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Clinical Evaluation of Immediate Implantation in Molars with Chronic Apical Periodontitis and Chronic Periodontitis

Jing Luo, Li He (Corresponding Author), Jiao Zhang, Ru Guo, Qiaoyun Yang, Menglin Liao

Department of Implant Dentistry, Deyang Stomatological Hospital, Deyang, Sichuan, 618000, China. Email: 15183821334@163.com

Xiuhong Guo

Key Laboratory of Oral & Maxillofacial Reconstruction and Regeneration, Southwest Medical University, Luzhou, Sichuan, 646000, China

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Abstract

To evaluate the clinical efficacy of immediate implant placement in molars affected by chronic apical periodontitis and chronic periodontitis, 50 patients admitted to a city-based southwest stomatological hospital in mainland China between July 2023 and July 2024 who required tooth extraction due to chronic apical periodontitis or chronic periodontitis and met the inclusion criteria were selected as samples. They were randomly assigned to an experimental group (Group A) and a control group (Group B), with 25 patients in each one. The experimental group underwent immediate implant placement, while the control group underwent delayed implant placement 3–6 months after extraction and all surgeries were performed by the same implant surgeon. The study compared the effects of the two treatment modalities on implant retention, complications, implant stability, surrounding soft tissue, vertical and horizontal margins, and peri-implant gaps. Results showed that at the 12-month postoperative follow-up, implant retention rates were high in both groups, with no statistically significant difference in retention rates between groups ($P > 0.05$). Regarding complication rates, the immediate implant group showed a significantly lower incidence than the delayed implant group, with a statistically significant difference ($P < 0.05$); immediately after post-operation, there was no statistically significant difference in ISQ scores between the two groups ($P > 0.05$). At 6 months postoperatively, ISQ scores in both groups had increased significantly compared to the immediate postoperative period, with statistically significant intra-group differences ($P < 0.05$). Furthermore, the ISQ score in the immediate implant group was higher than that in the delayed implant group, with a statistically

significant intra-group difference ($P < 0.05$); at the 12-month follow-up after crown restoration, the periodontal probing depth (PD), modified sulcus bleeding index (mSBI), and modified plaque index (mPI) were all lower in the immediate implant group than those in the delayed implant group, with statistically significant differences between groups ($P < 0.05$); at 12 months post-surgery, both the vertical and horizontal dimensions of the peri-implant gap were significantly reduced compared to the immediate post-operative period, and the differences between different time points within the group were statistically significant ($P < 0.05$). In conclusion, for molars with chronic apical periodontitis and chronic periodontitis that meet the indications, immediate implant placement combined with non-submerged healing and no bone grafting in the jump space, provided that thorough debridement, precise implantation, and initial stability are ensured, offers reliable efficacy, fewer complications, and excellent bone preservation. Thus, this approach can be considered as a preferred clinical treatment option and worthwhile to be applied on a larger scale.

Keywords: chronic apical periodontitis, chronic periodontitis, molars, immediate implant placement

1. Introduction

The procedure of placing an implant into the extraction socket immediately following tooth extraction is defined as immediate implant placement (Gao et al., 2023). As research has progressed, most scholars now recognize immediate implant placement as a valid treatment approach (Luo et al., 2023). Chronic apical periodontitis and chronic periodontitis are common conditions in clinical dentistry, characterized by high prevalence rates that significantly impact patients' oral health and quality of life (Braz-Silva et al., 2019). Traditional treatment principles suggest that performing implant placement in an extraction socket during the inflammatory phase may interfere with the osseointegration process between the implant and the alveolar bone due to the presence of inflammatory tissue, thereby reducing the success rate of the implant. Therefore, it is generally recommended that patients undergo implant surgery only after the inflammation has completely resolved and the extraction socket has healed stably (Bassir et al., 2019). However, with continuous advancements in dental implant technology and the accumulation of clinical experience, an increasing number of studies have begun to explore the feasibility of immediate implantation following the extraction of teeth affected by chronic apical periodontitis (Hollander et al., 2026). Recent clinical studies have shown that, during the non-acute phase when infection is effectively controlled, immediate implant placement is feasible. It can effectively shorten the duration of tooth loss, reduce physiological resorption of the alveolar bone, and maximize the preservation of alveolar bone height and width. This is of great significance for the subsequent stability of the implant as well as the aesthetic and functional restoration following crown placement (Truninger et al., 2011). Furthermore, immediate implantation reduces the physical distress and financial burden associated with multiple surgical procedures, thereby improving patient treatment compliance. However, there is currently no consensus regarding the long-term efficacy of immediate implantation in molars with chronic apical periodontitis. Clarifying the long-term clinical outcomes of this treatment approach is of great guiding significance for optimizing dental implant treatment plans, improving

treatment success rates, and enhancing patient prognosis. It can provide clinicians with a more scientific and rational basis for treatment decisions when managing such patients.

2. General Information and Methodology

2.1 General Information

50 patients admitted to our hospital between July 2023 and July 2024 who required tooth extraction due to chronic apical periodontitis or chronic periodontitis and met the inclusion criteria were selected. The entire study was conducted in accordance with the ethical guidelines of the Declaration of Helsinki and was approved by the hospital's Medical Ethics Committee. All study participants provided informed consent and voluntarily signed the informed consent form.

2.2 Inclusion Criteria

(1) Age > 18 years; (2) No gender restriction; non-pregnant females; (3) Vertical bone height from the alveolar socket floor to the maxillary sinus floor in the planned implant site ≥ 4 mm; mesio-distal interproximal space ≥ 9 mm; bucco-lingual alveolar socket wall distance ≥ 9 mm; (4) No bone fractures or bone fenestrations; (5) Good oral hygiene, with periodontal probing depths of adjacent teeth <3 mm; (6) Good general health, with no contraindications for implant surgery, such as blood pressure exceeding 160/100 mmHg, fasting blood glucose >8.0 mmol/L, or coagulation disorders; (7) The patient is informed and consents to participate in this study and is able to cooperate with examinations, surgical treatment, and post-discharge follow-up.

2.3 Exclusion Criteria

(1) Patients with concomitant cognitive impairment or psychiatric disorders who are unable to cooperate with treatment and long-term follow-up; (2) Acute inflammation in the affected tooth or adjacent tissues; (3) Patients on long-term bisphosphonate therapy; (4) Heavy smokers (＞20 cigarettes/day) or heavy drinkers; (5) Patients with benign or malignant tumors of the head and neck, or a history of chemotherapy or radiotherapy; (6) Patients with chronic periodontitis who have not undergone systematic treatment.

2.4 Treatment Methods

Simple randomization method was employed, another implantologist assigned random numbers to the patients, and Microsoft Excel was used to randomly assign 50 patients to the experimental group (Group A) and the control group (Group B), with 25 patients in each group respectively. The experimental group underwent immediate implant placement, while the control group underwent delayed implant placement 3–6 months after tooth extraction. All surgeries were performed by the same implantologist.

(1) Preoperative Preparation

Implants of appropriate length and diameter were selected based on the remaining alveolar bone volume measured via cone-beam CT. A full-mouth supragingival scaling was performed preoperatively. Prophylactic antibiotics were administered 1 hour prior to surgery,

followed by a 1-minute rinse with 0.5% povidone-iodine. The maxillofacial area was then disinfected, and a sterile drape was applied.

(2) Surgical Procedure

In the experimental group, under local anesthesia, a No. 15 circular scalpel was used to make a vertical oblique incision at the buccal third of the mesial adjacent tooth to the intended implant site, starting from the gingival margin and angling mesially at 15°–20° to a depth of 5 mm below the mucogingival junction. The incision was approximately 10 mm long. An intrasulcular incision was then made along the buccal surface of the affected tooth to the buccal surface of the mesio-distal adjacent tooth at the mesio-distal 1/3. Using a periosteal elevator, subperiosteal dissection was performed along the surface of the alveolar bone to completely elevate the buccal quadrangular mucoperiosteal flap. After extraction of the affected tooth, the lingual-palatal mucoperiosteum was appropriately dissected to fully expose the extraction socket. Trim the edges of the mucoperiosteal flap and the inflammatory granulation tissue on the medial side and use a curette of appropriate size to remove the inflammatory granulation tissue adhering to the inner wall of the alveolar socket, then polish the area with large, medium, and small ball burs until the alveolar socket walls are completely free of fibrous tissue. For alveolar sockets with intact root septa, first use a small ball bur to mark the root septa, then use a 2.0 mm guide drill for primary preparation. In the maxilla, the depth should be controlled at 1 mm from the maxillary sinus floor and insert a guide pin to determine the implant direction. In the maxilla, use a bone reamer to progressively enlarge the preparation. For alveolar sockets with incomplete root septa, use a stepwise preparation technique. After selecting the correct three-dimensional position, use a ratchet wrench to screw the implant into the site. Use a periodontal probe to confirm that the implant neck shoulder is located 1–1.5 mm below the alveolar bone margin, with approximately 3–5 mm of bone contact at the root end to ensure initial stability. Use a torque wrench to measure the post-insertion torque value, ensuring it exceeds 35 N·cm to confirm good initial stability of the implant. Then, insert the cover screw and close the site with sutures. Perform an immediate postoperative radiographic examination to ensure the implant is in the correct position.

In the control group, after local anesthesia, a vertical oblique incision was made in the buccal middle third of the mesio-adacent tooth at the intended implant site (as in the experimental group). A linear incision was made along the crest of the alveolar ridge extending to the mesio-adacent third of the disto-adacent tooth. The buccal mucoperiosteal flap was thoroughly elevated, and a preparation cavity was created with minimal three-dimensional positional deviation. A guide pin was inserted to confirm the implant orientation. and the implant was placed using a ratchet wrench (method identical to the experimental group), followed by immediate postoperative radiographic examination.

(3) Postoperative Care

Avoid brushing teeth or rinsing the mouth for 24 hours postoperatively. Starting the day after surgery, rinse with 15–20 ml of 0.5% chlorhexidine mouthwash for 7 days. Administer routine anti-inflammatory treatment for 3–5 days. Remove sutures 2 weeks postoperatively.

Patients are advised not to use the teeth on the implant side or the healing abutment for chewing food for 2 months postoperatively to avoid abnormal stimulation of the implant during the healing phase. If loosening of the healing abutment is detected, patients should return for a follow-up visit promptly and maintain good oral hygiene. All patients should return for follow-up visits every 3 months for periodontal maintenance therapy.

(4) Crown Restoration

Crown restoration is performed 6 months postoperatively. Following the second-stage surgery, the healing abutment is checked for stability, the gingival margin for redness or swelling, and adjacent and opposing teeth for tilting or elongation. Measure the ISQ score; if the value is ≥70, it confirms good osseointegration of the implant. The same dentist should take impressions, and the restoration should be fabricated at the same dental laboratory. After the restoration is completed, the patient should return for a follow-up visit. Once the crown is tried in and fully seated, the central screw channel should be sealed.

(5) Follow-up

Follow-up visits should be scheduled 6 and 12 months after crown restoration to assess and record implant retention rates and complications. Use a periodontal probe to measure the crown's periodontal probing depth (PD), modified sulcus bleeding index (mSBI), and modified plaque index (mPLI). Perform a cone-beam CT scan to measure and analyze vertical and horizontal marginal bone resorption around the implant, as well as osteogenesis in the jump space.

2.5 Clinical Observation Indicators

2.5.1 Implant Retention Rate and Complications

Each single implant was treated as a unit of statistical analysis. The criteria for determining clinical osseointegration were based on the conclusions of Buser's study (Buser et al., 2012). All study subjects were followed up for 12 months after completion of the superstructure restoration to calculate the overall implant retention rate in this group.

The specific evaluation criteria are as follows: (1) No displacement or migration of the implant was observed; (2) Patients exhibited no recurrent persistent pain, oral discomfort, or local sensory abnormalities; (3) No symptoms of peri-implant inflammatory infection were observed in the surgical site; (4) Clinical palpation and mobility tests indicated that the implant was stable, with no signs of loosening or mobility. Complications are classified into two major categories: biological and mechanical. Biological complications primarily include two common postoperative inflammatory conditions: peri-implant mucositis and peri-implantitis. Mechanical complications primarily involve abnormalities related to the prosthetic restoration, including prosthetic fracture, retention loosening, and various mechanical structural damage issues such as loosening or fracture of the central locking screw, abutment, or implant body (Lombardo et al., 2021). A higher implant retention rate and fewer complications indicate a superior implant procedure.

2.5.2 Implant Stability Quotient (ISQ)

Implant ISQ values were measured using a resonance frequency analyzer (Okuhama et al., 2022). Measurements were standardized to the same position and force level, with resonance frequencies recorded at four sites—buccal, lingual, mesial, and distal—on the implant. The average of these four values was taken as the final ISQ result. The dynamic changes in implant ISQ were recorded immediately postoperatively and at 6 months postoperatively to evaluate the initial implant stability and long-term stability of osseointegration following immediate implantation after extraction of teeth with chronic inflammation. An ISQ $\geq$ 70 was defined as indicating adequate clinical implant stability. The study analyzed the patterns of how chronic periapical infections and defects in periodontal hard and soft tissues affect the stability of osseointegration.

2.5.3 Peri-implant Soft Tissue Examination

Commonly used clinical periodontal assessment indices were employed to evaluate the health of peri-implant soft tissues. Follow-up was conducted 12 months after implant crown restoration, during which the periodontal probing depth (PD), modified sulcus bleeding index (mSBI), and modified plaque index (mPI) of the implant-supported prosthesis were measured and recorded. PD: The depth of the gingival sulcus around the implant was measured using a periodontal probe. Probing depths were recorded at six sites (buccal mesial, central, and distal; lingual mesial, central, and distal) with an applied force of approximately 25 g, and the average value was taken as the PD value for that implant. mSBI scoring criteria: 0—no bleeding after probing, healthy mucosa; 1—punctate bleeding after probing; 2—linear bleeding confined to the gingival sulcus; 3—severe bleeding or spontaneous bleeding extending beyond the gingival sulcus; mPLI scoring criteria: 0—no plaque on the gingival margin or within the gingival sulcus; 1—a thin layer of plaque visible on the gingival margin, detectable only upon probing; 2—obvious plaque and soft debris on the gingival margin, visible to the naked eye; 3—heavy plaque/soft debris on the gingival margin, accompanied by calculus and gingival inflammation. For each measurement, the most severe result was recorded as the study value.

2.5.4 Vertical and Horizontal Marginal Bone Resorption

Cone-beam CT images were acquired at two time points: immediately postoperatively and 12 months after crown restoration. The implant's long axis was defined as the reference axis L0, and the implant shoulder reference plane L1 was established perpendicular to L0. In the vertical direction, the vertical height H1 from the buccal and lingual alveolar crest to the shoulder plane L1 was measured; In the horizontal direction, the horizontal width W1 was measured from the outer edge of the buccal and lingual bone on the shoulder plane L1 to the implant margin. All measurements were repeated three times with a precision of 0.01 mm, and the results were averaged. The extent of buccal and lingual vertical and horizontal marginal bone resorption was compared between the immediate implant group and the delayed implant group.

2.5.5 Changes in the Gap in the Immediate Implant Group

Cone-beam CT scans were performed at two time points—immediately post-operation and 12 months after crown restoration. The long axis of the implant (L0) was defined, and a reference plane (L1) perpendicular to it was established at the implant shoulder. At both time points, the vertical distance H2 from the highest point of osseointegration to the reference plane L1 was measured, as well as the horizontal distance W2 between the inner surfaces of the buccal and lingual bone walls at the shoulder plane and the implant margin. Each measurement was repeated three times with a precision of 0.01 mm, and the mean value was taken as the final result to investigate the dynamic changes in the peri-implant gap in the immediate implant group.

2.6 Statistical Analysis

Data analysis was performed using SPSS 26.0 statistical software. All data were recorded by two researchers working in parallel and cross-checked to ensure accuracy. Continuous variables that followed a normal distribution are presented as mean ± standard deviation (SD), while those that did not follow a normal distribution are presented as median (interquartile range) [M (Q1, Q3)]. Categorical variables are presented as frequency (%). To assess the balance of baseline data between the two groups, continuous variables were analyzed using an independent samples t-test (for normally distributed data) or the Mann-Whitney U test (for non-normally distributed data), while categorical variables were analyzed using the chi-square test or Fisher's exact test (when the expected frequency was <5). For comparisons of categorical data between groups (e.g., implant survival rate, complication incidence), the chi-square test was used; for comparisons of continuous data (e.g., implant stability coefficient, periodontal soft tissue indices, marginal bone resorption), repeated-measures analysis of variance (ANOVA) was used for comparisons across different time points within a group, and independent samples t-tests were used for comparisons between groups at the same time point. For the immediate implant group, paired samples t-tests were used to compare the jump gap before and after the procedure. All statistical tests were two-sided, with a significance level of $\alpha = 0.05$; $p < 0.05$ was considered statistically significant.

3. Results

3.1 Comparison of Baseline Data Between the Two Groups

Comparisons of baseline data between the two groups, including age, gender, distribution of affected teeth, and preoperative bone volume in the implant site, revealed no statistically significant differences ($P > 0.05$). The groups were clinically comparable; see Table 1.

Table 1. Comparison of Baseline Data Between the Two Groups

Group	Number of Cases	Age (x±s; years)	Male/Female (cases)	Affected Maxillary Teeth/Affected Mandibular Teeth (cases)	Preoperative Bone Thickness from the Alveolar Socket Floor to the Maxillary Sinus Floor (x±s; mm)
Group A	25	42.36±5.42	13/12	11/14	5.28±0.63
Group B	25	41.89±5.17	14/11	12/13	5.19±0.58
χ^2/t		0.314	0.081	0.081	0.525
P		＞0.05	＞0.05	＞0.05	＞0.05

3.2 Comparison of Implant Retention Rates and Complication Incidence Between the Two Groups

At the 12-month postoperative follow-up, implant retention rates were high in both groups, and there was no statistically significant difference in retention rates between the groups ($P > 0.05$). However, the incidence of complications was significantly lower in the immediate implant group than in the delayed implant group, with a statistically significant difference ($P < 0.05$). Biological complications were predominant in both groups: in the immediate implant group, only one case of peri-implant mucositis occurred, which resolved following local irrigation and oral hygiene intervention; the delayed implant group had 3 cases of peri-implant mucositis, 1 case of peri-implantitis, and 2 cases of abutment loosening; all were controlled after symptomatic treatment. No severe mechanical complications, such as implant loss or fracture, occurred in either group. See Table 2 for details.

Table 2. Comparison of Implant Retention Rates and Complication Incidence Between the Two Groups [n (%)]

Group	Number of Cases	Number of Implants	Retained Retention Rate	Number of Complications	Complication Rate
Group A	25	25	25（100.00）	1	1（4.00）
Group B	25	24	24（96.00）	6	6（24.00）
χ^2			1.020		4.153
P			＞0.05		＜0.05

3.3 Comparison of Implant Stability Quotient (ISQ) Between the Two Groups at Different Time Points

Immediately post-operation, there was no statistically significant difference in ISQ values between the two groups ($P > 0.05$); at 6 months post-surgery, ISQ values in both groups had increased significantly compared to the immediate postoperative period, with statistically significant differences within each group ($P < 0.05$). Furthermore, the ISQ value in the immediate implant group was higher than that in the delayed implant group, with a

statistically significant difference between the two groups (P < 0.05). This suggests that the immediate implant group exhibits superior long-term osseointegration stability. See Table 3 for details.

Table 3. Comparison of Implant Stability Quotient (ISQ) Between the Two Groups at Different Time Points (x ± s; points)

Group	Number of cases	Immediately post-surgery	6 months post-surgery	*t*	*P*
Group A	25	58.62±3.15	74.45 ±2.83	18.691	＜0.05
Group B	25	57.98±3.07	70.21 ±2.96	14.339	＜0.05
t		0.728	5.155		
P		＞0.05	＜0.05		

3.4 Comparison of Peri-implant Soft Tissue Parameters Between the Two Groups at 12 Months Post-Restoration

At the 12-month follow-up after crown restoration, the periodontal probing depth (PD), modified sulcus bleeding index (mSBI), and modified plaque index (mPI) were all lower in the immediate implant group than those in the delayed implant group, with statistically significant differences between the groups (P < 0.05). This indicates that immediate implantation is more conducive to maintaining peri-implant soft tissue health. See Table 4 for details.

Table. 4 Comparison of Peri-implant Soft Tissue Parameters Between the Two Groups at 12 Months Post-Restoration (x ± s)

Group	Number of Cases	PD（mm）	mSBI （points）	mPI （points）
Group A	25	2.15±0.32	0.58±0.21	0.63±0.24
Group B	25	2.89±0.41	1.02±0.27	1.15±0.30
t		7.114	6.432	6.768
P		＜0.05	＜0.05	＜0.05

3.5 Comparison of Peri-implant Bone Resorption Between the Two Groups

Immediately post-operation, there were no statistically significant differences between the two groups in terms of vertical and horizontal peri-implant bone volume on the buccal and lingual sides (P > 0.05); at 12 months post-restoration, both groups exhibited varying degrees of marginal bone resorption. However, the immediate implant group showed significantly lower vertical and horizontal marginal bone resorption compared to the delayed implant group, with statistically significant differences between the groups (P < 0.05). See Table 5 for details.

Table 5. Comparison of Marginal Bone Resorption Around Implants in the Two Groups (x ± s, mm)

Group	Number of Cases	Vertical bone resorption	Horizontal bone resorption
Group A	25	0.42±0.11	0.35±0.09
Group B	25	0.78±0.15	0.62±0.12
t		9.677	9.000
P		＜0.05	＜0.05

3.6 Changes in the Jump Gap in the Immediate Implantation Group

Measurements of the jump gap in the immediate implant group were taken immediately post-operation and 12 months after restoration. The results showed that both the vertical and horizontal distances of the jump gap around the implant were significantly reduced at 12 months postoperatively compared to immediately post-operation. The differences between different time points within the group were statistically significant ($P < 0.05$), suggesting successful formation of new bone tissue within the jump gap and a favorable osseointegration process. See Table 6 for details.

Table 6. Comparison of Gap Changes in the Immediate Implantation Group (x ± s, mm)

Time Point	Number of Cases	Vertical Distance Between Jumps (H2)	Horizontal Distance Between Jumps (W2)	*t*	*P*
Immediately post-operation	25	1.26±0.23	0.98±0.20	4.593	＜0.05
12 months after restoration	25	0.31±0.08	0.24±0.07	3.293	＜0.05

4. Discussion

Chronic apical periodontitis and chronic periodontitis are the primary causes of molar tooth loss. Traditional treatment approaches often advocate for delayed implant placement following inflammation control; however, alveolar ridge resorption and remodeling after tooth extraction frequently result in insufficient bone volume, thereby increasing the difficulty of implant-supported restoration (Ahmad, 2024). This study compared the 12-month clinical outcomes of immediate versus delayed implant placement following thorough debridement of molars with chronic apical periodontitis or chronic periodontitis. The results showed that immediate implant placement achieved a high implant survival rate comparable to that of delayed implant placement, while offering advantages in terms of complication control, implant stability, soft tissue health, and preservation of marginal bone. This confirms that immediate implant placement in molars with well-controlled inflammation, using open healing and a non-bone-grafting approach for the gap, is safe and feasible, providing evidence-based support for clinical practice.

4.1 Safety and Feasibility of Immediate Implantation in Inflamed Teeth

Traditional views hold that an infected environment hinders osseointegration and advocate for delayed implantation after the resolution of inflammation; however, this approach involves a prolonged treatment period, significant bone resorption, and the need for a second surgical procedure (Yu et al., 2024). Recent studies (Yang et al., 2023), however, have demonstrated that thorough debridement in the non-acute phase can eliminate the infectious microenvironment, thereby creating conditions conducive to immediate implantation. In this study, flap debridement and ball-end reamer preparation of the bone walls to ensure no residual inflammatory fibrous tissue, combined with precise three-dimensional placement and adequate initial stability, reduced the risk of infection at the source—a core prerequisite for the success of immediate implant placement. At the 12-month follow-up, the retention rates for the immediate implant group and the delayed implant group were 100.00% and 96.00%, respectively ($P < 0.05$). This suggests that, with strict control of indications and standardized procedures, immediate implant placement in molars with chronic inflammation can achieve retention outcomes comparable to those of traditional delayed implant placement, thereby challenging the conventional perception that immediate implant placement is contraindicated during the inflammatory phase. Neither group experienced severe complications such as implant failure or fracture, indicating good safety. This result is consistent with the conclusions of recent studies (Will & Drago, 2023). Regarding complications, the incidence rate in the immediate implant group (4.00%) was significantly lower than that in the delayed implant group (24.00%), with only one case of peri-implant mucositis, which resolved after treatment. Immediate implantation preserves the alveolar ridge morphology and soft tissue cuff intact, reducing plaque retention and mucosal inflammation. In contrast, delayed implantation, due to alveolar bone resorption and soft tissue remodeling, is more prone to peri-implant mucositis, peri-implantitis, and abutment loosening, confirming the advantage of immediate implantation in reducing postoperative complications.

4.2 Effects of Immediate Implantation on Implant Stability and Osseointegration

Implant stability is a core indicator for evaluating treatment efficacy. This study showed that there was no significant difference in ISQ scores between the two groups immediately post-operation ($P > 0.05$); however, at 6 months postoperatively, the ISQ score in the experimental group (69.45 ± 2.83) was significantly higher than that in the control group (64.21 ± 2.96) ($P < 0.05$). This difference may be related to the reduction in alveolar bone resorption achieved by immediate implantation. The primary reason could be that after molar extraction, the buccal alveolar crest often undergoes resorption due to poor blood supply; immediate implantation supports the bone wall through the implant, thereby reducing physiological remodeling. Furthermore, the gap in the experimental group significantly narrowed within 12 months postoperatively (vertical distance decreased from 1.26 ± 0.23 mm to 0.31 ± 0.08 mm, and the horizontal distance decreased from 0.98 ± 0.20 mm to 0.24 ± 0.07 mm) ($P < 0.05$). This suggests that even without bone grafting, a thoroughly debrided gap can achieve osseous healing through the organization of the blood clot, which is consistent with the theory proposed by Schnutenhaus et al. (Schnutenhaus et al., 2018), which suggests that blood clots within extraction sockets can guide bone regeneration.

4.3 Advantages of Immediate Implantation for Soft and Hard Tissue Preservation

This study confirms that immediate implantation is superior to delayed implantation in terms of both soft and hard tissue preservation. Regarding hard tissue, at the 12-month restoration visit, the experimental group's vertical marginal bone resorption (0.42 ± 0.11 mm) and horizontal marginal bone resorption (0.35 ± 0.12 mm) were both significantly lower than those of the control group (0.78 ± 0.15 mm and 0.62 ± 0.12 mm, respectively) ($P < 0.05$), which is attributed to the reduction of stress concentration at the alveolar crest following implant placement and the avoidance of bone loss associated with healing of the extraction socket during delayed implantation (Tonetti et al., 2017). Regarding soft tissue, the experimental group's PD (2.15 ± 0.32) mm, mSBI (0.58 ± 0.21) points, and mPI (0.63 ± 0.24) points were all significantly lower than those in the control group ($P < 0.05$). This may be attributed to the fact that immediate implantation preserves the residual periodontal ligament and gingival attachment around the natural tooth, thereby reducing soft tissue recession and inflammatory accumulation during the healing process.

5. Limitations of the Study and Clinical Implications

The findings of this study provide positive short-term (12-month) evidence for immediate implant placement in molars with chronic infections. However, this study has certain limitations due to constraints of objective conditions, such as a relatively small sample size in a single-study center and a follow-up period of only 12 months which is relatively short; long-term efficacy requires a larger sample size and extended observation to confirm the result. Secondly, the study included only patients with chronic apical periodontitis and chronic periodontitis, and did not separately analyze the differential effects of these two conditions on treatment outcomes, The lack of subgroup analysis for these two disease entities makes it impossible to determine if differences in efficacy exist for the immediate implant strategy in periapical versus periodontal infection environments. Additionally, the strategy of leaving the gap unfilled with bone grafting may not be suitable for cases with large bone wall defects, and strict clinical selection of indications is necessary. This protocol may not be suitable for sites with significant bone defects (e.g., socket wall defects >2 mm), inadequate bone volume, or where sufficient primary stability cannot be achieved. Consequently, the success of this technique is highly dependent on strict case selection and precise surgical execution, and its conclusions cannot be extrapolated to all infected sites.

In summary, for molars with chronic apical periodontitis or chronic periodontitis that meet the indications (no acute inflammation, intact socket walls, ability to achieve good primary stability), this study supports immediate implant placement combined with non-submerged healing and a jump gap without bone grafting as a preferred treatment option. This protocol ensures a comparably high survival rate while significantly reducing complication risks, better preserving alveolar bone and soft tissue, and shortening the overall treatment time. When applying this protocol, clinicians must strictly adhere to the case selection criteria and meticulously execute the key technical steps of thorough debridement, achieving primary stability, and precise implant placement. Patients must also be informed of the necessity for long-term regular maintenance. Future research should focus on long-term follow-up,

subgroup analysis of different infection types, and multi-center validation with larger sample sizes.

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Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Macrothink Institute.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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