (0,0%)	

Table 8 : Reported data of each pertinent study on the incidence of infection after extraction.

3 authors observed infection among their study groups, ranging from 1,7% to 5,1%. (4)(15)(6). Guerrero *et al.* and Freudlsperger *et al.* did not give antimicrobials before nor after the extraction procedure, while Christensen *et al.* prescribed it after the surgery on a case-to-case basis.(4)(15)(6)

Sayed *et al.* prescribed antibiotics post-surgery, to all the patients, and three weeks later, during the follow-up consultations, no case (0,0%) of infection was reported.(5)

However, no study performed a follow-up later than 3 weeks after surgery.(4,5,6,15)

The prescription of antibiotics postoperatively seems to be preventing the development of infection.

The incidence of infections late onset, which tend to develop one month after surgery, is not reported, and could play a role in the total incidence of infections after extraction, increasing them.(57)

Author	Number of teeth (n)	Incidence of infection (n (%))	Reported overall Incidence/Teeth (n, (%))
Leung et al. 2015	612	18 (3,0%)	53/1209 (4,3%)
Frenkel et al. 2015	185	3 (1,6%)	
Moncao et al. 2015	116	5 (4,3%)	
Pedersen et al. 2018	231	27 (11,7%)	
Sureshkannan et al. 2020	65	0 (0,0%)	

Table 9 : Reported data of each pertinent study on the incidence of infection after coronectomy.

Sureshkannan *et al.* gave broad spectrum antibiotics for three days after the surgery, and did not observe any infection (0,0%) while Frenkel *et al.* did for a week and observe three cases at the one month follow-up.(7,12)

Monaco *et al.* prescribed antibiotics to be taken just before the procedure, and for four days after it. 5 alveolitis (presence of purulent exudates) were recorded 1 week postoperative.(11)

In the studies of Leung *et al.* and Pedersen *et al.* on the other hand, no antimicrobials were prescribed to patients, and both of their studies show infections (3,0% and 11,7% respectively).(8,10)

The administration of antibiotics during the perioperative period appears to reduce the onset of postsurgical infections.

In all four studies, patients were asked to come back for follow-up consultation during the first week after coronectomy, and were gradually followed up to a year or five, depending on authors, which permitted the inclusion of late-onset infections in the table data.(7,8,10,12)

Comparing the results obtained among the two groups, the coronectomy procedure seems to be at higher risk of developing infection than extraction (4,3% versus 1,6% respectively), even though late-onset infections data were not reported from the authors of the extraction group.

Relatively to remnants roots that could be causing infection, in a study of Sencimen *et al.*, significant rates of infection were observed in roots that had undergone pulpal treatment.(58)

None of the reviewed coronectomy studies had performed pulpal treatment on the root remnants.

Literature reports higher rates of infection among root remnants that underwent pulpal treatment, while untreated roots show healing with osteo-cementum formation.(58,59)

Swelling

Swelling was recorded by 2 authors, in each groups. Guerrero *et al.* was the only one to define what would be registered as swelling :"*obvious facial asymmetry* ".(6) However, swelling is a subjective characteristic, difficult to quantify.(6)

Postoperative swelling was evaluated by patients on a daily basis, starting on the day after surgery, using a scale from 0 to 3.(14,18) Swelling was considered a complication if present for 2 days or more during the first postoperative week.(11)

The length of the surgery did not appear to affect the occurrence of swelling.(4)

Author	Number of teeth (n)	Incidence of swelling (n (%))	Reported overall Incidence/Teeth (n, (%))
Christensen et al. 2012	114	28 (24,6%)	37/370 (10,0%)
Guerrero et al. 2014	256	9 (3,5%)	

Table 10 : Reported data of each pertinent study on the incidence of swelling after extraction.

Author	Number of teeth (n)	Incidence of swelling (n (%))	Reported overall Incidence/Teeth (n, (%))
Monaco et al. 2015	116	10(8,6%)	25/301 (8,3%)
Frenkel et al. 2015	185	15 (8,1%)	

Table 11 : Reported data of each pertinent study on the incidence of swelling after coronectomy.

Extraction showed to lead to a higher incidence of postsurgical swelling than coronectomy (10,0% versus 8,3% respectively).

Bleeding

A study realized by Pogrel *et al.* situates the inferior alveolar vein the most superiorly in the mandibular canal. It is also observed that the inferior alveolar artery has a lingual course when compared with the inferior alveolar nerve location.(60)

The author also states that an injury of the vein will result in a slow bleeding ("oozing") while a damage to the artery will generate a more abundant bleeding.(60)

It is of our understanding that when bleeding occurs, the roof of the mandibular canal is very likely breached, and profuse bleeding could be setting off alarm bells on a probable nerve injury.

Author	Number of teeth (n)	Incidence of bleeding(n (%))	Reported overall Incidence/Teeth (n, (%))
Neves et al. 2012	63	5(8,0%)	50/433 (11,5%)
Christensen et al. 2012	114	45 (39,5%) (post-op)	
Guerrero et al. 2014	256	0(0,0%)	

Table 12 : Reported data of each pertinent study on the incidence of bleeding after extraction.

Neves *et al.* reported 5 cases (out of 63) of bleeding during extraction surgery, and in two cases, bleeding and IAN deficit happened concurrently.(16)

In the study of Christensen *et al.*, the postoperative patient-reported bleeding rates were collected from the group operated by oral surgeons, as the group operated by dental students was made of mandibular third molar that were not in close anatomical proximity of the inferior alveolar nerve.(4) 39,5% of the patients reported bleeding at the follow-up consultation one week after surgery, but the amount, duration and onset of the bleeding are not developed.(4)

Guerrero *et al.* did not report any case of bleeding, most likely because despite the proximity of the mandibular third molars with the inferior alveolar canal, the tooth extracted were at "moderate risk" of nerve injury, and therefore not so close from the inferior alveolar vein and artery.(6)

Concerning the coronectomy procedure, Pedersen *et al.* was the only one to report on postoperative bleeding in two cases (out of 231). The cause of bleeding is not detailed, but it could be from traumatic origin, while eating or performing oral hygiene routine.(8)

Author	Number of teeth (n)	Incidence of bleeding (n (%))	Overall Incidence/Teeth (n, (%))
Pedersen et al. 2018	231	2(0,9%) (post-op)	2/231 (0,9%)

Table 13 : Reported data of each pertinent study on the incidence of bleeding after coronectomy.

Bleeding appears to be more prevalent in extraction procedure (11,5%) than in coronectomy (0,9%).

Pain

Pain was reported twice in the referenced extraction articles.

According to Christensen *et al.*, pain remained stable between the first 4 to 8 hours after extraction and decreased drastically after 24 hours.(4)

Sayed *et al.* included in their study, the prevalence of pain as part of a complex inflammatory response characterized by swelling, pain and trismus. A rate of 0,6% was reported at the 3 weeks follow-up consultation.(5)

Pain was assessed by 4 authors among the coronectomy articles.

3 authors used a visual analog scale (VAS) to quantify its intensity, while one did not define it.(8,10-12)

Analgesics were prescribed postoperatively except in the study of Sureshkannan *et al.*. This latter reported a postoperative pain incidence of at least 4 out of 10 (VAS) of 3,1%. It is however unclear as when pain was recorded since the author mentioned follow-up consultation were organized in 8-months to a year period, but mentioned the integration of pain as a complication if it occurred at least 24h after the coronectomy.(12)

Monaco *et al.* considered pain as a complication if it went over a period of 3 days during the postoperative week. Within the first month after surgery, 9% of the cases reported pain.(11)

From the second month to the twelfth following the procedure, 4 patients reported pain; 3 of them because of a periodontal disease and one with pulpitis. (11)

In the study of Leung et al. (2015), pain reported at one week after surgery was low: 3,2 out of 10, but present among 31,2% of the cases. At 6 months, 0,50% of the cases had pain (VAS: 2,7 out

of 10). Low rates of patients kept recording decreased degrees of pain in the following months, to finally reach 0,0% at the 36th month post-procedure until the final follow-up consultation.(11)

Pain, difficult to quantify since highly sensitivity-dependent, seems to be more studied after coronectomy, as roots remnants are left in situ and pulpal tissue left alive.

5.33 Exodontia-specific complications

Trismus

Trismus is usually the result of severed muscle tendon through repeated muscle stimulation during surgery or multiple anaesthesia injections leading to inflammation of the area. Trismus normally resolves within 2 weeks.(61)

Trismus was evaluated by three authors.(4–6)

Guerrero *et al.* defined it as a "mouth opening of <25mm postoperatively ".(6)

The author reported an occurrence one week after surgery of 2,0%. However, the study only included molars at moderate risk of IAN injury, which could mean the surgery is less perilous and lengthy than molars at high risk, resulting in less muscular trauma and thus a lower rate of trismus.(6)

Sayed *et al.* assessed trismus along with swelling and pain, and observed it in 2,1% cases among maxillary and mandibular third molars.(5)

Christensen *et al.* reported 86,6% of trismus, following extraction performed by oral surgeons.(4)

Ecchymosis

Ecchymosis was assessed by Guerrero *et al.*, and defined as "presence of blue spots on the side operated". A prevalence of 2,7% was reported at the follow-up one week after extraction.(6)

5.34 Coronectomy-specific associated complications

Root migration and need of second procedure for roots removal

It has been observed that after coronectomy, the retained roots tend to migrate, mostly asymptomatically in direction of the oral cavity. Their evolution is reported through radiographs, realised during follow-up consultations.(8,24)

Perdersen *et al.* reported different patterns of migration, among which the mesio-coronal movement was the most frequent, followed by the coronal and mesial ones.(8)

Studies show variables percentages of root migration away from the mandibular canal, ranging in the above analysed records values between 80,0% and 97%.(8,9,11,24)

Regarding the speed of migration, several factors seem to play a role, such as sex of the patient, age and tooth status i.e. pattern and depth of impaction, root form and eruption status. Leung *et al.* found that roots of distoangularly impacted mandibular molars were less likely to show migration compared to vertical, mesioangularly and horizontal ones in the 6 months following the procedure.(24)

In the study conducted between 2005 and 2009 by Kohara *et al.*, patients aged 29 years had a greater root migration distance than the ones in theirs 30s and 40s. Remnants of eruption forces due to the root apexification occurring until 25 years old and the densification and sclerosis of the bordering bone in older patients could play a role in the migration process.(35)

Age plays a role in root migration; for every year increase in age, Leung et al. (2018) and Kouwenberg et al. (2016) reported that root migration was reduced by 0,203mm and 0,047mm respectively.(11,22,24)

This negative correlation is in agreement with the findings of other authors.(9)

However, neither did sex, eruption status, depth of impaction and root form appeared to be correlated with root migration at any follow-up interval.(9,22,24)

Roots migrate the most during the 6-12months following the procedure and tend to stabilize around the 24th month postoperative.(8,9,24)

In the study of Leung *et al.*, the mean migration distance at 6 months was 1,98mm, at 12 months 2,67mm, at 24 months 2,92mm, at 36 months 2,96mm and at 60 months 2,80mm.(10)

The negative mean root migration at 36–60 months is likely due to the root migration outliers, which ultimately led to root exposure and subsequent root removal at a time point later than 36 months postoperative.(10)

During the first 6 months after coronectomy, 91,1% of the roots had migrated, while between the 6th and 12th month after procedure, 61,4% had.(24)

At 24 months postoperative, a small portion of roots had kept migrating (24,3%), but it is around that time they started stabilizing step-by-step, as further migration was being observed in only 2,5% and 4,2% at 36 and 60 months respectively.(24) Similar results are to be observed from different authors.(8,35)

Very few migrations into the oral cavity are observed, ranging in the analysed articles from 0,0% to 3,4% leading to a second surgical procedure for roots removal. None of the second procedures caused IAN injury.(8,9,11,12)

Percentages remain low presumably due to the surgery procedure, which consists in resecting the tooth 3-4mm below the edge of the alveolar bone to keep away the roots from the risk of exposure in the oral cavity due to migration.(7,8,12,22,24)

Yeung *et al.* reported that no cases required root extraction caused by eruption in the oral cavity after the second year post coronectomy.(9)

The turning point in term of eruption of the root in the oral cavity appears to be during the second year post procedure since migration distance decreases after that.(11)

Factors leading to the interruption of root migration are not yet clarified.

However, in the study conducted by O'Riordan *et al.* , the formation of bone coronally to the root seems to suggest the ending of the root's migration.(62)

Incomplete coronectomy

Coronectomy, consisting of separating the tooth crown from its roots while preserving as much buccal bone as possible, despite looking like a straightforward procedure can reveals itself difficult to perform depending of the tooth angulation.(63)

Enamel lipping is the remnant resulting from the fracture line obtained through a fissure bur cut and elevator to split the tooth horizontally.(63)

Enamel is not vascularized and is therefore considered a foreign body by the surrounding tissues which will prevent the socket to heal properly.(63)

In order for the coronectomy to be completed and not compromised, a surgery to remove the enamel lipping is necessary.(63) 2 authors reported the necessity to repeat coronectomy due to enamel lipping, in low rates: 0,2% and 2,2%.(7,10)

Frenkel *et al.* advises to get an immediate postoperative orthopantomography in order to make sure no enamel remains, and if not, to repeat the procedure to avoid future infection.(7)

Root mobilisation leading to total extraction

Rates of intra-operative root mobilization was reported by two authors. Root mobilization, also considered as failed coronectomy in the reviewed articles, happens when excess force is used to fracture the crown, caused by an incomplete sectioning between the root and crown.(12)

Sureshkannan *et al.* observed 5 failed coronectomies out of 65 cases (7,7%), of which, all the mobilized roots (luxated or unintentionally removed) were conical.(12)

No failed coronectomy was reported from Monaco *et al.*, among a study population made of 116 third mandibular molars.(11)

Wound healing

Monaco *et al.* assessed secondary intention healing as healing of the wound with the alveolus exposed in the oral cavity, and observed 9 cases between one month and three years after the procedure. Of these cases, none of them presented any postoperative complication.(11)

Frenkel *et al.* reported at one month follow-up (out of 102 teeth) 46 showing evidence of sinus opening, at 6 months follow-up (out of 64 teeth) 5 that were still unsatisfactorily healed at 12 months follow-up (out of 34 teeth) 2 who had failed to heal, presenting a sinus opening.(7)

It was in the understanding of the author that patients who did not present for follow-up consultations were not undergoing any complications.(7)

Periodontal pockets

Periodontal depth was assessed by four authors. Three of them released measurements of the distal site of the second mandibular molar adjacent to the remnant roots of the mandibular third molar over periods of time going from 6 months up to 7,3 years.(7–9)

Frenkel *et al.* stated that the most frequent diagnosis leading to the need for extraction; in this case, coronectomy, among the study population was pericoronitis. Periodontal depth was measured 6 and 12 months after the procedure, with respectively a mean of 4mm and 3,8mm on the distal site of the adjacent mandibular second molar.(7)

Yeung *et al.* observed at the follow-up examination which took place, on average, 7,3 years after the coronectomy, that pocket depths on three distal sites (distobuccal, distolingual and middistal) of the adjacent second molar were for the most part ≤ 3mm (76,2%) and to a lesser extent 4-5mm (16,7%) and 6-9mm (7,1%).(9)

5 years after coronectomy, Pedersen *et al.* reported pocket depths distal to the adjacent second molar of 2mm (27,0% of cases), 3mm (41,0% of cases), 4mm (23,5% of cases), 5mm (7,5% of cases), 6mm (1,0% of cases).(8)

No periodontal probings of the adjacent second molar were realized prior to surgery.(7–9,22) It is therefore unknow if a local periodontal pathology was present before the coronectomy procedure, but as shown by Frenkel *et al.* it seems there is a tendency for decrease of the pocket depth distal to second molar over time. Yeung *et al.* and Pedersen *et al.* report the same tendency with pocket depth values tending to normalize.(8,9)

Age was not found to be related to the formation of deep pockets on the distal site of the adjacent molar, such as depth of the pocket was not a positive predictive value for coronectomy failure.(7,22)

6. Conclusion

In the last decade, coronectomy gained popularity among oral surgeons as it was introduced with the purpose of decreasing one major complication arising from extraction: Inferior alveolar nerve impairment, often providing grounds for medicolegal cases.

Coronectomy, in all the reported series reviewed, was associated with a decreased occurrence of nervous lesions, although it did not eliminate them completely. On the other hand, coronectomy was associated with higher infection rates than extraction.

Root remnants left in situ are at risk of migration and eruption in the oral cavity. However, percentages remain very low and combined with bone grafting technique this complication could disappear.

Extraction, a more radical procedure, goes along with considerable rates of dry socket, swelling and bleeding which can take several weeks to resolve.

In light of the results obtained, coronectomy seems to be an interesting alternative to extraction as it widens the spectrum of care of many pathological mandibular third molars that cannot be conservatively treated.

All things considered, “primum non nocere” requires considering all possible options to safeguard the patient’s best interest.

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