J Oral Med Oral Surg 2023;29:1
https://doi.org/10.1051/mbcb/2022032

https://www.jomos.org

JOMOS
Journal of Oral Medicine and Oral Surgery

Systematic Review

Does surgical removal of mandibular third molar influence the periodontal status of the adjacent second molars? A systematic review

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(Received: 29 July 2022, accepted: 7 November 2022)

Keywords:
Third molar surgery / impacted tooth / flap design / periodontal defect / periodontal healing

Abstract – Objective: This study aimed to assess the influence of mandibular third molar surgical removal on the periodontal status of adjacent second molars and to investigate the potential impact of the flap design. **Methods:** A systematic review of the literature, registered in PROSPERO, has been carried out from Pubmed and Scopus databases following PRISMA guidelines from January 2010 to January 2022. PICO method was used to select the relevant articles. Studies comparing the periodontal status of the second molar before and after mandibular third molar removal were considered. **Results:** Twenty-three studies involving 1067 patients were included. The two main parameters studied were periodontal pocket depth and clinical attachment level. The envelope flap and the triangular flap were the most commonly used flap techniques. Periodontal health of adjacent second molar was maintained or improved in most of the included studies. The flap design did not seem to have a significant influence either. **Conclusion:** Avulsion of impacted third molar in healthy young adults does not impair the periodontal health of adjacent second molars. Further studies, with higher levels of evidence, are needed to confirm these results and to identify possible risk factors (such as age, impaction depth or periodontal disease) responsible for poorer healing.

Introduction

Third molars are the most frequently impacted teeth, meaning that they cannot erupt into their normal functional position [1]. Their average worldwide rate of impaction is 24.40%, with a significantly higher risk for mandibular third molars (57.58%) [2]. Impaction could be related to several parameters such as inadequate space to allow tooth eruption or a mechanical obstacle (contact with the second molar, cyst or tumor, *etc.*) [1–3]. Partially or completely impacted third molar can also cause complications, such as recurrent pericoronitis, decays of the third or the second molar, second molar external root resorption or periodontal damages, thereby indicating their avulsion [4–6].

Surgical removal of third molars is one of the most common procedure in oral and maxillofacial surgery, which is carried out under local or general anesthesia [3,7,8]. The removal of the impacted third molar first requires raising a full-thickness mucoperiosteal flap for proper visibility of the surgical site, usually followed by an osteotomy depending on the impaction depth [9,10]. Several well-known potential postoperative complications can occur after third molar removal such as pain, facial swelling, local bleeding, infection or nerve damage thus leading to impaired oral functions and discomfort [8,11,12]. Most of these complications can be prevented or controlled by local treatment.

Periodontal health of the adjacent second molar following mandibular third molar extraction is another frequently reported concern. As early as 1973, Gröndahl *et al.* have been interested in the supporting tissues of the distal surfaces of mandibular second molars in this context. They demonstrated a significant decrease in pocket depth distal to the second molar one year after third molar avulsion [13]. Since then, numerous studies with often contradictory results have been conducted in this field [10,14–19]. Although this parameter has thus been studied since the early 1980 s, there is still no consensus concerning the effects of impacted lower third molar removal on periodontal status of the adjacent second molar. Some studies even recommend guiding tissue regeneration procedures, filling of third molar sockets, or orthodontic extraction of mandibular third molar, to prevent or limit postoperative

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periodontal damages and to maintain the periodontal health of the second molars [4,20–25]. Furthermore, there is also no consistent data to select a flap design that would prevent periodontal defects [5,10].

This study thus aimed to perform a systematic review assessing the effect of impacted lower third molar removal on periodontal health of adjacent second molars. The second objective was to investigate the potential impact of the flap design performed during surgery.

Materials and methods

This review was performed according to the criteria of the Preferred Reporting Items for Systematic reviews and Meta-analyses (PRISMA) system [26]. The present study has also been registered in PROSPERO database (N°CRD42021249919).

Study design

The search strategy was developed based on the PICO reporting system. The following focused question was defined: "What's the influence of lower third molar removal on periodontal health of adjacent second molars? Does the flap design influence periodontal health of adjacent second molars?"

PICO question

- Population: Patients with at least one impacted or partially impacted lower third molars requiring avulsion.
- Intervention: Lower third molars removal.
- Comparators: Periodontal parameters measured before and after surgery.
- Outcomes: Effect of the avulsion, and/or the flap design performed, on the periodontal status of adjacent second molars.

Search strategy and selection criteria

An electronic search of the MEDLINE _ Pubmed and Scopus databases was carried out using the following search combination: " ("Third molar" OR wisdom) AND (second molar) AND (periodontitis OR "bone loss" OR PPD OR CAL OR attachment OR pocket OR flap)". This research was completed manually through the list of references of all publications included by the search.

We searched for clinical studies published in English from January 2010 to January 2022. Studies comparing periodontal status of adjacent second molars before and after impacted mandibular third molars removal and/or comparing different flap designs were considered. Only randomized and prospective clinical trials were included. Retrospective studies, case series and case reports were thus excluded.

Screening of studies and data collection

Following the eligibility criteria defined beforehand, three independent reviewers (LM, MR and MF) performed the article selection and data extraction. After duplicates removal, titles and abstracts were screened in the first time according to the following questions: "What's the influence of impacted lower third molar removal on periodontal health of adjacent second molars? And did the flap design can influence the periodontal health of adjacent second molars ?". Full-text articles were then assessed, and finally, the article selection was made. Any disagreement between the reviewers on the eligibility of particular studies was resolved through discussion with a fourth reviewer (SC). Data were finally extracted using structured generated tables. Collection of data such as the type of study, number of patients included, study duration, periodontal parameters or flap design were reported and synthetized in data boards.

The risk of bias assessment was carried out using the Cochrane collaboration risk of bias and RoB 2 tools [27,28]. For each study, the overall judgment was low risk of bias in case of achieving low risk in all domains, unclear risk in case one or more domains demonstrated unclear risk, and high risk when having at least one high risk domain [29]. Finally, data analysis was performed in a descriptive way, since the information obtained did not enable meta-analyses.

Results

Search outcomes

Initial research generated 152 potentially relevant articles from Scopus and 194 from PubMed databases. Elimination of duplicates led to 296 publications. After screening titles and abstracts, 29 publications were retained for further investigations. Then, a selection was made based on the full text of articles and eight articles were excluded for not meeting the inclusion criteria. Furthermore, two articles were selected thanks to the manual research in the bibliography of the chosen articles. Finally, 23 studies involving 1067 patients requiring impacted or partially impacted lower third molars removal were included in this systematic review and the follow-up duration spanned between two weeks to two years (Tab. I). The selection process is shown in Figure 1 (flowchart). Risk of bias ranged from low to high with a high risk for the vast majority of included studies. Detailed results of risk of bias assessment are presented in Figures 2 and 3. Finally, a wide heterogeneity of the measurement methods was observed making impossible to compare them.

Periodontal parameters

Periodontal pocket depth (PPD) and clinical attachment level (CAL) were the most investigated parameters, followed by plaque index, gingival index, bleeding on probing and gingival recession (Tab. II).

Table I. Characteristics of the included studies comparing adjacent second molar periodontal health.

Author	Objective	Study design	Number of subjects	Mean age ± Standard deviation (Min–Max)	Study duration
Ahmad M, 2021	To compare the influence of two flap designs on the periodontal status of M2	Randomized controlled trial	60	23.22 ± 3.17	6 months
Alqahtani NA, 2017	To compare the influence of two flap designs on post-operative outcomes and the periodontal status of M2	Randomized, split-mouth cross-over comparative study	60	(18–41)	3 months
Aniko-Włodarczyk M, 2021	To evaluate the effect of M3 removal on the periodontal status of M2	Interventional, prospective study	60	24. 82 ± 5.51	2 months
Baldini N, 2015	To compare the influence of two flap designs on the periodontal status of M2	Randomized, single-blinded, comparative and prospective study	52	37.8 (18– 46)	6 months
Baqain ZH, 2012	To compare the influence of two flap designs on post-operative outcomes and the periodontal status of M2	Randomized, split-mouth cross-over, comparative, prospective study	19	21.4 ± 2.3	4 months
Briguglio F, 2011	To compare the influence of three flap designs on post-operative outcomes and the periodontal status of M2	Randomized, double-blinded, comparative and prospective study	45	(18–41)	24 months
Desai A, 2014	To compare the influence of two flap designs on post-operative outcomes and the periodontal status of M2	Randomized, interventional, comparative and prospective study	30	25 (20– 30)	15 days
Dicus-Brookes C, 2013	To assess the impact of M3 removal on the periodontal status of M2	Interventional, prospective study	69	21.8 (20–25)	3 months
Fakour SR, 2017	To compare the influence of two flap designs on the periodontal status of M2	Randomized, single-blinded, split-mouth cross-over comparative study	25	42.8 ± 3.2	2 months
Faria AI, 2012	To compare the influence of two flap designs on post-operative outcomes and the periodontal status of M2	Interventional, prospective study	25	21.03 ± 4.38	12 months
Kim H-R, 2011	To compare the influence of flap and flapless extractions of M3 on post-operative outcomes and the periodontal status of M2	Randomized, split-mouth cross-over, comparative, prospective study	30	27 (19–49)	3 months
Korkmaz YT, 2015	To compare the influence of two flap designs on post-operative outcomes and the periodontal status of M2	Randomized, single-blinded, split-mouth cross-over comparative and prospective study	28	22.43 ±3.02 (18–28)	3 months
Laurito D, 2016	To compare the influence of two flap designs on post-operative outcomes and the periodontal status of M2	Interventional, prospective study, double blind	24	22.42 ±3.45	2 months
Melo Stella PE, 2017	To evaluate the effect of M3 removal on the periodontal status of M2	Interventional, prospective study	23	20.3	6 months

Table I. (continued).

Author	Objective	Study design	Number of subjects	Mean age ± Standard deviation (Min–Max)	Study duration
Montero J, 2011	To assess the impact of M3 removal on the periodontal status of M2	Interventional, prospective study	48	23.01	12 months
Mudjono H, 2020	To compare the influence of two flap designs on the periodontal status of M2	Prospective, split-mouth study	15	(19–26)	1 month
Ottria L, 2017	To assess the impact of M3 removal on the periodontal status of M2 comparing three flap designs	Interventional, prospective study	150	(14–21)	3 months
Passarelli PC, 2019	To assess the impact of M3 removal on the periodontal status of M2	Interventional, prospective study	89	35 ± 18.7 (18–81)	6 months
Petsos H, 2016	To assess the impact of M3 removal on the periodontal status of M2	Interventional, prospective study	78	16 ± 2	6 months
Pham T, 2019	To assess the impact of M3 removal on the periodontal status of M2	Interventional, prospective study	38	21.89 ± 2.74	6 months
Silva JL, 2011	To assess the impact of M3 removal on the periodontal status of M2 comparing two flap designs	Split-mouth cross-over, comparative, prospective study	24	23 (14–33)	3 months
Sridharan G, 2020	To compare the influence of two flap designs on post-operative outcomes and the periodontal status of M2	Randomized, single-blinded, split-mouth cross-over comparative study	25	26.5 (18–35)	1 month
Tabrizi R, 2013	To assess the impact of M3 removal on the periodontal status of M2	Interventional, prospective study	50	20.9 (18–25)	6 months

M2: second molar.

Periodontal pocket depth

A measurement of PPD was performed in 22 studies (Tab. II). Number of site assessed in these studies ranged from 1 to 7 and three articles did not mention how many measurements were performed.

PPD evolution before and after surgery

Pre and postoperative measurements of the PPD were carried out and communicated in 16 articles. Among these 16 studies, ten studies showed a significant decrease in PPD distal to the second molar after lower third molar removal [30–39] whereas five studies showed a significant increase [5,9,40–42]. One study did not observe significant difference in PPD values before and after surgery [43].

Relation between PPD and age

Only one study investigated the correlation between age and pocket depth [35]. Multiple linear regression model showed that older subjects (average age 55 years +/– 16.2 with a range of 26 to 81 years) presented at endpoint more pockets >4 mm than the group of young participants.

Relation between PPD and mandibular third molar position

Tooth position was reported in 14 articles and its potential effect on PPD was investigated in only four publications [33–35,37]. Two studies were based on Pell & Gregory classification (I, II, III then A, B and C) [34,35]. The first study showed that PPD measurement before surgery was significantly higher when the wisdom tooth was deeply impacted [35]. However, no significant difference between the three groups was evidenced after the surgery with values ≤4 mm. Stella *et al.* also observed that whatever the tooth position or the time of follow-up, PPD measurements never exceeded 4 mm [34]. In two studies, mandibular third molars were classified into "superficial molars" or "deep molars" by assigning a score from the Pell & Gregory classification [33,37]. Montero *et al.* showed that the "deep molars group" had a

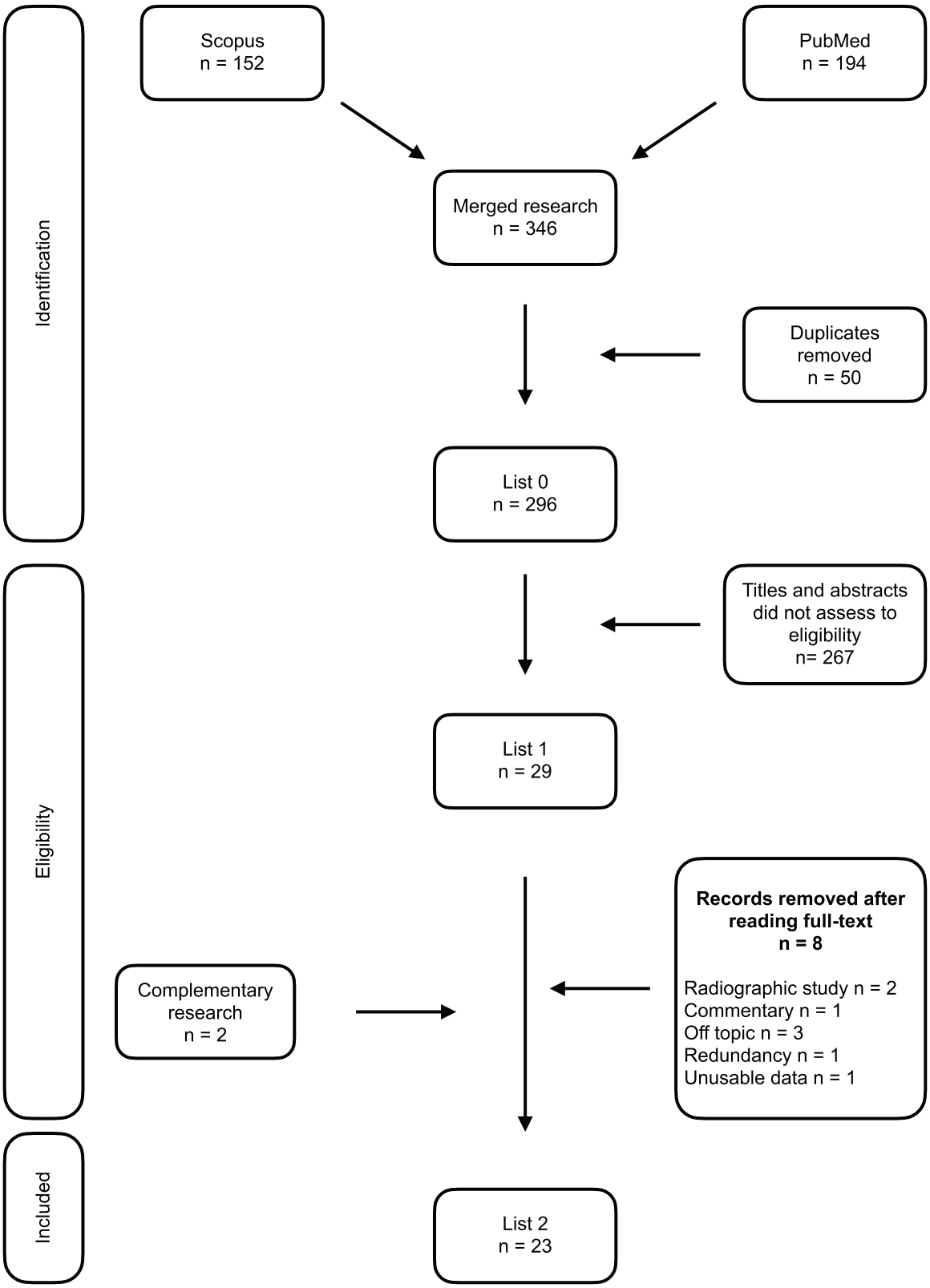

Fig. 1. Flow diagram of the screened publications.

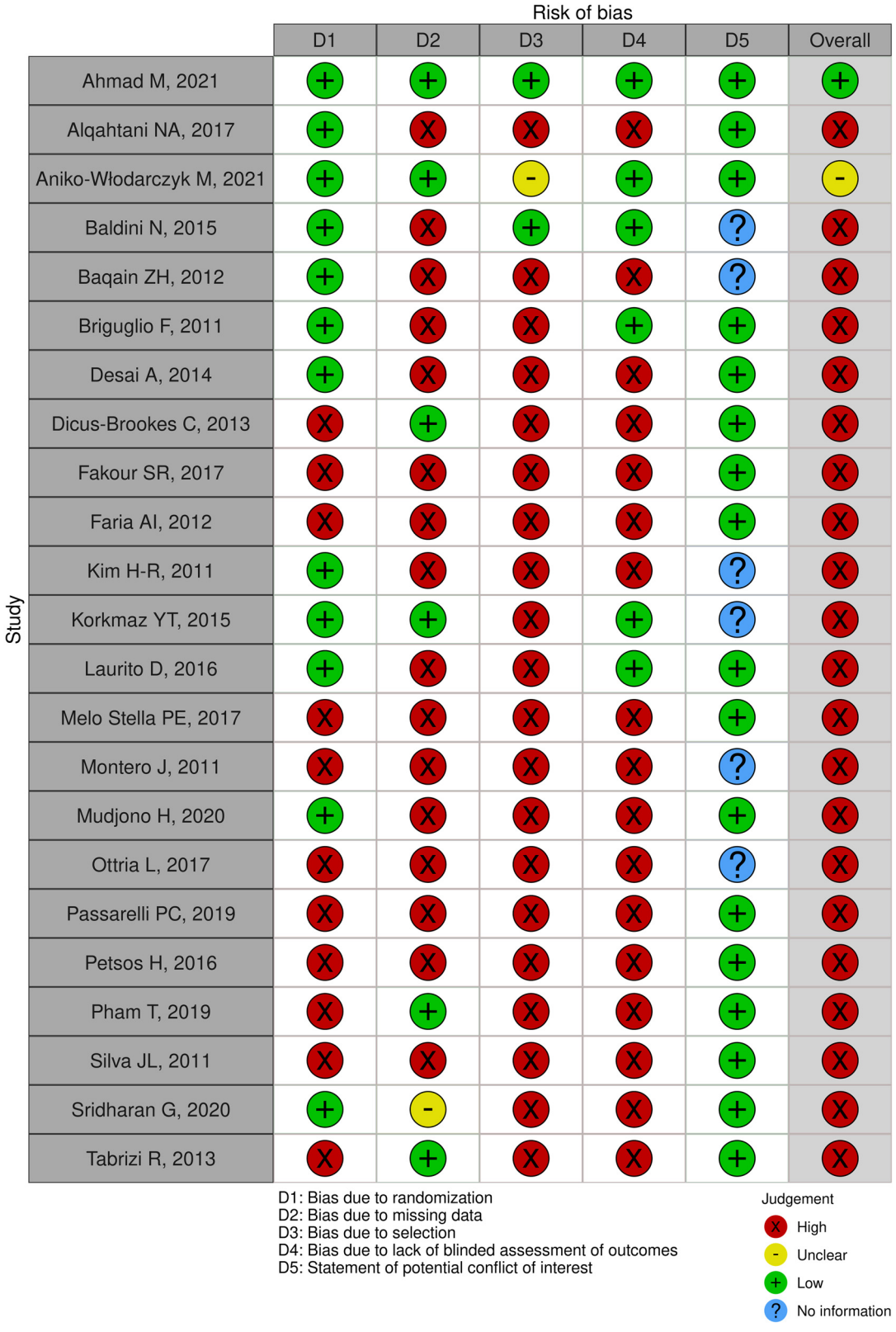

Fig. 2. Quality assessment of the included studies. Quality assessment of each included study using the Cochrane Risk of Bias Tool 2.

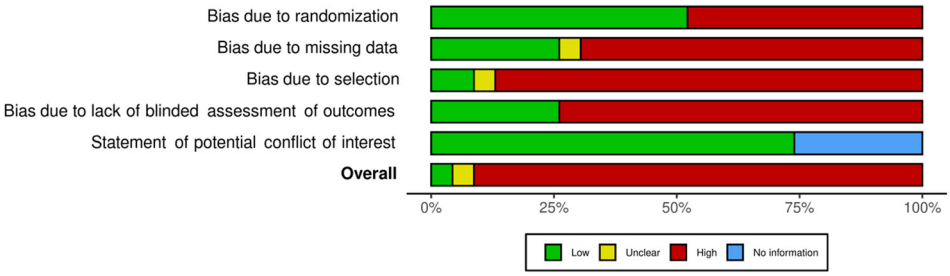

Fig. 3. Risk of bias summary for the included studies using the Cochrane Risk of Bias Tool 2.

significantly greater initial PPD compared to the "superficial molars group". However, the reduction of the PPD at final time in this group was significantly greater than in the superficial molars group [33]. Pham *et al.* did not observe significant difference of PPD between both groups before and after surgery [37].

PPD evolution in patients with initial pocket depth higher than 4 mm

Seven studies focused exclusively on patients without pre-existing periodontal pockets (PPD $<$ 4 mm) [9,10,32,34,37,41,44], while others included patients regardless of their initial PPD measurements. In most cases, the same trend of PPD decrease was observed, even if some persistent pockets of more than 4 mm according to the initial values were observed.

Only one study included impacted third molars with distal periodontal defects located in the second molars with a PPD superior to 7 mm [31]. A significant decrease of the PPD was observed but the mean distal PPD remained above 4 mm. Another study included patients with an average distal PPD of 4.32 mm at baseline that decreased below 4 mm after three months [30]. In one study, 86% of the second molars showed periodontal pockets $\geq$4 mm in at least one of the six sites analyzed [45]. After three months, 45% of the mandibular second molars remained with at least one periodontal pocket $\geq$4 mm. However, there were significantly more teeth with at least one periodontal pocket $\geq$4 mm before than after surgery. Another study included 72 mandibular second molars (over 89 teeth) presenting a mean distal PPD of 5.85 +/− 1.2 at baseline [35]. After 6 months, 73,6% of mandibular second molar had a mean distal PPD inferior to 4 mm.

Clinical attachment level

Ten studies investigated the clinical attachment level (CAL). The sites assessed in these studies ranged from 1 to 6. A significant decrease in CAL value was observed in eight studies [9,31,35–38,43,46], whereas two studies reported a significant increase in CAL after surgery [32,42].

Plaque index

The plaque index (PI) was evaluated in seven studies. The site assessed in these studies ranged from 1 to 6 and two articles did not mention the number of measurements performed.

Four studies showed a significant decrease of the PI [32,33,35,37], whereas a significant increase of the PI was reported in two studies [9,43]. This could be explained by short-term measurements after the surgery (only two weeks): this could be a difficult period for patients to maintain good oral hygiene due to post-operative pain and discomfort. Finally, one study did not observe any significant difference concerning the PI before and after surgery [43].

Gingival index

Seven studies investigated the gingival index (GI) [5,32,33,35–38]. The sites assessed in these studies ranged from 4 to 6. Among the seven studies, four studies showed a significant decrease in GI after lower third molar removal. One study showed a significant increase of GI the first week after the surgery, which was no longer significant after eight days [5]. No significant difference was observed by Petsos *et al.* [38]; GI measurements were not provided in one study [36].

Bleeding on probing

Bleeding on probing (BoP) was assessed in eight studies and showed conflicting results. The number of sites assessed ranged from 1 to 7 and one article did not mention the number of measurements performed. Two studies observed a significant decrease in BoP after lower third molar removal [35,37], whereas two studies showed a significant increase [9,34], and one study did not observe significant differences of BoP measurements before and after surgery [43]. Unfortunately, evolution of BoP between baseline and post-operative time-points were not provided in the result section of three studies [31,36,39].

Gingival recession

Gingival recession was assessed in two studies [32,47]. One study reported a significant increase in gingival recession at the disto-vestibular site of the second molar after surgery. The other study observed only two small recessions among the 150 patients included [47].

Table II. Details of periodontal parameters assessed and main results of the included studies.

First author	Periodontal parameters studied (*n* = Number of sites assessed)	Conditions and Flap design	Results
Ahmad M, 2021	PPD (*n* = 2) CAL (*n* = 2) BL (*n* = 2)	Triangular flap Envelope flap	Significant increase in distal and buccal PPD in both groups from baseline to six months, with significant higher values in envelop group Significant increase in distal and buccal CAL in both groups from baseline to six months Significant increase in distal BL in both groups from baseline to 3 months and 3 months to 6 months and significantly higher in EF patients compared to SF patients at 3 months
Alqahtani NA., 2017	PPD (*n* = 1)	Triangular flap Envelope flap	Significant increase of PPD in both groups from baseline to 3 months No significant difference between the two flaps
Aniko-Włodarczyk M, 2021	PPD (*n* = 6) GI (*n* = 4)	Triangular flap Non-operated opposite side	Significant enhancement of PPD in the operated side after eight weeks GI significantly increased in the operated side seven days after the surgery. This difference was no longer significant after eight weeks.
Baldini N, 2015	PPD, CAL, BoP, PI (*n* = 2)	Envelope flap Trapezoidal flap	Significant reduction in PPD and CAL after surgery in both groups No significant difference between the two flap designs after 6 months follow-up BoP and PI:NS
Baqain ZH, 2012	PPD, BoP, PI (*n* = 1)	Triangular flap Envelope flap	Increase in distal PPD in the early postoperative period in both groups; significantly greater with envelope flaps Increase in BoP and PI in both flaps; greater in the triangular group for PI but the difference did not reach statistical significance
Briguglio F, 2011	PPD, CAL, BoP, PI (*n* = 6)	Triangular flap Envelope flap modified by Thibauld and Parant Envelope flap modified by Laskin	Significant decrease in PPD and CAL in all three groups; significantly greater decrease for the triangular flap BoP and PI:NS
Desai A, 2014	PPD (*n* = 1)	Triangular flap Envelope flap	Significantly more distal pockets after 15 days in the triangular flap group
Dicus-Brookes C, 2013	PPD (*n* = 6)	Third molar removal (flap: NS)	The proportion of patients with at least a PPD $>$ 4 mm on any M2 at enrollment decreased significantly after surgery
Fakour SR, 2017	PPD (*n* = 1)	Triangular flap Envelope flap	No significant difference between the two flaps from preoperative values to 2 months follow-up
Faria AI, 2012	PPD, CAL, BoP, GI (*n* = 5)	Envelope flap	Significant decrease of PPD and CAL after surgery No significant difference between PPD at 3 months, 6 months and 12 months The highest PPD and CAL values were always found at the centro-distal site of the second molar BoP and GI:NS
Kim H-R, 2011	PPD (*n* = 4)	Envelope flap Flapless	PPD was significantly higher in the envelope flap group 1 and 3 months after the surgery The difference in the PPD between the 2 groups were significant at 1 and 3 months after surgery

Table II. (continued).

First author	Periodontal parameters studied (*n* = Number of sites assessed)	Conditions and Flap design	Results
Korkmaz YT, 2015	PPD, GI, PI, GR (*n* = 6)	Laterally rotated triangular flap Envelope flap	Significant decrease in PPD in both groups, but the decrease was significantly greater in the triangular group than the envelope group GI and PI decreased significantly in both groups but the decrease was significantly greater in the triangular group Significant increase in GR at the disto-vestibular site in both groups with significant greater values in the envelop group
Laurito D, 2016	PPD (*n* = 7) BoP (*n* = 7) PI (*n* = 4)	Triangular flap Transposed flap	No significant difference between the two groups preoperatively and 60 days after surgery for all the parameters
Melo Stella PE, 2017	PPD, BoP, PI (*n* = NS)	Envelope flap	Significant decrease in PPD from baseline to 180 days follow-up Significant increase in BoP from baseline to 180 days follow-up Significant increase in PI was recorded after extraction
Montero J, 2011	PPD (*n* = 1) GI (*n* = 4) PI (*n* = 4)	Triangular flap Envelope flap	Significant decrease in PPD after surgery in both groups but significantly greater decrease in patients with a deep periodontal pocket preoperatively Significant decrease in GI and PI after surgery in both groups
Mudjono H, 2020	CAL (*n* = 1)	Triangular flap Reversed triangular flap	No significant difference between both flaps Significant decrease of CAL between day 14 and day 30
Ottria L, 2017	PPD (*n* = NS) CAL (*n* = 3) GR (*n* = NS) PI (*n* = NS)	Triangular flap Modified triangular flap Envelope flap	No significant difference between groups that show complete recovery of the periodontium after surgery Two slight gingival recessions were observed NS for each periodontal parameters
Passarelli PC, 2019	PPD, CAL, BoP, PI, GI (*n* = 6)	Triangular flap	Significant improvement in CAL, PI, GI and BoP The mean values of PPD at DB and DL sites at 6 months were reduced but the difference was no statistically significant No significant difference at final time between deeply and superficially impacted molars
Petsos H, 2016	PPD, CAL, PI, GI (*n* = 6)	« Short-envelope » flap	Significant decrease in PPD and CAL from baseline to 6 months follow-up An average improvement for the GI, deterioration for the PI, but the differences were not statistically significant
Pham T, 2019	PPD, CAL, BoP, PI, GI (*n* = 4)	Third molar removal (flap: NS)	Significant decrease in PPD, GI, BoP, PI from baseline to 6 months follow-up CAL significantly increases from baseline to 1 month follox-upand then significantly decreases until final time No significant difference between the superficial and deep molar group on PPD, GI, PI, BOP CAL is significantly lower in the superficial molar group
Silva JL, 2011	PPD (*n* = 3)	Vertical incision L-shaped incision	No significant difference between both flaps Significant decrease from baseline to 60 days, but no significant difference between 60 and 90 days

Table II. (continued).

First author	Periodontal parameters studied (*n* = Number of sites assessed)	Conditions and Flap design	Results
Sridharan G, 2020	PPD (*n* = NS)	Triangular flap Modified triangular flap	No statistical significant difference between both flaps
Tabrizi R, 2013	PPD, CAL (*n* = 1)	Triangular flap	Significant increase in PPD from baseline to 26 weeks post-operative Significant decrease of CAL from baseline to 26 weeks post-operative

BL: bone level, BoP: bleeding on probing, CAL: clinical attachment loss, GI: gingival index, GR: gingival recession, NS: Not specified, PI: plaque index, PPD : periodontal pocket depth.

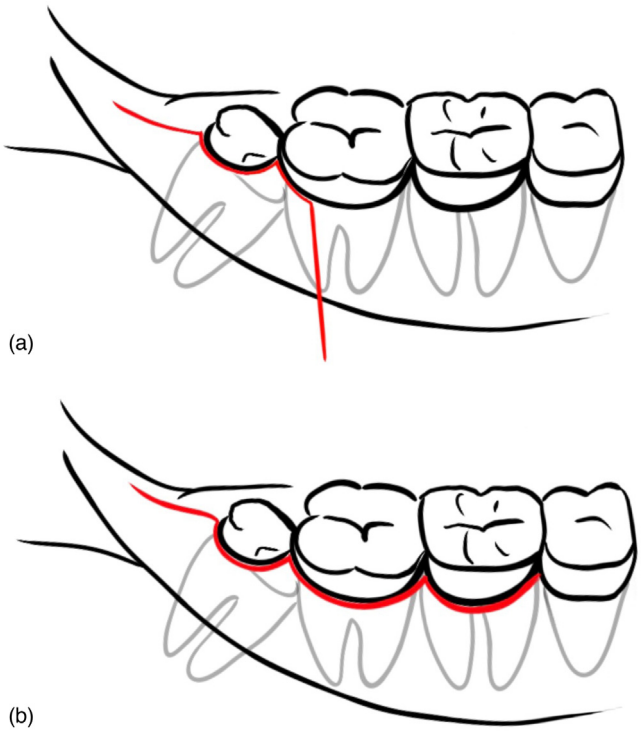

Fig. 4. Illustration of the most commonly performed flap designs to remove impacted mandibular third molar: (A) triangular flap (B) envelope flap.

Influence of flap design

Twenty-one studies specified the flap design used to perform mandibular third molar removal (Tab. II). The triangular flap or one of its variants was found in 18 studies, and the envelope flap or one of its variants in 14 studies (Fig. 4). Fourteen studies investigated the influence of the flap design on the periodontal status of second molar after impacted mandibular third molar extraction [42]. Among them, nine studies reported that surgical flap designs had no impact on the adjacent molar periodontal health. Most of the studies that observed significant differences between flaps showed better periodontal measurements in the triangular group compared to the envelope flap group [9,31,32,42]. The only study reporting a better periodontal healing with the envelope flap compared to the triangular flap did not provide PPD values and distal pocket assessment was only performed 15 days after the surgery [10]. Finally, one study compared the effects of flap and flapless extractions, in patients with partially impacted third molar [48]. The mean probing depth was significantly higher in the envelope flap group after surgery compared to the flapless group.

Discussion

This systematic review aimed to assess the influence of mandibular third molar removal on the periodontal status of the adjacent second molars. The potential effect of the flap design was also investigated.

The outcomes yielded substantial evidence to suggest that impacted or partially impacted mandibular third molar removal does not impair the periodontal health of the adjacent second molar. PPD and CAL were the most investigated parameters, followed by PI, GI, BoP and gingival recession. Most of the included studies showed a significant improvement of these periodontal parameters few months after the surgery. Only five studies reported an increased PPD after third molar removal [5,9,40–42]. However, it is noteworthy that those mean PPD values have increased by less than one millimeter and remained below three or four millimeters, thus indicating the preservation of a non-pathological periodontium. Third molar removal may allow healing of a clinically healthy periodontium of the adjacent second molar and can provide better access for cleaning [35]. Assessment of CAL was performed in eleven studies. Most of them showed a significant decrease of CAL after third molar removal. CAL is a crucial parameter allowing to determine, in addition to the pocket depth, the possible occurrence of gingival recession or hypertrophic gingival healing. Most of the included studies also reported a significant decrease of PI and GI when these parameters were considered. Their increase in some studies could be related to the difficulty to maintain proper hygiene at the surgical site at early stage of observation [9]. The limited number of studies that have considered the last parameters (BoP and gingival recession) as well as the contradictory results obtained prevent us from drawing definitive conclusions.

Low level of evidence suggests that age, pre-operative deep pockets or deep third molar impaction are correlated to a smaller decrease in PPD, or to the persistence of periodontal pockets greater than 4 mm. Only one study outlined that older patients are more likely to present residual periodontal pockets after surgery. Passerelli *et al.* reported that older patients had more pockets greater than four mm six months after extraction than younger patients [35]. These results can be explained by a decrease in the immune response to plaque with age [49]. It has been reported that in the absence of intervention, periodontal health around the mandibular second molar worsened over time, potentially resulting in deeper pockets and thus less effective healing [50]. The presence of larger pre-existing intra-bony defects in older populations could also explain the persistence of larger bone defects than in younger population [18,51,52]. Unfortunately, most of the included patients in the present review were below 25 years old, making it impossible to conclude on an association between age and poorer periodontal healing after third molar avulsion. Only two other studies had a sample with a mean age greater than 30 years and four studies did not provide mean age or median age, and only specified sample boundaries [31,44,46,47], even though age seems to play a key role in PPD evolution. The presence of deep pockets preoperatively also seems to be a determining factor on the degree of healing of the distal periodontium. Although in our study, a significant improvement was noted in all publications considering patients with pockets greater than 4 mm, two studies mentioned residual PPD greater than four mm [35,39]. Passarelli *et al.* observed that patients with preoperative periodontitis were 41.4 times more likely to have a PPD superior than four mm at six months compared to healthy patients [35]. Another study suggested that a pathogenic microbial flora, from the orange and red complexes, could be present in large quantities in patients with pockets superior than five mm on the mesial site of the third molar and distal to the second molar [52]. These bacteria could be responsible of the poorer periodontal healing observed after surgery. It has also been suggested that these pathogenic bacteria were markers of future periodontitis in patients who did not yet have pockets [53]. However, to date there is insufficient evidence to recommend the systematic use of mechanical debridement of second molars after the extraction of third molars to prevent periodontal defect [54]. Finally, only four studies investigated the influence of impaction depth on the periodontal health and showed inconsistent results, thereby making it difficult to draw any conclusion. Further studies with higher level of evidence seem necessary to establish a correlation between these factors and the evolution of PPD.

The present study also aimed to establish whether or not the choice of flap design had an impact on periodontal healing of adjacent second molars. We observed that the envelope flap and the triangular flap were the most commonly used flap techniques for mandibular third molar removal. Some variants of these conventional flaps were also proposed suggesting minor modifications that are usually considered of little clinical significance [55]. The triangular flap involved an incision from the distobuccal edge of the second molar dropping into the mandibular vestibule, and a second part was a relieving incision from the ramus to the distobuccal side of the second molar [4,55]. The envelope flap usually involved a sulcular incision from the first to the second mandibular molar and a distal relieving incision along the external oblique ridge to the ramus [4,55]. This is corroborated by other recent studies focused on third molar surgery which stated that they both account for the vast majority of incision performed, although various modifications and alternative designs have been described [55,56]. Among the 14 studies comparing flap techniques, nine studies reported that surgical flap designs had no impact on the adjacent molar periodontal health. This is consistent with several older studies, published before 2010, which also observed comparable periodontal healing regardless of the flap design [57–62]. In our study, when significant differences were observed, results showed better periodontal healing in the triangular group compared to the envelope flap group [9,31,32,42]. It has been suggested that the triangular flap preserves the buccal attached gingiva and the periodontal ligament of the second molar and may reduce potential periodontal complications of the adjacent second molars [4]. However, these observed differences should be considered with caution. Two of the four studies mentioned above highlighted the weak clinical relevance of the observed differences, thereby suggesting that surgeon should choose the flap design according to their own preferences [9,31]. Baqain *et al.* thus pointed out that in spite of the statistically significant difference in periodontal status between the two flap designs,

the clinical significance of this difference is undermined [9]. Indeed, PPD reduction of less than 1 mm and CAL gain of less than 0.5 mm could be considered as clinically insignificant values from the periodontal point of view [29,63].

Finally, there are some limitations related to the present systematic review that should be mentioned. Some studies showed limited sample size or lack of randomization and/or control group resulted in unclear or high risk of bias. It would be interesting for upcoming studies to be based on the split-mouth design which allow to evaluate two conditions randomly assigned to either the right or left halves of the dentition, thereby limiting inter-individual variability [64]. Another identified drawback of this systematic review is the variability of employed methodologies. Besides, some measurement methods showed poor accuracy and reliability while some authors did not provide all the values obtained for each analysis time [10,43–45,47,48]. This may be because several studies were interested in the overall postoperative course and did not focus on periodontal healing. The heterogeneity of employed methodologies and the lack of information provided did not allow to perform a meta-analysis, thereby outlining the critical need for further clinical standardized researches. We thus suggest the following guidance to conduct future studies that exclusively focus on the adjacent second molar periodontal healing. These should be randomized split mouth comparative study investigating with standardized methods the following parameters: PPD, CAL, BoP, IG and IP. Finally, studies duration should be at least 3 to 6 months since several authors have reported a bias related to postoperative local inflammation when measurements are performed in the early postoperative stage [30,36,41].

Conclusion

Within the current study's limitations, the findings suggest that impacted mandibular third molar removal preserves or improves the periodontal health of adjacent second molars. However, age and pre-existing deep periodontal pockets may be risk factors for poorer periodontal healing and persistence of pockets deeper than four millimeters. The flap design has no negative effect on the periodontal tissues of the adjacent second molar in the long term, thereby allowing the surgeon to choose the most appropriate access flap according to the clinical situation. Further studies with more standardized protocols and a higher level of evidence will be necessary to validate these results and to highlight other possible risk factors (impaction depth, history of periodontitis, etc.) that may influence periodontal healing of the adjacent second molar.

Authors contributions

M.F. and MR conceived the idea. MF, MR, LM and SC conducted the systematic review. MF led the writing. SC and JCF contributed to the writing and critically revised the manuscript.

Conflicts of interests

The authors declare the absence of conflict of interest.

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