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Impact of active Oxygen-Based Oral Gel on Healing After Immediate Implant Placement with Custom-Made Healing Abutment: (A Randomized Controlled Study)

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ABSTRACT

Immediate implant placement in mandibular molars remains surgically challenging because of wide extraction sockets, possible residual infection, and early soft-tissue instability. Optimizing postoperative healing and minimizing inflammation are essential for long-term implant success. Active oxygen–based oral gels such as Blue®m possess antimicrobial and tissue-regenerative properties; however, their clinical effect following immediate molar implant placement has not been fully established. This study evaluated the clinical effect of active oxygen–based gel on healing after immediate implant placement in mandibular molars using custom-made healing abutments, with emphasis on pain, peri-implant inflammation, wound healing, implant stability, and marginal bone changes. A randomized controlled clinical trial was conducted on 24 patients requiring immediate implant placement in mandibular molar sites. Patients were randomly allocated into: -study Group (n=12): application of Blue®m Gel immediately after implant placement. -Control Group (n=12): immediate implant placement without gel application. All implants were placed using a standardized surgical protocol with custom-made healing abutments to preserve peri-implant soft tissue architecture. Postoperative assessment included pain using the Visual Analog Scale (VAS), inflammatory response, soft-tissue healing, implant stability quotient (ISQ), and radiographic marginal bone loss. Data were analyzed using descriptive and comparative statistics. The test group demonstrated significantly lower postoperative pain and inflammatory scores during the early healing period. Faster epithelialization and improved soft-tissue closure were observed in the gel group during the first two postoperative weeks. Mean ISQ values were slightly higher in the test group, although the difference was not statistically significant. Lower early marginal bone loss was also observed at 6 months. Application of active oxygen–based Blue®m Gel following immediate implant placement in mandibular molars enhanced early postoperative healing by reducing pain and inflammation,

accelerating soft-tissue healing, and improving peri-implant tissue stability.

INTRODUCTION

Immediate implant placement has become widely used in modern implantology because it shortens treatment time and helps preserve alveolar bone and surrounding soft tissue after tooth extraction [1]. However, achieving predictable healing remains challenging due to complications such as infection, inflammation, delayed osseointegration, and soft tissue instability.

Custom-made healing abutments have been introduced to improve soft tissue adaptation and contouring around implants. These abutments contribute to better esthetic outcomes, tissue architecture, and implant stability compared with conventional healing abutments [2]. Nevertheless, they do not directly control bacterial contamination or enhance wound healing.

Active oxygen-based oral gels have attracted attention because of their antimicrobial and tissue-regenerative effects. By increasing local oxygen availability, they may enhance cellular activity, accelerate healing, and reduce bacterial load. Previous studies have reported favorable outcomes when these agents were used in oral and maxillofacial procedures [3], [4].

Although both active oxygen-based gels and custom-made healing abutments have shown individual clinical benefits, their combined use during immediate implant placement has not been adequately investigated. Few randomized controlled studies have evaluated the synergistic effect of combining oxygen therapy with personalized soft tissue management [2], [3].

Therefore, this study aimed to evaluate the efficacy of an active oxygen-based oral gel used with custom-made healing abutments in improving soft tissue healing, reducing postoperative complications, and supporting early implant success following immediate implant placement.

LITERATURE REVIEW

Dental implant placement involves inserting a titanium fixture into alveolar bone to replace missing teeth and restore function and aesthetics. Implant timing is classified into immediate, early, and delayed protocols depending on healing stage after extraction [5].

Successful implant therapy depends on multiple factors including bone quality and quantity, surgical technique, implant design, and systemic and oral health conditions [6]. Among these, timing of placement plays a crucial role in biological response and long-term outcomes [5].

Immediate implant placement (Type I) is performed directly after tooth extraction in the same surgical session. It reduces treatment time, preserves alveolar bone and soft tissue contours, and minimizes surgical interventions [7- 9]. It is also associated with improved patient satisfaction, particularly in esthetic zones when combined with immediate provisionalization [7].

However, immediate placement has biological and technical limitations. It requires adequate primary stability and strict case selection. Risks include infection, soft tissue recession, and implant failure in cases of poor bone quality or pre-existing pathology [9]. It is contraindicated in active infection, insufficient bone volume, or uncontrolled systemic diseases such as uncontrolled diabetes [5]. Buccal plate defects may also require augmentation procedures [5].

Early implant placement (Type III), performed after 12–16 weeks, allows partial bone healing and improved soft tissue conditions, reducing recession risk and improving bone volume compared to

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immediate placement [5].

Delayed implant placement (Type IV), performed after >16 weeks, provides maximum bone stability and predictable outcomes but is associated with longer treatment time and possible ridge resorption requiring grafting [9], [10].

Healing abutments are temporary components placed on implants to guide soft tissue healing and establish an appropriate emergence profile. They protect the implant–abutment interface, support mucosal maturation, and prepare the site for prosthetic restoration.

Custom-made healing abutments improve soft tissue contouring, enhance emergence profile formation, and reduce prosthetic complications compared with stock abutments [2], [11]. They also promote better gingival architecture and biological sealing.

Healing abutments are classified into stock (prefabricated) and CAD/CAM-fabricated types [12], [13. Stock abutments are cost-effective and readily available, while CAD/CAM abutments offer superior precision and tissue adaptation.

Functionally, they are divided into healing and definitive abutments. Healing abutments are used during tissue maturation, while definitive abutments support final prostheses.

Surgical protocols include one-stage (non-submerged) and two-stage (submerged) approaches. One-stage placement allows immediate soft tissue healing around the abutment when primary stability is sufficient [14]. Two-stage protocols are used in compromised cases where submerged healing under a cover screw is required [14].

In immediate implant placement, especially in mandibular molars, custom healing abutments are essential due to wide extraction sockets and complex root morphology. They help preserve soft tissue volume, prevent collapse, and establish a stable emergence profile [15], 16].

They can be fabricated chairside, via CAD/CAM systems, or by 3D printing [17], [16]. Chairside fabrication allows immediate application, while digital workflows improve precision and reproducibility.

Despite their advantages, custom abutments are technique-sensitive, time-consuming, and may increase cost. In posterior regions such as mandibular molars, esthetic benefit is limited, although functional benefits in tissue stability and hygiene remain important.

Active oxygen-based oral gels have emerged as adjuncts in implant dentistry due to antimicrobial and regenerative properties. They enhance oxygen availability, improve cellular metabolism, promote angiogenesis, and support collagen synthesis while reducing bacterial load [3], [4].

Formulations containing sodium perborate and glucose oxidase release controlled oxygen and hydrogen peroxide, creating an antimicrobial and healing-promoting environment [18- 19]. Additional components such as lactoferrin contribute anti-inflammatory and antibacterial effects [20].

These gels are used in implant surgery, periodontal therapy, and oral wound management, with evidence suggesting improved soft tissue healing and reduced inflammation [3], [21], [19].

Although both custom healing abutments and oxygen-based gels independently improve peri-implant healing, their combined effect has not been sufficiently investigated. Limited evidence exists regarding their synergistic role in immediate implant protocols, particularly in mandibular molars where anatomical and biological challenges are significant [2], [3], [11].

PATIENTS AND METHODS

Study Design and Setting

This prospective, randomized, controlled, parallel-group clinical trial was conducted at the Department of Oral and Maxillofacial Surgery, Faculty of Oral and Dental Medicine, Future University in Egypt. The study adhered to the Declaration of Helsinki (2013) and was approved by the Research Ethics Committee (REC-FUE No: FUE.REC(10)/1-2025). All clinical procedures, including patient selection, surgical intervention, and follow-up, were performed in the Postgraduate Oral Surgery Clinic under standardized

aseptic conditions by a single experienced oral surgeon to ensure procedural consistency.

Sample Size

A total of 24 patients (12 per group) were included based on previous similar studies, with a statistical power of 80% and a 95% confidence interval, accounting for possible dropout. Statistical analysis was performed using SPSS version 26, with significance set at $p < 0.05$.

Randomization and Blinding

Participants were randomly assigned in a 1:1 ratio into two groups using a computer-generated randomization sequence. Allocation concealment was achieved using sealed opaque envelopes.

- **Group A (Test group):** Immediate implant placement with custom healing abutment and application of oxygen-based gel (Blue®m).
- **Group B (Control group):** Immediate implant placement with custom healing abutment without gel application.

Blinding was applied at the outcome assessment level, where the examiner responsible for clinical follow-up and data collection was unaware of group allocation to minimize assessment bias.

Eligibility Criteria

Inclusion Criteria

Patients aged 25–55 years requiring immediate implant placement in mandibular molar sites were included. Adequate bone volume was confirmed using CBCT, including intact buccal and lingual plates and sufficient interradicular and apical bone support. Primary implant stability of ≥32 Ncm was mandatory. All patients were systemically healthy (ASA I–II) and provided informed consent.

Exclusion Criteria

Patients were excluded if they were heavy smokers (>20 cigarettes/day), had uncontrolled systemic diseases (e.g., diabetes or cardiovascular disease), active oral infections, poor oral hygiene, pregnancy or lactation, recent radiotherapy or chemotherapy, or bone metabolic disorders affecting healing.

Preoperative Assessment

Each patient underwent comprehensive evaluation, including medical and dental history, medication review, and allergy screening. Extraoral examination assessed facial symmetry, lymph nodes, and temporomandibular joint function. Intraoral examination evaluated gingival health, mucosal condition, alveolar bone status, tooth mobility, occlusion, and oral hygiene using Plaque and Bleeding Indices. Radiographic assessment included periapical radiographs and CBCT when indicated for bone quality and anatomical mapping.

Surgical Protocol,figure (1-2)

All procedures were performed under local anesthesia using 2% lidocaine with epinephrine 1:100,000. Atraumatic extraction was carried out while preserving socket walls. In mandibular molars, root separation and controlled extraction were performed to maintain interradicular bone integrity. Socket debridement was followed by careful evaluation of residual septal bone.

Osteotomy preparation was performed using sequential drilling under copious irrigation at low speed (1000 rpm), extending 3 mm beyond the socket apex. Implants were placed 2 mm subcrestally, achieving primary stability ≥32 Ncm, confirmed using torque measurement and ISQ analysis.

Intervention Protocol

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In Group A, approximately 2 mL of oxygen-based gel (Blue®m) was placed into the socket prior to implant insertion and left for 10 minutes. After implant placement, an additional 1 mL was applied before placement of the custom healing abutment. Postoperatively, 1 mL was reapplied on days 1, 3, and 7 around the gingival margin to enhance soft tissue healing and reduce inflammation.

In both groups, custom healing abutments were fabricated immediately chairside using composite to replicate the natural emergence profile, maintaining peri-implant soft tissue architecture and preventing collapse of the socket walls.

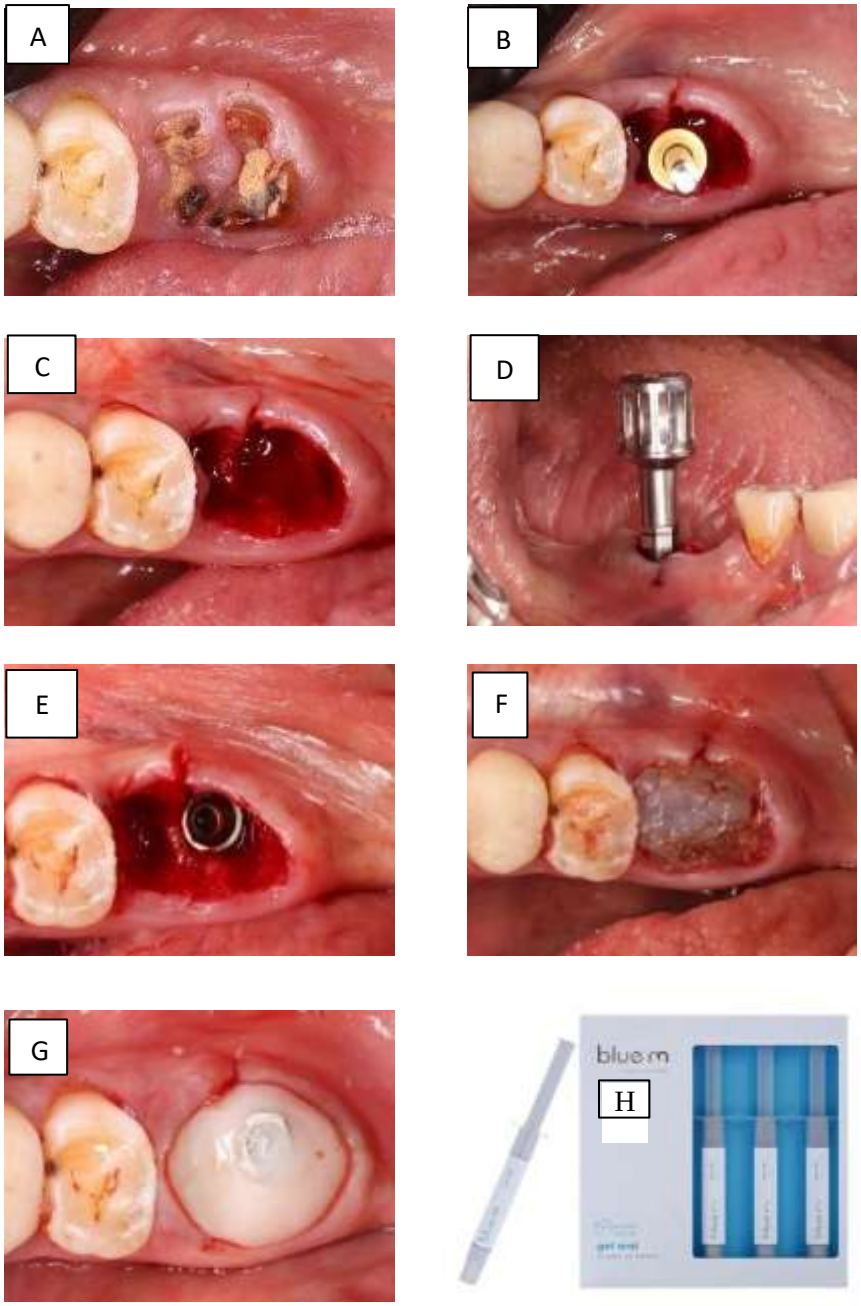

Figure (1): Show the steps of surgical extraction 36 and immediate implanement with custom healing abutment Group A (Blue m application): A) Remaining roots of 36, B) Drilling through the roots in the inter-radicular bone septum, C) Extraction of remaining roots. And D) Insertion of implant by driver implant, E) Implant placement, f) Blue m gel application, G) Custom healing abutment, H) Blue m gel kit.

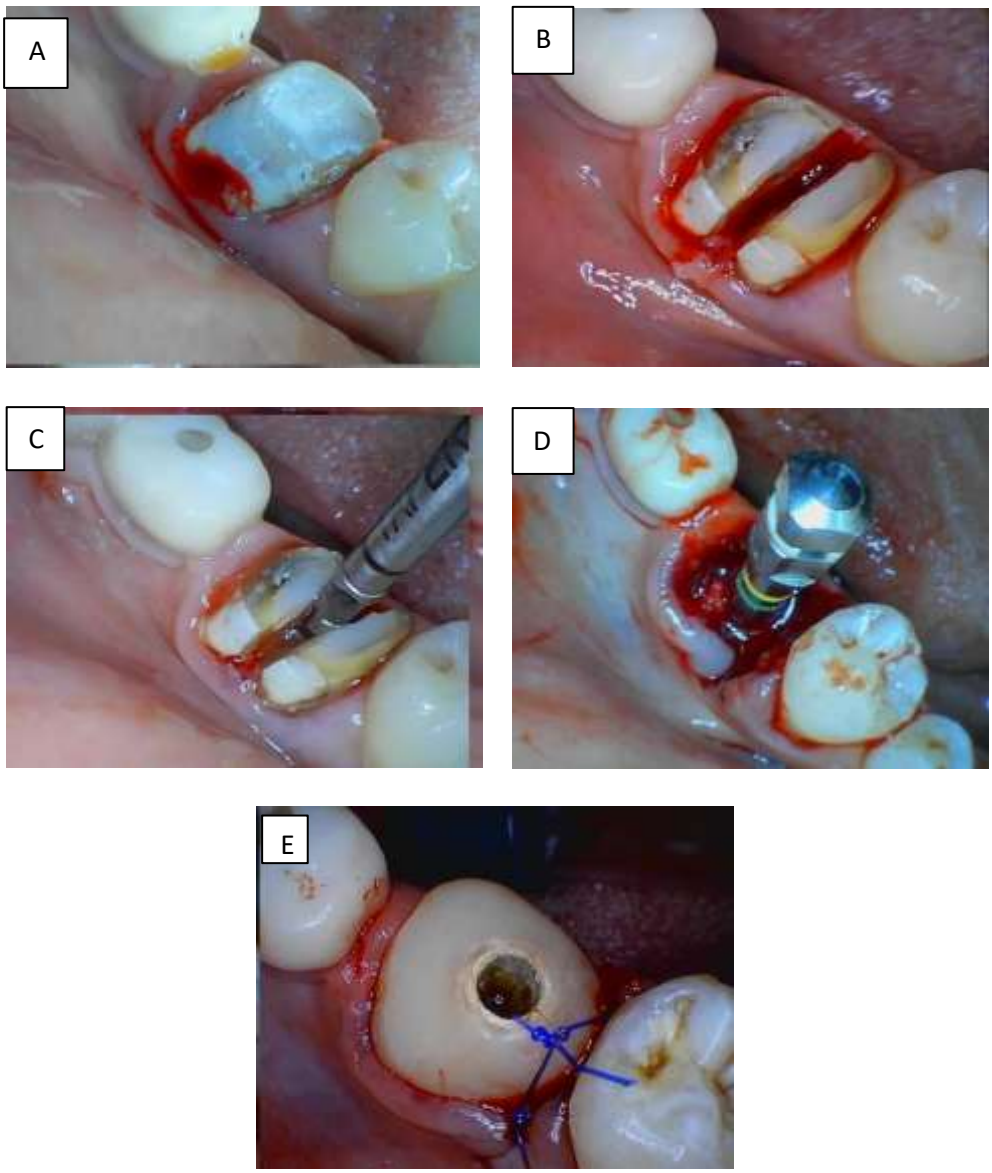

Figure (2): Show steps of surgical extraction of 46 and immediate implant placement with custom healing abutment only Group B, A) Hopless 46, B) Seperation of mesial and distal roots by fissured bur, C) Drilling through the roots in the inter-radicular bone septum, D) Implant placement by driver implant, E) Custom healing abutment.

Postoperative Care

All patients received antibiotics (amoxicillin-clavulanate 1 g every 12 hours plus metronidazole 500 mg every 12 hours for 7 days), NSAIDs (diclofenac potassium 50 mg every 8 hours for 3 days), and chlorhexidine-based mouth rinse twice daily for 10 days. Patients were instructed to maintain gentle oral hygiene and avoid brushing the surgical site for the first week.

Follow-Up and Outcome Measures

Follow-up visits were scheduled at baseline, 3, 7, 14, 30 days, and at 3 and 6 months.

Primary outcomes included soft tissue healing (Wound Healing Index), peri-implant inflammation (0–3 scale), pain assessment using Visual Analogue Scale (VAS), and wound healing duration.

Secondary outcomes included marginal bone loss assessed radiographically at 3 and 6 months using

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standardized periapical radiographs with long-cone paralleling technique and calibrated digital software analysis.

Radiographic Evaluation.figures (3-4)

Radiographs were standardized using individualized holders and phosphor plate imaging systems. Bone levels were measured mesially and distally relative to the implant platform using calibrated software. Measurements were compared over time to assess marginal bone resorption.

Figure (3): Taking the digital periapical radiograph with paralleling technique.

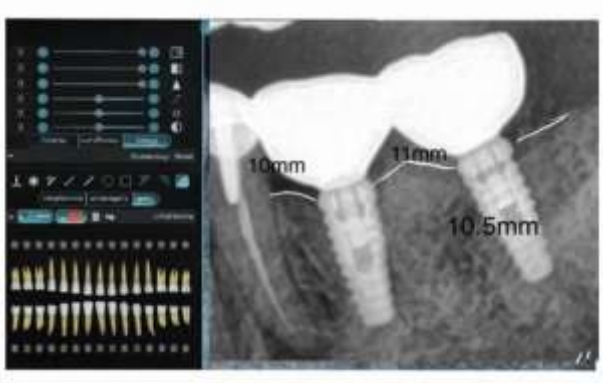

Figure (4): Showing calibration of software after importing periapical radiograph in from of JPG.

Prosthetic Phase.figues (5-6)

Definitive prosthetic rehabilitation was performed after 3 months using screw-retained zirconia crowns fabricated digitally and delivered following confirmation of implant stability and satisfactory soft tissue healing.

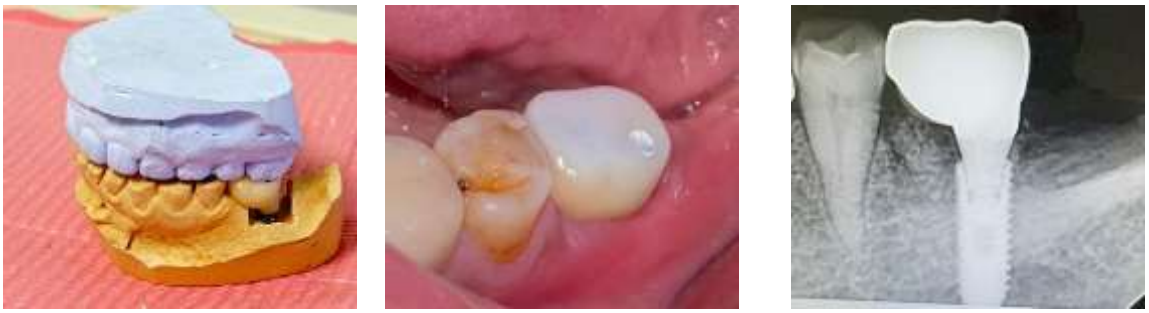

Figure (5): Showing prosthetic phase of 36 for: group A. A) Zirconic crown by digital printed, B) Fixation of crown by retained screw technique, C) Periapical radiographic show the prosthesis with implant.

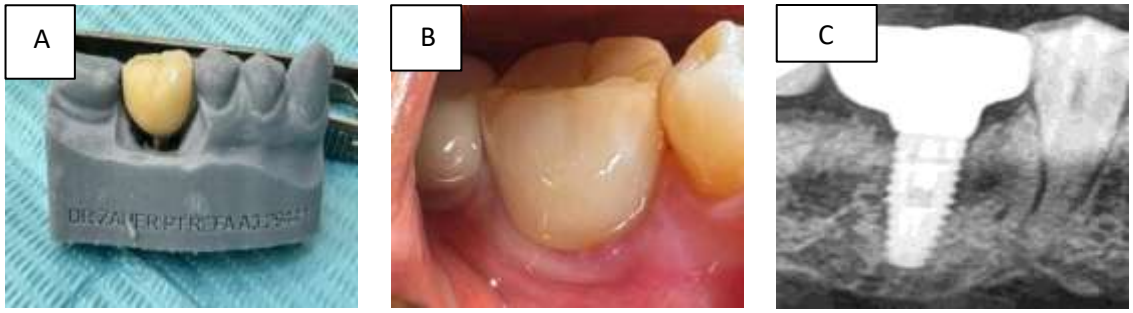

Figure (6): Prosthetic phase of 46 for: group B of immediate implant without Blue M gel application with custom healing abutment A) Zirconic crown by digital printed, B) Fixation of crown by retained screw technique, C) Periapical radiographic show the prosthesis with implant.

Statistical Analysis

Data were analyzed using SPSS version 26. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Independent t-tests were used for intergroup comparisons, while Chi-square or Mann–Whitney tests were applied when appropriate. A p-value < 0.05 was considered statistically significant.

RESULTS

1. Study population and demographics

A total of 24 implants in 21 patients were included. All implants achieved successful osseointegration with complete follow-up. No postoperative infections or implant exposures were reported in any case.

Demographic data:

The demographic data for all the patients are included in table 2, figure 13-15. There were no significant differences in age, sex, implant site, or baseline ISQ values between groups.

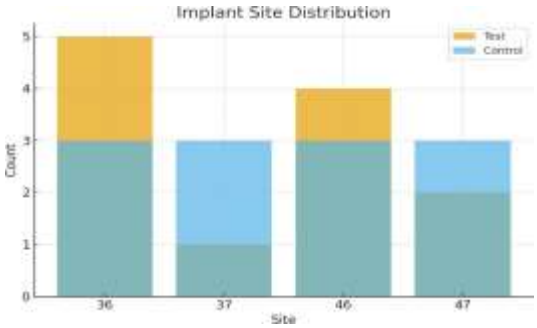

Figure (7): Chart of implant site distribution.

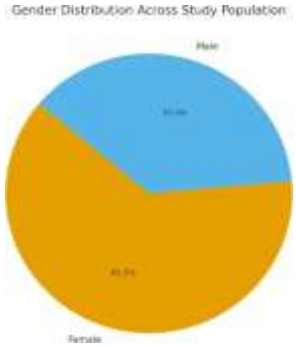

Figure (8): Chart of gender distribution across study population.

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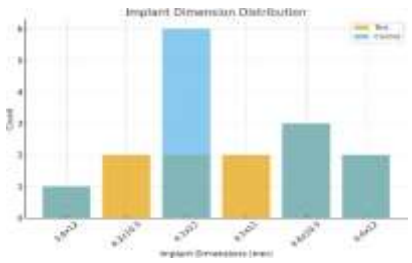

Figure (9): Chart of implant dimensions mm.

2. Post-operative pain (VAS 0–10).figure(10)

The study group (Blue®m gel) showed significantly lower pain scores at all time points compared with the control group ($p < 0.001$).

- **Day 0:** 1.67 vs 7.50
- **Day 3:** 1.11 vs 4.17
- **Day 7:** 0.83 vs 2.22

Clinically, the study group showed rapid pain resolution, while the control group demonstrated prolonged postoperative discomfort. The study group experienced
approximately 78% pain reduction on Day 0 and near complete resolution by Day 7.

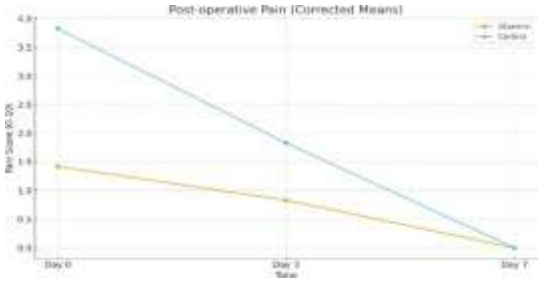

Figure (10): Chart of post-operative pain until day 7

Post-operative pain was evaluated using the Visual Analog Scale (VAS 0–10) at Day 0, Day 3, and Day 7. A clear difference was observed between the study group A and the control group B, with the test group consistently reporting lower pain scores at all time points.

3. Post-operative inflammatory response.figures(11-12-13)

Inflammation was significantly reduced in the study group during the early healing phase (0–7 days).

- Day 0: 0.50 vs 2.25
- Day 3: 0.33 vs 1.25
- Day 7: 0.25 vs 0.67
- Day 14 & 30: complete resolution in both groups

The study group demonstrated faster inflammatory control, particularly within the first week, while both groups achieved full recovery by Day 14.

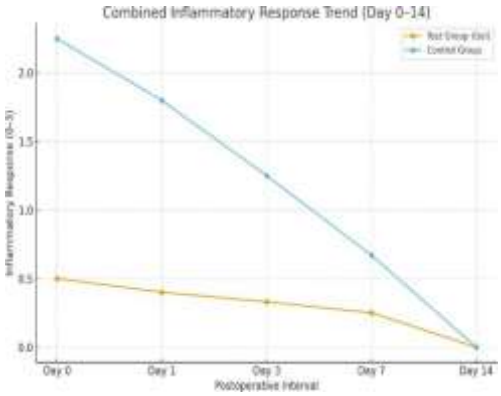

Figure (11): Chart of inflammatory respond 0-14 day for both groups

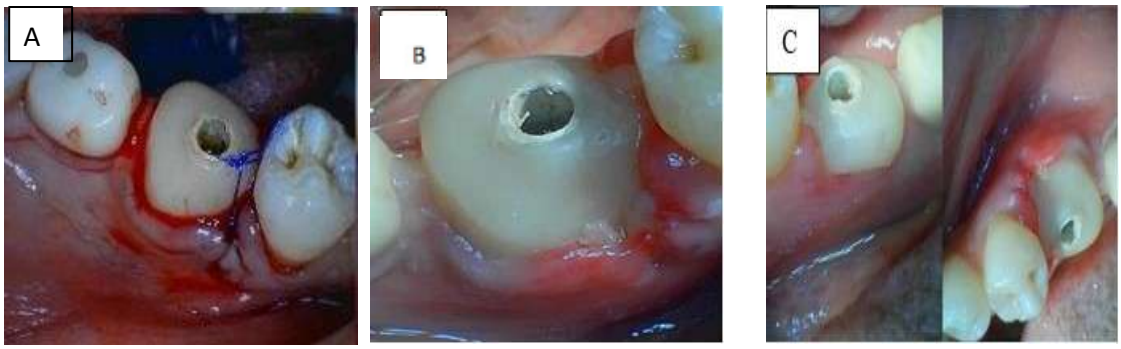

Figure (12): Show 46 the inflammatory respond after immediate implant with custom healing abutment 0-3,7 day (without Blue m gel)(control group)
A) Custom healing 46 immediate after surgery, B) Custom healing 3 days after surgery C) Custom healing abutment 7 days after surgery.

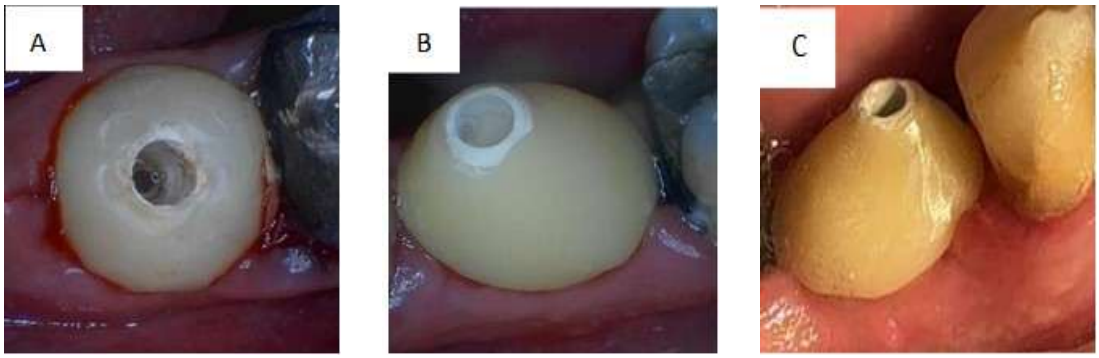

Figure (13): Show36 the inflammatory respond after immediate implant with custom (With blue m application) (study group)
A) custom healing 46 immediate after surgery, B) custom healing 3 days after surgery, C) custom healing abutment 7 days after surgery.

4. Wound healing duration. figure (14)

Healing occurred significantly faster in the study group.

- Study group: **6.5 days**
- Control group: **18.5 days**

This indicates nearly two-fold acceleration of soft tissue healing with Blue®m gel.

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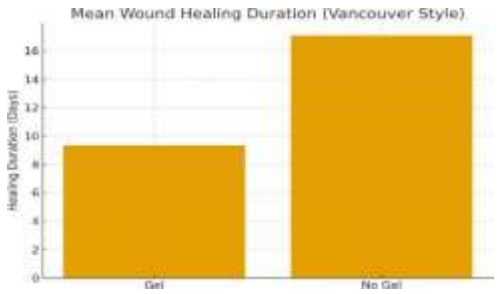


Figure (14): Chart of mean wound healing duration

5. Primary implant stability (ISQ).figure(15)

Both groups showed clinically acceptable stability with a slight, non-significant advantage in the study group:

- Study group: 72.33 ± 2.84
- Control group: 69.83 ± 2.41 ($p > 0.05$)

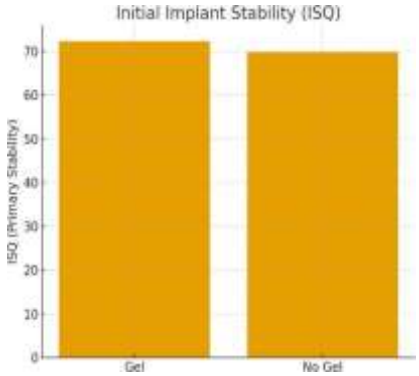


Figure (15): Chart of initial implant stability

6. Marginal bone loss (3–6 months) figures(16-17-18)

Both groups demonstrated minimal bone changes with no statistically significant difference.

- Study group: −0.21 mm (bone preservation)
- Control group: 0.17 mm (slight bone loss)

Slightly better bone preservation was observed in the study group.

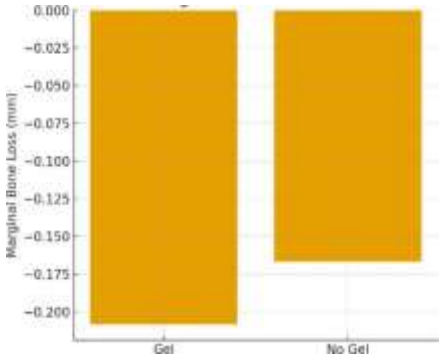
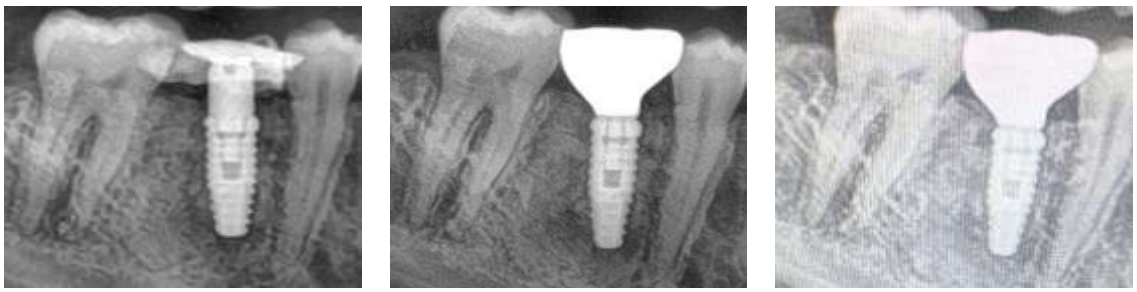
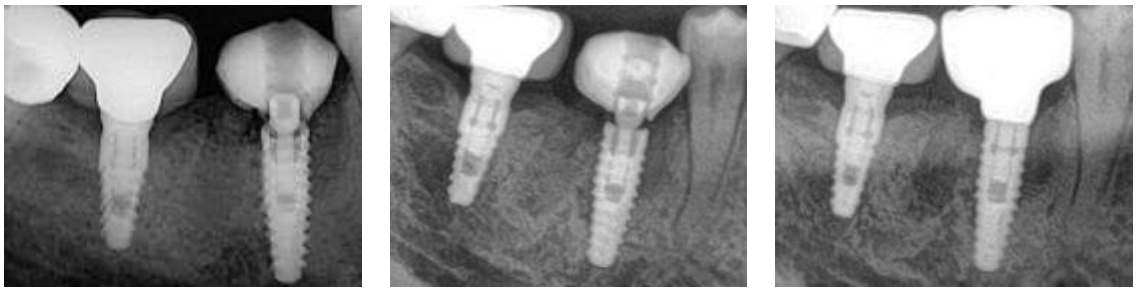


Figure (16): Chart of marginal bone loss mm after 6 months



0 Day **After 3 Monthes** **After 6 Monthes**

Figure (17): Show the bone level at 46 immediate after implant and after 3-6 months postoperative (group A)



0 Day **After 3 Monthes** **After 6 Monthes**

Figure (18): Show the bone level at 46 immediate after implant and after 3-6 months postoperative (group B)

DISCUSSION

Dental implant therapy is often limited by prolonged treatment time, traditionally requiring multiple surgeries and 4–6 months of healing. However, advances in implant surfaces and techniques now allow predictable immediate placement with comparable survival rates [22].

This study evaluated the effect of an active oxygen–based gel (Blue®m Gel) on healing after immediate implant placement in mandibular molars using custom healing abutments. The results demonstrated improved early outcomes, including reduced pain, inflammation, faster soft-tissue healing, and slight preservation of marginal bone. These findings support the role of oxygen-based therapies in enhancing implant wound healing [18], [23- 25].

The biological rationale of active oxygen is its ability to enhance oxygenation, improve antibacterial defense, and stimulate angiogenesis—key factors in early wound repair. This is particularly relevant in immediate implants where surgical trauma and bacterial load are higher [19], [23- 25].

Pain reduction was significantly greater in the study group at all time points. By Day 7, near complete pain resolution was observed, whereas the control group still reported discomfort. These results agree with studies reporting reduced postoperative symptoms with oxygen-based gels [3], [19], [24], [25]. [19] showed improved mucosal symptoms through enhanced oxygenation and microbial reduction [24]. Similarly, [18] reported decreased postoperative pain due to accelerated healing and antibacterial effects [3], [25].

However, conflicting evidence exists. [26] found no significant pain reduction in non-surgical periodontal procedures, and [27] reported only modest effects without mechanical debridement. These differences may relate to lower surgical trauma in periodontal procedures compared to implant surgery.

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In this study, custom healing abutments likely enhanced outcomes by maintaining soft-tissue stability and avoiding repeated abutment disconnection, which may reduce inflammatory triggers.

Inflammation followed a similar pattern, with rapid reduction in the test group and complete resolution by Day 14. These results align with studies reporting anti-inflammatory effects of oxygen gels through improved perfusion and bacterial control [3], [25], [28]. Some studies suggest limited effects unless combined with mechanical debridement, indicating that oxygen therapy is more effective in larger surgical defects such as extraction sockets [29].

Soft-tissue healing was significantly faster in the study group. This is supported by evidence that oxygen enhances keratinocyte migration, fibroblast activity, collagen formation, and angiogenesis [29]. Differences from minor periodontal studies are expected due to smaller wound size in those procedures.

The mechanisms underlying these effects include improved ATP production, antibacterial action against anaerobes (e.g., P. gingivalis), enhanced angiogenesis, accelerated epithelial migration, and reduced inflammatory cytokines [3], [19], [20], [24- 26], [30].

Although secondary outcomes showed no significant differences, marginal bone loss was slightly lower and primary stability slightly higher in the study group. Similar trends were reported by [31], who linked Blue®m gel to improved healing outcomes in bone-related defects. These findings suggest that inflammation control may indirectly support early bone preservation by reducing osteoclastic activity [2], [24], [25].

Overall, this study demonstrates that Blue®m Gel significantly improves early postoperative healing in immediate implant cases. The combination with custom healing abutments appears to further enhance outcomes by stabilizing soft tissues and limiting inflammation. This protocol may therefore represent a beneficial adjunct in implant therapy.

CONCLUSION

At the end of this study, we concluded that:

1- Clinically, Blue®m Gel represents a valuable adjunct in immediate implant protocols, particularly in molar extraction sockets where healing demands are high. Its use leads to greater patient comfort, fewer postoperative complications, and more predictable early implant outcomes and reduced early marginal bone remodeling.

2- Application With Custom-Made Healing Abutments The clinical protocol of combining Blue®m gel with a custom-made healing abutment showed clear benefits in stabilizing soft tissues and reducing complications. Adoption of this combined technique is recommended for optimizing healin0plog outcom.

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