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Adjunctive Therapies in Maxillary Expansion: Bridging Orthopedic Force and Bone Preservation

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Abstract: ***Maxillary expansion (ME) is an established treatment for transverse maxillary deficiencies but can cause undesirable effects such as buccal bone loss, dental tipping, and periodontal compromise. This review evaluates current adjunctive approaches aimed at enhancing skeletal outcomes and minimizing complications in rapid maxillary expansion techniques, including RME, MARPE, and SARPE. Biological methods (platelet-rich plasma, injectable platelet-rich fibrin, bioactive glass/fibrin glue, krill oil), surgical and mechanical aids (micro-osteoperforations, corticotomies, piezosurgery), and pharmacologic agents (strontium ranelate, rhBMP-2) have demonstrated potential to accelerate bone regeneration, improve expansion stability, and reduce relapse. Reported mechanisms include stimulation of osteoblastic activity, angiogenesis promotion, reduction of skeletal resistance, and modulation of bone turnover. Integrating these adjunctive measures into ME procedures may enhance skeletal expansion efficiency, preserve periodontal health, and optimize patient outcomes.***

Keywords: maxillary expansion, adjunctive therapy, bone regeneration, i-PRF, LLLT, micro-osteoperforations

1. Introduction

Maxillary constriction (ME) can result in several functional and esthetic problems, including poor facial harmony, occlusal disharmony, a narrowed pharyngeal airway, increased nasal airway resistance, mouth breathing, altered tongue posture, and even obstructive sleep apnea.[1, 2] Among various types of malocclusions, a transverse maxillary deficiency (TMD) is one of the most commonly encountered skeletal discrepancies.[3] To address ME, three main treatment approaches are available: rapid maxillary expansion (RME), surgically assisted rapid palatal expansion (SARPE), and segmental LeFort osteotomy.[4, 5]

In prepubertal patients, RME is considered a reliable and effective treatment modality for correcting TMD. However, its success in patients treated after their growth peak is less predictable due to the significant variation in the developmental stages of midpalatal suture fusion.[6] In skeletally mature patients, increased interdigitation of the midpalatal suture and reduced bone elasticity make ME more challenging, especially at the osseous articulations with adjacent craniofacial structures.[5] For such cases, surgical separation of the midpalatal suture, known as SARPE, is often indicated to overcome skeletal resistance.[7, 8]

With the advent of temporary anchorage devices, Mini-Implant-Assisted Rapid Palatal Expansion (MARPE) has gained popularity as a minimally invasive alternative. MARPE transmits expansion forces directly to the basal bone via mini-screw anchorage, maximizing skeletal expansion while minimizing undesirable dentoalveolar tipping.[9, 10] Evidence indicates that MARPE produces more parallel opening of the midpalatal suture compared to conventional RME, making it a predictable option for patients beyond peak growth.[11, 12] Studies have reported potential dentoalveolar side effects, including dental tipping and reductions in alveolar bone and root volume of the anchorage teeth.[13]

Despite its clinical effectiveness, ME is associated with several adverse effects, including buccal bone loss, dental tipping, root resorption, and periodontal complications. These side effects can compromise both the functional and esthetic outcomes of treatment. Given the growing clinical interest and the expanding body of evidence, a comprehensive review of adjunctive approaches to ME is warranted to help clinicians optimize treatment protocols and minimize associated complications. This article critically examines the current adjunctive procedures used alongside various ME techniques—including RPE, MARPE, and SARPE—discusses their underlying biological rationale, summarizes reported clinical outcomes and potential limitations, and identifies gaps in the literature to guide future research directions.

2. Adjunctive Procedures for Minimizing Bone Loss Following maxillary expansion

1) Platelet-Rich Plasma

Platelet-rich plasma (PRP) was defined by Marx in 2004 as an "autologous concentration of platelets in a small volume of plasma. "[14] PRP is composed of approximately 94% platelets, 5% RBCs, and 1% WBCs.[15] Various systems and protocols have been developed for the preparation of PRP, generally involving a two-phase centrifugation process. The first centrifugation step separates the components of whole blood, and the second concentrates the platelets to produce PRP.[16] The resulting product is a rich source of autologous growth factors, which are responsible for its wide range of clinical applications in dentistry. Growth factors found in PRP include platelet-derived growth factor (PDGF),

transforming growth factor-beta (TGF-β), vascular endothelial growth factor (VEGF), epithelial growth factor (EGF), insulin-like growth factor-1 (IGF-1) and fibroblast growth factor (FGF).[17] PRP contains growth factors along with cytokines, adhesive proteins, proteases, antiproteases, and leukocytes, enhancing its regenerative potential. Marx (1998) reported that combining PRP with autogenous bone grafts improved bone density and maturation.[14] However, its efficacy remains debated, with studies showing both positive and inhibitory effects on bone metabolism.[18]

A randomized split-mouth trial on 18 patients (12–16 years) undergoing conventional RME with a Hyrax appliance tested injectable PRP on the buccal side of supporting teeth. Post-treatment analysis showed no significant changes in buccal bone plate thickness or crest level compared to controls, and alveolar defects occurred more often in the PRP group, indicating no healing benefit.[19]

2) Low-Level Laser Therapy

Low-level laser therapy (LLLT) is a non-invasive, cost-effective treatment modality that delivers low-energy light without raising tissue temperature beyond physiological limits. Its application in orthodontics has gained interest due to its ability to stimulate various transient biochemical responses, which trigger a cascade of cellular and molecular events.[20] It facilitates the release of bioactive substances such as histamine, serotonin, and bradykinin, and stimulates the arachidonic acid pathway, leading to the conversion of prostaglandins into prostacyclin. Additionally, LLLT enhances ATP production, accelerates cell division and promotes both soft and hard tissue repair. It supports bone regeneration, regulates fibroblast activity, and normalizes the deposition of collagen and elastic fibers. Moreover, by increasing peripheral blood circulation, LLLT exerts anti-inflammatory effects and accelerates overall tissue healing.[21, 22]

Angeletti et al. (2010) [23] treated 13 SARME patients with LLLT (830 nm, 100 mW) over eight sessions, targeting the midpalatal anterior suture. The therapy improved bone regeneration compared to controls, but optical density at 7 months was still lower than before surgery, suggesting that complete bone remineralization requires more time.

Cepera et al. (2012) [24] applied LLLT (780 nm, 40 mW) to 27 children (8–12 years) undergoing RME, enhancing midpalatal suture opening and bone regeneration. Some relapse occurred by the 7-month follow-up, indicating the need for longer retention.

Garcia et al. (2016) [25] treated 39 children (6–12 years) with LLLT (660 nm, 100 mW) over seven sessions, stimulating bone repair in both inferior and superior maxillary sutures. Irradiation was applied at specific midpalatal points with varying dosages, showing positive healing effects.

Ferreira et al. (2016) [26] applied LLLT (780 nm, 70 mW) in 12 sessions to 14 patients (8–14 years), significantly increasing anterior maxillary optical density. Each point received 35 J/cm² over 20 seconds bilaterally, indicating enhanced bone repair.

Based on current evidence, LLLT appears promising for stimulating bone regeneration and speeding midpalatal suture healing after RME, leading to improved suture opening and mineralization. However, limited data highlight the need for long-term, randomized clinical trials to establish standardized protocols.

3) Corticopuncture / Micro-osteoperforations

Micro-osteoperforations (MOP) or alveocentesis, are a minimally invasive technique used to accelerate orthodontic tooth movement. This procedure involves creating controlled microtrauma in the alveolar bone without raising a mucoperiosteal flap, thereby preserving the structural integrity of surrounding hard and soft tissues. As an adjunctive approach, MOP stimulates the regional acceleratory phenomenon (RAP), enhancing bone remodeling and reducing overall treatment time with minimal surgical intervention. MOP is founded on the principle of the RAP—a localized biological response to noxious stimuli that enhances bone remodeling and healing. First described by Harold Frost.[27]

In MOP, small perforations are strategically created in the alveolar bone to stimulate a localized biological response. This technique elevates the levels of inflammatory cytokines in the surrounding tissues, thereby enhancing bone remodeling. The induced inflammatory response promotes osteoclastic activity and leads to a temporary state of transient osteopenia, which reduces bone density and facilitates accelerated orthodontic tooth movement.[27]

MOPs are tailored to clinical goals: deep (3–7 mm) perforations near target teeth for catabolic effects, and shallow (1–2 mm) broader perforations for anabolic effects. They're best placed in attached gingiva, preferably on the buccal plate, with 2–4 perforations per site. Sessions are repeated every 4–8 weeks, with 3–5 deep sessions for catabolic goals, while anabolic applications may continue until treatment completion.[27]

Suzuki SS et al. (2018) [28] reported a 35-year-old male where MARPE alone failed to separate the suture. After corticopuncture with eight perforations (2–5 mm deep), MARPE achieved 3.14 mm premolar and 2.06 mm molar expansion with minimal tipping, suggesting CP as a less invasive alternative to SARPE in resistant adult cases.

Pednekar MJ et al. (2022) [29] found that adding MOP to MARPE in the midpalatal suture produced greater skeletal expansion—especially in the nasal cavity and interzygomatic width—than MARPE alone, with favorable expansion patterns, minimal tooth angulation, and reduced dental side effects.

Elawady AR et al. (2024) [30] conducted a study on 18 young adults (18–22 years) with maxillary constriction, randomly assigned to two groups. Group 1 received maxillary skeletal expansion (MSE) with MOPs limited to the midpalatal suture, while Group 2 received MSE with MOPs in both the midpalatal suture and buccal cortices. Results showed that both protocols significantly improved transverse maxillary dimensions, confirming the positive skeletal effects of MSE, regardless of MOP location.

4) Injectable Platelet-Rich Fibrin (i-PRF)

Choukroun et al. introduced PRF, which represents the second generation of platelet concentration. PRF is a natural fibrin matrix made from autogenous fibrin derived from the patient's blood, without the use of anticoagulants.[31] It offers several advantages over PRP, including simpler preparation and the absence of chemical manipulation, making it strictly autologous.[32]

PRF is a three-dimensional biomaterial composed of dense fibrin networks enriched with leukocytes, cytokines, structural glycoproteins, and growth factors such as TGF-β1, PDGF, VEGF, and thrombospondin-1. Leukocytes within the scaffold play a key role in growth factor release, immune regulation, antimicrobial activity, and matrix remodeling, aided by PRF's slow polymerization.[33, 34] Based on leukocyte content and fibrin structure, platelet concentrates are classified into four types: (1) Pure PRP (Vivostat PRF, PRGF, E-PRP) -liquid without leukocytes, convertible to gel; (2) Leukocyte-rich PRP (Curasan, Regen, Magellan) -liquid with leukocytes, convertible to gel; (3) Pure PRF (Fibrinet) - solid fibrin without leukocytes; and (4) Leukocyte-rich PRF (Choukroun's PRF, A-PRF, i-PRF, L-PRF, Concentrated Growth Factors) - solid fibrin with leukocytes.[35]

Studies[36, 37] have shown that PRF is a promising biomaterial for bone and soft tissue regeneration, with no associated inflammatory reactions. It can be applied alone or with bone grafts to promote hemostasis, bone growth, and maturation. In vitro findings indicate that PRF enhances cell attachment, stimulates osteoblast proliferation and differentiation[38] and provides a slow, sustained release of growth factors and cytokines for up to 28 days.3[9] The preparation requires a single centrifugation cycle at 700 rpm for 3 minutes.[40]

Awni KM et al. (2023) [41] conducted a dog model study to assess i-PRF in bone regeneration during ME with MSE. Eighteen adult dogs were assigned to three groups: control (MSE only), corticotomy without i-PRF, and corticotomy with i-PRF. Histology at 15 and 45 days revealed significantly greater new bone formation in the i-PRF group (29.3% at 15 days; 76.55% at 45 days), along with increased osteoblasts and vascularization. The authors concluded that i-PRF promotes osteogenesis and angiogenesis in surgically expanded midpalatal sutures.

5) Piezosurgery

Piezosurgery is an ultrasonic bone-cutting technique (25–29 kHz) that selectively cuts mineralized tissue while sparing soft tissues. It works via the piezoelectric effect, where piezoceramic rings generate microvibrations (60–210 µm) that shatter bone. Soft tissues remain unaffected, as their cutting threshold is >50 kHz. Continuous irrigation produces a cavitation effect, aiding site cleaning, visibility and antimicrobial action. Biologically, it minimizes thermal damage, preserves osteoblasts/osteocytes, enhances periosteal microcirculation, supports bone metabolism, maintains bone microstructure, and may slightly improve new bone formation compared to conventional tools.[42]

6) Strontium ranelate

Strontium ranelate (SR), a divalent strontium salt of ranelic acid, is a novel pharmacological agent developed for the management of osteoporosis. Its unique pharmacological profile enables optimization of bone metabolism by simultaneously stimulating bone formation and reducing bone resorption, making it a promising agent for increasing bone mass and strength while preserving normal mineralization.4[3]SR acts through two mechanisms: it decreases bone resorption by inhibiting osteoclast activity and differentiation, and it promotes bone formation by stimulating pre-osteoblast replication and collagen synthesis.[43]

Zhao S et al. (2015) [44] studied 20 adult male rabbits with calvarial defects, treating one group with oral strontium ranelate (900 mg/kg/day). The treated group showed significantly greater new bone formation and more mature trabeculae at 2 and 4 weeks, suggesting SR can accelerate early bone regeneration and enhance bone quality.

7) Human recombinant bone morphogenetic protein-2

Human recombinant bone morphogenetic protein-2 (rhBMP-2) is a bioengineered form of the naturally occurring BMP-2, a potent osteoinductive growth factor belonging to the TGF-β superfamily. BMP-2 plays a critical role in skeletal development, fracture repair and bone regeneration by inducing mesenchymal stem cells to differentiate into osteoblasts and chondrocytes.[45] rhBMP-2 promotes bone regeneration by attracting mesenchymal stem cells, stimulating osteoblast differentiation, enhancing collagen and matrix protein production, increasing hydroxyapatite deposition, and inducing angiogenesis for improved healing.[46]

Liu et al. (2009) [47] studied rhBMP-2 in beagle dogs after SARPE, comparing expansion alone, expansion with a collagen sponge, and expansion with rhBMP-2–loaded sponge. At 2 and 4 weeks, the rhBMP-2 group had greater new bone formation, higher density, and more mature trabeculae, suggesting it accelerates regeneration and may shorten post-expansion retention time.

8) Bioactive glass/fibrin glue composite hydrogel

A bioactive glass (BG) /fibrin glue (FG) composite hydrogel is an injectable scaffold combining BG's osteoinductive properties with FG's biocompatibility and healing capacity. FG, derived from fibrinogen and thrombin, supports cell attachment and vascularization but degrades quickly and has low mechanical strength. Adding mesoporous BG enhances strength and bone regeneration by releasing calcium, phosphate, and silicon ions that form a hydroxycarbonate apatite layer, stimulate osteoblasts, and promote angiogenesis. FG stabilizes BG at the defect site, allowing sustained ion release and maintaining a moist, cell-friendly environment, making the composite well-suited for craniofacial and orthopedic bone repair.[48]

Zhao H et al. (2022) [48] found that a BG–FG composite hydrogel achieved the highest bone volume, trabecular connectivity and defect closure in rat calvarial defects compared to either material alone. Histology showed mature bone formation, with FG enhancing BG retention and sustained ion release, highlighting its potential for craniofacial bone regeneration.

9) Krill oil (KO)

Krill are small marine crustaceans found in polar seas, mainly harvested from the largest Antarctic shrimp-like zooplankton, Euphausia superba. Unlike fish oil, 100% KO is particularly rich in eicosapentaenoic acid and docosahexaenoic acid (39.29–80.69%) and contains naturally occurring bioactive components such as astaxanthin, sterols, tocopherols, vitamin A, flavonoids and minerals. Its lipid content is predominantly in phospholipid form, giving it higher bioavailability than fish oil, which primarily contains triglycerides. Beyond its nutritional profile, KO exhibits immunomodulatory and anti-inflammatory effects, supports both psychological and physiological health, and stimulates bone metabolism by inhibiting osteoclastic activity while promoting osteoblastic activity.[49]

Simsek D et al. (2024) [49] reported that krill oil supplementation, given during or before RME in rats, improved midpalatal suture bone architecture. Micro-CT, histology, and immunohistochemistry confirmed enhanced bone formation, indicating KO may aid suture healing and reduce relapse.

3. Discussion

Adjunctive procedures in ME aim to optimize skeletal outcomes while minimizing adverse effects such as buccal bone loss, dental tipping, and periodontal compromise. Biologic agents such as i-PRF and bioactive glass/fibrin glue hydrogels enhance osteoblast activity, angiogenesis, and bone maturation by providing sustained growth factor release and a bioactive scaffold. Nutraceutical supplementation, exemplified by krill oil, introduces anti-inflammatory and antioxidant mechanisms that modulate bone turnover in favor of formation over resorption. Pharmacologic options like strontium ranelate show a dual anabolic–anticatabolic effect, potentially accelerating bone consolidation. Mechanical and minimally invasive surgical adjuncts—piezosurgery, MOPs, and corticotomies—act by lowering skeletal resistance, stimulating the RAP, and promoting rapid suture separation with improved parallelism of expansion. LLLT augments cellular metabolism and collagen synthesis, accelerating bone repair, although long-term mineralization outcomes remain under investigation. Most studies report benefits in bone formation, quality, or expansion stability, but evidence is limited by small sample sizes, variable protocols, and short follow-up, highlighting the need for standardized, long-term trials.

4. Conclusion

Adjunctive approaches to ME -whether biological, surgical, or pharmacological—offer promising means to minimize bone loss, accelerate suture separation, and improve the stability of skeletal changes. Techniques such as i-PRF application, bioactive glass composites, krill oil supplementation, piezosurgery, and MOPs have demonstrated potential benefits in enhancing bone regeneration and reducing relapse risk. While current findings are encouraging, the variability in study design and limited long-term data underscore the need for high-quality randomized clinical trials to establish optimal timing, dosage, and combinations of these adjuncts. Integrating these evidence-based adjunctive therapies into clinical protocols may allow clinicians to achieve greater skeletal expansion efficiency, preserve periodontal health, and enhance patient outcomes in both adolescent and adult populations.

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