

# Effects of Impacted Lower Third Molar Extraction on Periodontal Tissue of the Adjacent Second Molar

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**Abstract:** The extraction of impacted lower third molars (ILTM) is one of the most common procedures in oral-maxillofacial surgery. Being adjacent to lower second molars, most impacted lower third molars often lead to distal periodontal defects of adjacent second molars. Several symptoms may occur after extraction, such as periodontal pocket formation, loss of attachment, alveolar bone loss and even looseness of second molar resulting in extraction. The distal periodontal defects of second molars are affected by many factors, including periodontal conditions, age, impacted type of third molars, and intraoperative operations. At present, several studies have suggested that dentists can reduce the risk of periodontal defects of the second molar after ILTM extraction through preoperative evaluation, reasonable selection of flap design, extraction instruments and suture type, and necessary postoperative interventions. This review summarizes the research progress on the influence factors, interventions methods and some limitations of distal periodontal defects of adjacent second molar after extraction of impacted mandibular third molars, with the aim of opening up future directions for studying effects of ILTM extraction on periodontal tissue of the adjacent second molar.

**Keywords:** impacted lower third molar, periodontal defect, alveolar bone defect, second molar, teeth extraction

## Introduction

Impacted Lower Third Molar (ILTM), with an incidence of 66–77%,<sup>1</sup> is the most common impacted tooth. Due to the abnormal position and blocked eruption, ILTM often leads to recurrent wisdom tooth pericoronitis, adjacent tooth caries, lower anterior arch crowding, periodontal defects of adjacent molars, tooth root resorption and even temporomandibular joint disorders.<sup>2</sup> Most scholars believe that ILTM with pathological symptoms, especially mid-to-high mesial inclination, should be prophylactically removed early.<sup>3</sup>

ILTM extraction is more likely to have surgical complications than normal tooth extraction as a result of adjacent teeth obstruction and bone tissue embedding. Common postoperative complications, including pain, swelling, infection and local bleeding, can be effectively controlled by timely symptomatic treatment.<sup>4</sup> Other complications, such as adjacent tooth injury, will affect mid-long-term prognosis of the tooth when it occurs.<sup>5</sup> Due to the lack of obvious subjective symptoms in a short term, dentists often ignored the effect of ILTM extraction on the periodontal health of the second molar. Therefore, oral surgeons often perform few treatments on the second molar after ILTM extraction.

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At present, there is a growing interest in the influence of ILTM extraction on the periodontal health of second molars. The main methods to evaluate the effect of ILTM extraction on the second molar periodontal tissue are periodontal examination and imaging examination. Commonly used indicators are periodontal pocket depth (PPD), clinical attachment loss (CAL), and distal bone level of the second molar. Using 215 ILTM surgery cases and after 2 years, Kugelberg et al<sup>6</sup> found that on the distal of the adjacent second molar, 43.3% has probing depth more than 7mm, and 32.1% has intrabony defects more than 4mm. Also, thanks to periodontal defects, plaque accumulation and local inflammation were further accelerated, which cause the second molar periodontal-endodontic combined lesions and even early tooth loss.<sup>7</sup> Therefore, during the ILTM extraction surgery, dentists should consider the periodontal health of second molars.

Several studies have suggested that dentists can reduce the risk of periodontal defects of the second molar after ILTM extraction through preoperative evaluation, reasonable selection of flap design, extraction instruments and suture type, and necessary postoperative interventions. So we reviewed the influence factors, and intervention methods of distal periodontal defects of adjacent second molar after ILTM extraction.

## Preoperative Evaluation

ILTM extraction is one of the most common procedures in oral-maxillofacial surgery. Detailed consultation, clinical and imaging examinations are still required before surgery to design the best surgical procedure and minimize the damage to the periodontal tissues.

## Periodontal Status

Generally, second molars periodontal status was evaluated through consultation, clinical and imaging examinations, specifically including periodontitis history, intrabony defects (IBD), deep periodontal pockets, plaque accumulation, and gingival inflammation. Studies have indicated that the preoperative periodontal condition influences the postoperative periodontal condition of the second molars. Through multiple regression analysis, Kugelberg et al<sup>8</sup> showed that the size of the distal bone defect of the second molar after surgery is related to the preoperative periodontal status. Passarelli et al<sup>9</sup> found that compared with non-periodontitis patients, patients with periodontitis history have 41 times probability of periodontal disease (PPD>4mm). The preoperative PPD is more

than 7mm, and the PPD is still more than 4mm at post-operative 6 months.

## ILTM Impacted Type

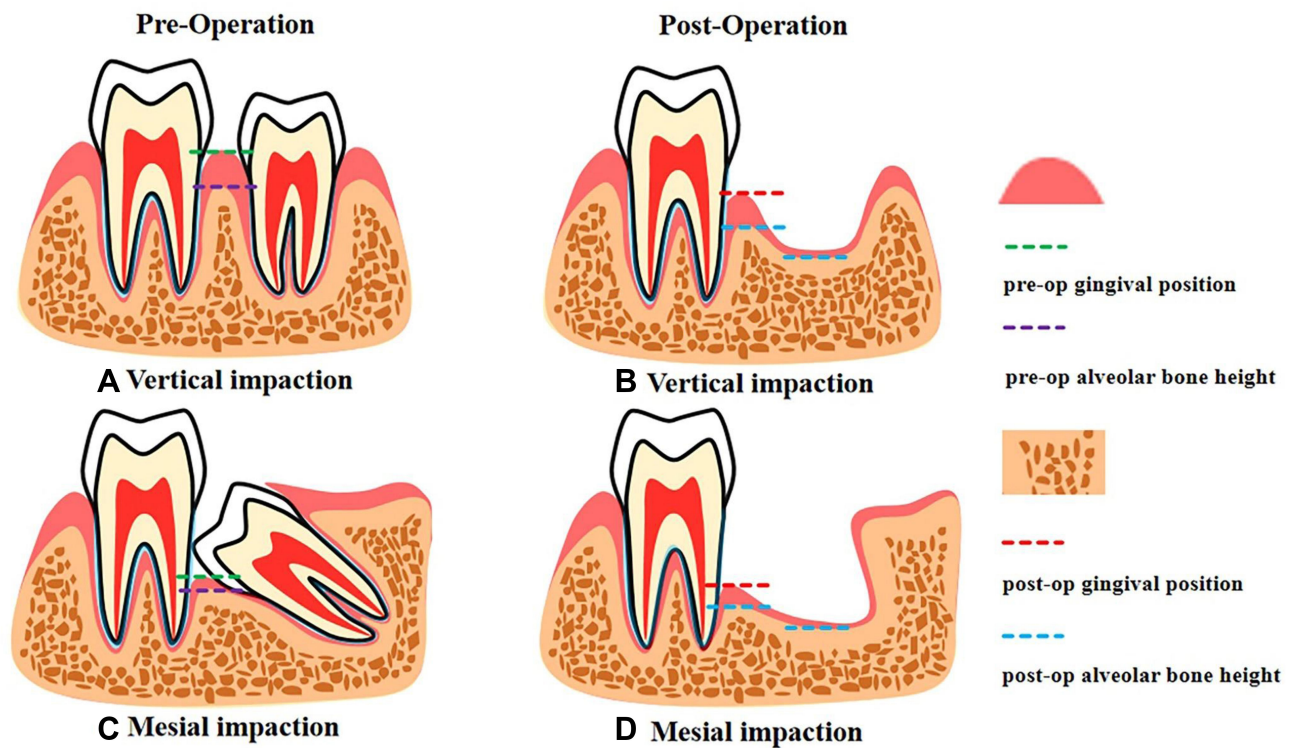
According to the relationship between the long axis of ILTM and the adjacent second molars, Winter classified ILTM into vertical impaction, mesial impaction, distal impaction, horizontal impaction, and inverted impaction.<sup>10</sup> Kim et al<sup>11</sup> indicated that the incidence of distal alveolar bone loss in the adjacent second molars is closely related to the ILTM impacted type (Figure 1).

The research by Kugelberg et al<sup>12</sup> showed that the type of impacted third molars that are most likely to form periodontal pockets and bone defects in the distal part of the second molars is the mesial impaction, followed by the horizontal impaction, and the vertical impaction is the lowest.<sup>13</sup> It was so hard to maintain oral hygiene in the mesial or horizontal impaction, resulting in the accumulation of plaque microorganisms, and then the formation of periodontal pockets and alveolar bone loss in the distal adjacent second molars.<sup>14</sup>

In addition, for non-eruptive ILTM, it can be divided into completely impacted (completely in bone) and submucosal impacted (completely covered by oral mucosa), which have different effects on postoperative periodontal tissues. Studies have shown that if there is a bone plate above the ILTM, the postoperative PPD and CAL levels only have a little change.<sup>15</sup> This is consistent with a recent study by Nunn et al, who found that a significantly increased risk of submucosal ILTM periodontal defect compared with complete ILTM, with a 4.8-fold increase after submucosal ILTM removal and only a 1.7-fold increase after complete ILTM removal.<sup>16</sup> Complete ILTM removal usually only has buccal defects, while the submucosal ILTM already has a coronal bone wall missing, and the buccal bone wall usually needs to be partially removed intraoperatively. Especially in the coronal plane, the ILTM is in close contact with the second molar, and there is no obvious bone boundary, which will cause greater defects in the distal periodontal tissue of the second molar after surgery.<sup>17</sup>

## Age of Patients

The difficulty of ILTM extraction increases with age, owing to continuous root development, periodontal ligament thinning, ankylosis of the tooth, mandible becomes harder and brittle, and hypercementosis.<sup>18</sup> Many studies suggested that the best extraction period is before the age



**Figure 1** Pre- and post-operative soft and hard tissue comparison of vertical and mesial impacted lower third molar extraction: (A) pre-operation vertical impaction, (B) post-operation vertical impaction, (C) pre-operation mesial impaction, (D) post-operation mesial impaction.

of 25, from which complications increase significantly and healing time is longer.<sup>19</sup> In a case-control study of 868 patients, Chiapasco et al<sup>20</sup> reported that the PPD of the distal second molar after the third molar surgery over 25 years old was 3 times that of those before 25 years old. Through a retrospective study, Kugelberg et al<sup>21</sup> showed significant differences in the level of bone defect between 2 and 4 years after ILTM extraction. Two years after tooth extraction, patients  $\leq 25$  years old had 16.7% of bone defects exceeding 4mm in the distal second molar, 40.7% of patients  $>25$  years old had bone defects exceeding 4mm. After 4 years, the former dropped to 4.2%, while the latter rose to 44.4%, indicating that ILTM extraction before the age of 25 may have a beneficial effect on periodontal health of the second molar.

Currently, some recognized risk factors for preoperative evaluation include periodontal status, ILTM impacted type and age of patients. Thus, ILTM extraction often leads to the risk of sustainable periodontal defects or forming new periodontal defects in the distal second molar after surgery, which mostly occurs in the following situations: ①Mesial or horizontal impaction of mandibular third molars; ②Age  $>25$  years old; ③Preoperative

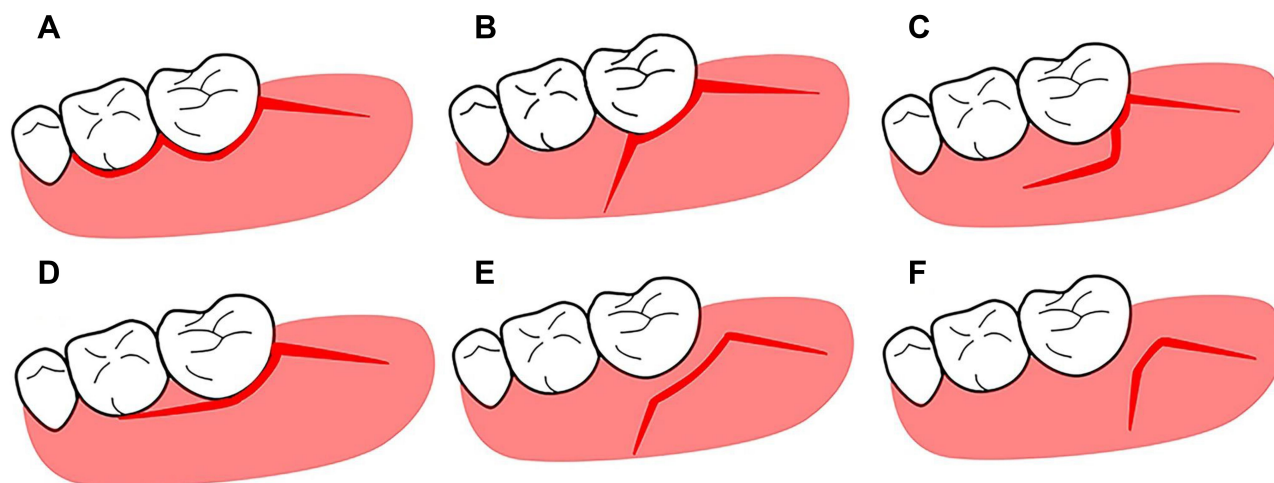
probing depth exceeding 7mm, attachment loss exceeding 6mm; ④Patients with periodontal inflammation, poor oral hygiene, and poor plaque control.

## Tooth Extraction Operation

ILTM is often hindered by adjacent tooth, bones, and soft tissues, which requires flap surgery, bone removal, tooth separation and soft tissue suture during extraction process. Flap design, bone removal and suture may affect the distal periodontal health of the second molar after surgery. To reduce the influence of ILTM extraction, scholars have designed different flap approaches, extraction instruments used to remove bone and split teeth and suture type.

## Flap Design

Each step of the mucoperiosteal flap will break the homeostasis of the alveolar bone and activate osteoclasts.<sup>22</sup> After ILTM surgery, an important factor affecting the periodontal healing of second molars is the remaining amount of periodontal ligaments and gingival fibers.<sup>23</sup> In the case of a thin gingival biotype, the design of the standard flap may lead to attachment loss and periodontal pockets formation of the second molar.<sup>24</sup> The modified



**Figure 2** Illustration of the flap designs used in impacted mandibular third molar extraction: (A) standard envelope flap, (B) standard triangular flap, (C) Szmyd flap, (D–F) modification flaps.

design of standard flaps, such as triangular, Szmyd and envelope flaps, which moved 1–2mm down from the standard incision line that preserves the periodontal ligament adjacent to the second molar and the attached gingiva to the buccal surface can reduce potential periodontal complications of the adjacent second molars<sup>25</sup> (Figure 2).

Multiple studies suggested that the correct flap design is beneficial to periodontal health in the short term. Suarez-Cunqueiro et al<sup>26</sup> evaluated the effects of triangular flaps and modified triangular flaps on the periodontal condition of the second molar after ITLM extraction. At 5 and 10 days postoperatively, they observed that compared with the triangular flap, the modified triangular flap design can reduce the PPD of the distal second molar, indicating that the modified triangular flap is more beneficial to postoperative periodontal health. Similarly, Kirtiloğlu et al<sup>27</sup> reported that the modified Szmyd flap has a smaller probing depth than the triangular flap at 1 week, 2 weeks and 4 weeks after surgery. Also, the preoperative and postoperative plaque index and gingival index are similar, revealing that the early differences between the two flap designs are not caused by plaque accumulation, but may be related to the preservation of the intact gingival margin around the second molar and no crevicular incision.

Clinical studies have shown that it takes at least 3 months for the distal periodontal healing of the second molars.<sup>28,29</sup> Therefore, the relevant indicators of periodontal status 3 months after extraction have evaluation significance. In a systematic review and meta-analysis, Chen et al<sup>30</sup> used cases followed up for at least 3 months to assess the effect of different flap designs on periodontal status. They showed that the Szmyd flap and modified flap design may be the

most effective way to reduce the postoperative probing depth. Comparing the effects of the envelope flap and the triangular flap on the periodontal condition of the adjacent second molars, Korkmaz et al<sup>31</sup> found that probing depth of the triangular flap was significantly less than that of the envelope flap at 3 months after surgery. Therefore, compared with the envelope flap, the triangular flap design is better for periodontal health (Table 1).

The above research shows that different flap designs affect the probing depth of the postoperative periodontal pocket. Compared with the triangular flap design, the Szmyd flap and the modified flap are more beneficial to periodontal health, while the triangular flap design is better than the envelope flap.

## Extraction Instrument

Chisels, a common tool in traditional tooth extractions, are used to remove bones and split teeth, which are likely to bring about inevitable postoperative trauma.<sup>33</sup> With the development of minimally invasive concept, minimally invasive tooth extraction instruments, including ultrasonic bone knife, 45° contrast-angle turbine handpiece, elongated impacted tooth bur, modified minimally invasive dental elevator (thinner edge), and buccal retractor, has been widely used.<sup>34</sup> The different ILTM extraction instruments affect the second molar not only in postoperative reaction but in the periodontal health. Coomes et al shown that after using a traditional chisel to split the crown of the mandibular third molar, which appeared a fracture seam of 0.47 to 0.7 mm on the buccal plate.<sup>35</sup> Araujo MG et al<sup>36</sup> suggested that the fracture of the buccal bone plate had

**Table 1** Clinical Periodontal Characteristics of Flap Design

Author/Year	N° Patients	Variable	Flap Design	Follow-Up	Conclusion
Chen et al 2017 <sup>30</sup>		PPD	Triangular/Envelope/Szmyd flap/ Modified Triangular/Envelope/ Szmyd flap	>3 Month	The szmyd flap and modified flap may be the most effective in reducing PPD, the envelope flap may be the least effective
Korkmaz et al 2015 <sup>31</sup>	28	PPD	Envelope flap/Triangular flap	3 Month	The triangular flap had lesser postoperative PPD than envelope flap
Briguglio et al 2011 <sup>32</sup>	45	PPD, CAL	Envelope flap/Modified Envelope flap/Triangular flap	12 Month	The triangular flap has a statistically significant reduction in PPD and an increase in AL compared to the other group
Monaco et al 2009 <sup>29</sup>	24	PPD	Triangular flap/Envelope flap	7 Day	The triangular flap had lesser postoperative PPD than envelope flap
Kirtiloglu et al 2007 <sup>27</sup>	18	PPD, CAL	Triangular flap/Modified Szmyd flap	7 Day, 14 Day	The modified Szmyd flap had lesser postoperative PPD than triangular flap
Suarez-Cunheiro et al 2003 <sup>26</sup>	27	PPD	Triangular flap/Modified Triangular flap	5 Day, 10 Day	The modified triangular flap had lesser postoperative PPD than triangular flap

adverse effects on the adjacent teeth, such as the alveolar bone resorption. Wang et al<sup>37</sup> compared the alveolar bone healing after traditional bone removal and minimally invasive high-speed turbine tooth extraction. The result showed that the alveolar bone density after the minimally invasive tooth extraction group was higher than conventional tooth extraction group at 7 days and 30 days, and the difference was significant ( $p < 0.05$ ). In the accuracy and safety of bone removal, the ultrasonic bone knife is better than the high-speed turbine. It can not only reduce postoperative swelling, pain and soft tissue damage but also avoid the negative effects of high-speed turbines, such as osteonecrosis caused by heat generation. The use of ultrasonic osteotome can reduce the distal bone defect of the adjacent second molar and increase the alveolar bone density in the surgery area.<sup>38</sup> Therefore, ultrasonic osteotome can better preserve the bone mass in the distal second molars. The above results show that traditional tooth extractions surgery causes different degrees of periodontal damage, while minimally invasive tooth extractions surgery can effectively promote alveolar bone healing.

In addition, for the lower ILTM, conventional minimally invasive tooth extraction surgery may still result in bone loss and periodontal pockets formation in the distal second molar.<sup>39</sup> Therefore, scholars designed ultrasonic osteotome window: using ultrasonic osteotome to

open a window on the mandibular buccal bone plate, removing tooth, and resetting bone fragments.<sup>40</sup> The extraction socket forms a closed space that effectively isolates the growth of epithelial cells to benefit bone tissue regeneration<sup>41</sup> and shortens the healing time.

## Suture Type

Suture is the last step in the ILTM extraction procedures. The close suture of the extraction wound can improve postoperative wound healing.<sup>42</sup> However, studies have shown that different suture types have different effects on the periodontal tissue.<sup>43</sup> Widely used interrupted sutures are usually the surgeon's first choice. The anchor suture is another suture technique, which fixes the distal buccal-lingual gingival flap to the adjacent tooth in an anchor-like manner to avoid the V-shaped gap formation in the distal adjacent tooth. Cetinkaya et al<sup>44</sup> compared the effects of interrupted sutures and anchor sutures on the periodontal tissue of the adjacent second molar 6 months after ILTM extraction. They found that the PPD and CAL of distal second molars in the interrupted suturing group were significantly higher than those in the anchored suturing group, indicating that anchor sutures may be a better choice, to maintain the health of periodontal tissues and prevent periodontal problems. Furthermore, Zhu et al<sup>45</sup> adopted the self-comparison research method and found that interrupted

suture and “8” suture were statistically significant in terms of PPD at 6 months after surgery. The “8” suture is more conducive to the healing of the distal periodontal tissue of the adjacent teeth, which may make the mucosal epithelium closer to the distal root surface of the adjacent tooth to form a barrier to prevent food debris from embedding, thereby protecting the periodontal tissue in this area for regeneration and restoration.<sup>46</sup> The above studies show that anchor suture and “8” suture are more beneficial to periodontal tissue healing than interrupted suture. Currently, no controlled studies of other suture types have been reported and need to be further studied.

### Postoperative Intervention of ILTM Extraction on Periodontal Effects of Second Molars

Surgical extraction of ILTM will increase the risk of persistent or developing new periodontal defects in the distal second molar. Over the years, scholars have proposed different interventions to promote periodontal tissue regeneration, including non-surgical periodontal treatment, guided tissue regeneration, bone graft, filling collagen sponge, transplantation of cell active ingredients and so on (Figure 3). Space provision, wound stabilization and cell induction are the key factors, which can be obtained by using these technologies.

### Non-Surgical Periodontal Treatment

Scaling and root planing, as the main methods of periodontal basic treatment, is widely used in clinic. Pons-Vicente et al<sup>47</sup> compared the effects of ultrasound and simple manual scaling and root planing on the distal second molar after ILTM extraction. The results show that there is no significant difference between the two treatment methods on the distal periodontal tissue of the second molar. Because periodontal treatment can completely remove the plaque and calculus, which locate on the distal surface of the second molar and expose on the root surface. After ILTM extraction, relevant periodontal treatment intervention can provide strong conditions for the recovery of the distal periodontal tissue of the second molar.<sup>48</sup> Xie et al<sup>49</sup> performed ILTM extraction combined with simultaneous periodontal treatments. After 6 months, they found that plaque index, gingival index, bleeding index, probing depth of periodontal pocket and bone loss in the experiment group was significantly lower than those in the control group, indicating that periodontal treatment can make the distal alveolar bone of the adjacent second molar more flatter, which is beneficial to eliminate periodontal pockets and intrabony defects. Also, the elimination of periodontal pocket benefits plaque control, gingiva health and accelerates wound healing.<sup>50,51</sup>

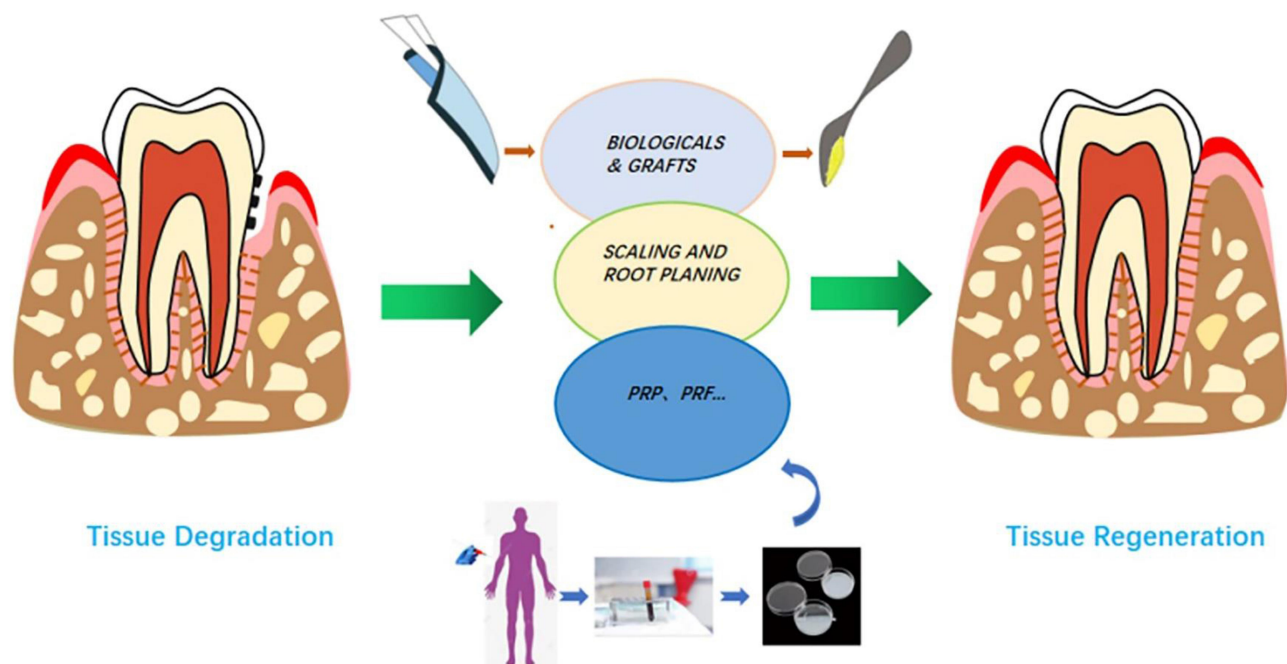


Figure 3 Endogenous tissue engineering for periodontal regeneration.

## Guided Tissue Regeneration

Guided tissue regeneration (GTR) technology uses biocompatible barrier membranes (absorbable or non-absorbable) between the bone defect area and the surrounding tissues as a barrier, which prevents gingival epithelium and connective tissue from infringing the root surface during the healing process while allowing the periodontal cell to selectively migrate into the defect. In this way, the new cementum and periodontal ligament fibers are formed, that is, the formation of new adhesive healing. Cortell-Ballester et al<sup>52</sup> initiated an experiment after ILTM extraction, setting an absorbable collagen membrane placed on one side and a blank control on the other side. Six months after surgery, PPD and CAL of the distal second molars in the experimental group were significantly reduced compared with those in the control group, indicating that the absorbable collagen membrane can stimulate bone regeneration, improve the attachment level and bone filling, reduce the probing depth, and lead to faster healing of periodontal tissues. Similar to the former experimental design, Corinaldesi et al<sup>53</sup> evaluated 11 cases of bilateral mandibular second molars with preoperative PD  $\geq 6$ mm and bone defect  $\geq 3$ mm to GTR using absorbable collagen membrane and non-absorbable collagen membrane. The results confirmed that the absorbable collagen membrane had the same effect as the non-absorbable membrane in terms of the probing depth and attachment loss. Both treatment methods were successful 9 months after surgery.

## Bone Graft

Although autologous bone graft remains the “gold standard” for bone regeneration,<sup>54</sup> it can also aggravate patient’s injury and limit by the patient’s own bone mass.<sup>55</sup> Therefore, it is recommended to use bone substitute materials or autogenous bone with bone substitute materials.<sup>56</sup>

Bone substitute materials include allograft bone, xenograft bone and synthetic bone. Due to immunogenic reaction, disease transmission, ethical problems and infection risks, allograft bone is currently rarely used in the repair of distal bone defects in the second molar after ILTM extraction.<sup>57</sup> In the synthetic bone substitute materials, hydroxyapatite (HA) and bioactive glass are mainly used for bone defect repair. Singh et al suggested that HA with collagen membrane can increase bone regeneration in distal bone defects of second molars, but it is no longer used for repairing bone defects because of its degradability and poor plasticity.<sup>58</sup> Thronson et al<sup>59</sup> demonstrated that bioactive glass had a good effect on CAL, but no significant change in bone height, indicating that its osteogenic

effect was poor. However, xenograft bone is widely used in clinical practice, among which the most commonly used is Geistlich Bio-Oss<sup>®</sup>. Emerging investigations are demonstrating that single Bio-Oss materials can promote the repair of periodontal bone defects.<sup>60</sup> Sammartino et al<sup>61</sup> further also confirmed that both single Bio-OSS and the mixture can significantly decrease CAL and PPD, promote distal bone regeneration of the second molars, and the combined effect is better after ILTM extraction.

## Filling Collagen Sponge

Collagen sponge, a kind of biomedical material with a similar structure to human collagen, is the main constituent protein of the extracellular matrix and an important component of tissues and scaffolds for cells.<sup>62</sup> Studies have shown that filling the collagen sponge after ILTM extraction benefits the migration of osteoblasts, stabilizes blood clots, promotes soft tissue healing, and protects wounds and bone reconstruction.<sup>63</sup> Clinically, collagen sponge has been mainly used to prevent and repair periodontal defects. Wang et al<sup>64</sup> have found that the alveolar bone loss in the experimental group (filling collagen sponge after the mesial ILTM extraction) was significantly reduced compared with the control group, indicating that collagen sponge prevents postoperative periodontal defects and maintains the periodontal health of the second molars. In addition, Kim et al<sup>65</sup> also proved that the placement of absorbable collagen sponge reduced the periodontal probing depth and accelerated the healing of periodontal defect in the adjacent second molars.

## Transplantation of Cell Active Ingredients

Cell active component transplantation implants various cell active components into the extraction socket, such as platelet-rich plasma (PRP), platelet-rich fibrin (PRF), concentrated growth factor (CGF) and other blood platelet concentrates. Cell active component transplantation stimulates cell proliferation, repairs bone defects and promotes bone regeneration by releasing various growth factors.<sup>66</sup> Multiple studies reported that PRP can promote alveolar defects healing and new bone formation after ILTM extraction, and reduce postoperative reactions. Gandevivala et al<sup>67</sup> put the PRP into the extraction socket, and the experimental group was significantly different from the control group in terms of PPD. Similarly, Bhujbal et al<sup>68</sup> conducted the same study and found that the average bone density of the PRP group was significantly higher than that of the control group. Doiphode et al<sup>69</sup> further evaluated the repair effect of PRP and PRF on bone defects, and found that PRF improved periodontal health more significantly.

The periodontal management of the adjacent second molar after ILTM extraction is challenging in clinicians. Different interventions can restore the original periodontal structure and a functional attachment to promote periodontal tissue regeneration. These interventions have good clinical effects in the treatment of periodontal defects, and can be used as treatment to prevent periodontal complications after third molar extraction (Table 2)

## Limitations of Current Research Insufficient Attention of Oral Surgeons

The ILTM extraction is a complicated surgery because of its special location, adjacency to important anatomical structures and small surgical fields. Extraction involves the manipulation of both soft and hard tissues, so the patient usually experiences pain, swelling, trismus, inferior alveolar nerve and lingual nerve injury in the immediate postoperative period.

**Table 2** Clinical Periodontal Characteristics of Bone Regeneration Techniques

Author/ Year	N° Patients	Variable	Regeneration Technique	Follow-Up	Conclusion
Kim et al 2020 <sup>65</sup>	31	PPD	Collagen sponge/ Control	3 Month	Significant reduced PD
Wang et al 2018 <sup>64</sup>	120	Bone loss	Collagen sponge/ Gelatin sponge	3 Month	the collagen sponge significantly reduced bone loss compared with the Gelatin sponge
Bhujbal et al 2018 <sup>68</sup>	20	Bone density	PRP/ Control	6 Month	The PRP increased bone density compared with the control group
Xie et al 2018 <sup>49</sup>	52	PPD, Bone loss	Scaling and Root planing/ Control	6 Month	Scaling and Root planing significantly decreased PPD and bone loss compared with those in the control group
Gandevala et al 2017 <sup>67</sup>	18	PPD	PRP/ Control	3 Month, 6 Month	The PRP reduced PPD compared with the control group
Chen et al 2017 <sup>60</sup>	12	CAL, Bone density	Bio-oss/ Control	5 Year	The single Bio-OSS significantly decreased PPD and increased bone density
Doiphode et al 2016 <sup>69</sup>	30	PPD, Bone density	PRP/ PRF/ Control	6 Month	The PRP and PRF decreased PPD and increased bone density compared with the control group
Cortell et al 2015 <sup>52</sup>	56	PPD, CAL	Resorbable membrane/ Control	6 Month	The resorbable membrane Control significantly reduced PPD and AL compared with those in the control group
Singh et al 2013 <sup>58</sup>	25	PPD, Bone level	HA+collagen/ absorbable gelatin sponge	6 Month	HA+collagen increased in the alveolar bone level, improvement of PPD and better wound healing compared with absorbable gelatin sponge
Corinaldesi et al 2011 <sup>53</sup>	11	PPD, CAL	Resorbable membrane/ Non resorbable membrane	9 Month	The absorbable membrane obtained the same marked PPD reductions and CAL gains as non-resorbable ePTFE membranes after M3 extraction.
Sammartino et al 2009 <sup>61</sup>	45	PPD, CAL, Bone density	Bio-oss/ Bio-oss-Collagen membrane/ Control	6 Month	Both single Bio-OSS and the mixture can significantly decreased PPD and gained CAL
Thronson et al 2002 <sup>59</sup>	14	CAL Bone formation	Bioactive glass/ Control	12 Month	The bioactive glass significantly increased AL but not the level of bone formation



Generally, these complications seriously affect the patient's quality of life and have attracted great attention from clinicians, which is why they can be well controlled in a short term. However, postoperative complications are not limited to these, periodontal defects in the distal part of adjacent second molars often occurs. Due to the lack of obvious subjective symptoms, clinicians often ignore them and do not receive timely postoperative treatment, leading to plaque accumulation and local inflammatory diseases, which eventually affects the mid-long-term prognosis of second molars.<sup>5</sup>

## Different Periodontal Examination

### Methods

Periodontal examination methods comprised periodontal probing and imaging evaluation, but different examination methods may show the state of the disease unilaterally, bringing different experimental results. Periodontal probing, including common periodontal probe and the electronic periodontal probe, can detect the PPD and CAL. Compared with electronic periodontal probing, the accuracy of common periodontal probes is greatly affected by subjective factors (probing intensity, angle and so on), patient cooperation, soft tissue inflammation.<sup>70</sup> Therefore, the experimental data obtained by using different periodontal probe have a large error, leading to wrong conclusions. Imaging methods, including curved tomography and cone-beam CT (CBCT), can assess the distal bone level of the second molar. Assessing the same group of patients, curved tomography showed that 62.9% of patients had bone defects, while CBCT showed that 80% of patients had bone defects, indicating a significant difference between the two methods.<sup>71</sup> Compared with CBCT, curved tomography underestimated the severity of the distal bone defect of the second molar ( $p < 0.05$ ). It is currently believed that CBCT can assess the level of alveolar bone more detail and reliability.

## Different Periodontal Evaluation Indicators

PPL, CAL, alveolar bone height and density are often used to evaluate the influence of ILTM extraction on the periodontal health of adjacent second molars. However, there is currently no recognized index and index standard for this, four indicators are rarely used at the same time after tooth extraction, and normally only one or two of them are used, which may not accurately describe the actual periodontal condition. Christiaens et al<sup>72</sup> believed that the diagnosis of

periodontal disease should combine clinical examination index (including PPD and CAL) with imaging analysis, which has high diagnostic sensitivity. Therefore, combining the four evaluation indicators can more objectively and accurately study the periodontal effect of ILTM extraction on the adjacent second molars.

## Different Standards for Periodontal Probing

When performing periodontal probing on the distal of the second molar before and after ILTM extraction, some scholars focused on a specific location, and some scholars focused on the average of 2–3 locations. Tabrizi et al<sup>73</sup> thought that if there are pre-operative intrabony defects and iatrogenic injury during third molar surgery, it is more valuable that the periodontal parameters are measured at three sites at the distal part of the second molar to provide a more accurate and visible periodontal condition. However, only a few scholars<sup>74</sup> selected five sites around the distal second molars, that is, buccal, dis-buccal, mid-distal, dis-lingual, lingual. They believed that multi-site measurements permitted the detailed assessment of the distal periodontal status of the second molar in an unprecedented way, although greatly complicates the analyses of the results.

## Critical Consideration

Since the 1980s, many studies have focused on the relationship between ILTM and periodontal health, as well as the impact of ILTM extraction on periodontal tissue health.<sup>75</sup> In our previous study, ILTM extraction resulted in periodontal tissue defects in adjacent second molars.<sup>73,76,77</sup> However, there are some controversies in the scientific literature. Blakey et al<sup>78</sup> investigated the periodontal pathology following asymptomatic ILTM extraction. Preoperatively, the sites with PPD  $\geq 4$ mm in the distal second molars was 6.6%, while the postoperative reduction was 1.4%. The same research was done by Pham et al.<sup>79</sup> After 3 and 6 months, PPD decreased and bone level increased, which was statistically significant, further indicating that ILTM extraction contributes to periodontal health of the distal second molar. Besides, Dicus-Brookes et al<sup>80</sup> evaluated the effect of ILTM extraction with mild pericoronitis on the periodontal status of adjacent second molars and found that significantly fewer patients (46%) had at least one site PPD  $\geq 4$ mm in the distal second molar after 3 months compared with before surgery (88%). These

results demonstrated that ILTM extraction significantly improved the distal periodontal condition of the second molar and had a positive effect on the overall periodontal health. Careful analysis revealed that the study sample lacks homogeneity. Moreover, different studies use different periodontal evaluation indicators and imaging methods to assess periodontal conditions. Technical errors are often not considered, and there is a lack of detailed assessment of periodontal tissue healing. Therefore, further standardized studies are needed in the current literature to determine the effect of ILTM extraction on periodontal healing.

## Conclusion and Perspectives

The periodontal condition of the adjacent second molars is affected by many factors, including preoperative periodontal status, ILTM extraction time, impacted type, flap design, extraction instruments and suture type. To minimize the periodontal damage of the adjacent second molars, it is recommended that the ILTM extraction should be evaluated by preoperative consultation, clinical and imaging examinations. The reasonable flap design, suture type and minimally invasive tooth extraction surgery will reduce periodontal damage. Whether to perform periodontal interventions is based on preoperative evaluation and intraoperative procedures. Valid postoperative periodontal interventions promote the repair of the distal periodontal defects of the second molars. However, owing to the inconsistency of indicators, there is a lack of effective comparison in the literature regarding which intervention offers the better postoperative periodontal healing, so a larger sample size must be needed to validate in the future. As far as current research is concerned, there are still some limitations in the effect of ITLM extraction on the periodontal tissue of adjacent second molars, which need to be further improved.

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## Disclosure

The authors report no conflicts of interest in this work.

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