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Review Article

Drugs influencing orthodontic tooth movement

[1]Ruchi Saini, [2]Shehla Rafique, [3]Tanjula Shair, [4]Dinesh Kumar Maddhesia, [5]Anupriya Srivastava, [6]Antra Negi

[1]Associate Professor, [2,3,5,6]Assistant Professor, Department of Orthodontics and Dentofacial Orthopedics, Subharti Dental College & Hospital, Swami Vivekanand Subharti University, Meerut, U.P. India;
[4]Assistant Professor, Department of Orthodontics and Dentofacial Orthopedics, Uttaranchal Dental and Medical Research Institute, Uttarakhand, India

ABSTRACT:
Orthodontic tooth movement is a complex biological process involving changes that span from the tissue level down to the molecular level. The application of orthodontic forces triggers a cascade of inflammatory responses mediated by various chemical agents. Key biochemical mediators such as prostaglandins, cytokines, and interleukins play crucial roles in regulating these molecular events. With a growing number of adult patients undergoing orthodontic treatment, the influence of systemic diseases and their associated medications has become increasingly relevant, as these factors can either enhance or impede the rate of tooth movement. Furthermore, the use of analgesics for pain management has been shown to produce variable effects on orthodontic outcomes. Therefore, it is essential for orthodontists to possess a thorough understanding of the molecular mechanisms involved in tooth movement and how different pharmacological agents may impact this process. This review aims to provide an overview of the biological basis of orthodontic tooth movement and the effects of commonly used drugs.
Keywords: Drugs, Orthodontic Tooth Movement, Analgesics, Aspirin, Acetaminophen, Fluorides, Bisphosphonates

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Corresponding author: Ruchi Saini, Associate Professor, Department of Orthodontics and Dentofacial Orthopedics, Subharti Dental College & Hospital, Swami Vivekanand Subharti University, Meerut, U.P. India

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INTRODUCTION

According to WHO (1966), drug is any substance or product that is used to modify or explore physiological systems or pathological states for the benefit of the recipient. During orthodontic treatment, drugs are prescribed to manage pain from force application to biological tissues, manage temporomandibular joint (TMJ) problems and tackle some infection throughout the course of treatment.[1] Apart from these drugs, patients who consume vitamins, minerals, hormonal supplements, and other compounds for the prevention or treatment of various diseases can also be found in every orthodontic practice. Some of these drugs may have profound effects on the short- and long-term outcomes of orthodontic practice. Hence, it is necessary to review the mechanism of action and effects of commonly used drugs on tissue remodeling and orthodontic tooth movement.[2]

Analgesics

Analgesic is a drug that selectively relieves pain by acting on the CNS or peripheral pain mechanisms, without significantly altering consciousness. Nonsteroid anti-inflammatory drugs (NSAIDs) do not affect the tenderness induced by direct application of PGs, but block the pain-sensitizing mechanism induced by bradykinins, tumor necrosis factors (TNFs), interleukins (ILs), etc.[3] The analgesic action is mainly due to obtunding of peripheral pain receptors and prevention of PG medicated sensitization of nerve endings. NSAIDs are a relatively weak inhibitor of PG synthesis and anti-inflammatory action may be exerted by reduced generation of superoxide by neutrophils, and TNF release, free radical scavenging, and inhibition of metalloprotease activity in cartilage.[4]

Effect of NSAIDs on tooth movement

Most commonly used medications in orthodontics are for control of pain following mechanical force application to tooth. Inhibition of the inflammatory reaction produced by PGs slows the tooth movement. Recent research demonstrated the molecular mechanisms behind the inhibition of tooth movement by NSAIDs.[5] The levels of matrix metalloproteinases (MMP9 and MMP2) were found to be increased, along with elevated collagenase activity, followed by a reduction in procollagen synthesis which is essential for bone and periodontal remodeling. The whole process is controlled by inhibition of cyclooxygenase (COX) activity, leading to altered vascular and extravascular matrix remodeling, causing a reduction in the pace of the tooth movement.[6]

Aspirin

Acetylsalicylic acid and the related compounds, and their action result from inhibition of COX activity, which converts unsaturated fatty acids in the cell membrane to PGs. Clinical experience shows that orthodontic tooth movement is very slow in patients undergoing long-term acetylsalicylic therapy.[7] Salicylate therapy decreases bone resorption by inhibition of PGs' synthesis and may effect differentiation of osteoclasts from their precursors. Therefore, it is recommended that patients undergoing orthodontic treatment should not be advised to take aspirin and related compounds for longer period during orthodontic treatment.

COX-2 Inhibitors

An interesting recent development is seen in prescriptions of a specific COX-2 inhibitor, a drug with no effect on PGE2 synthesis. The drug selectively blocks the COX-2 enzyme and impedes the production of PGs that cause pain and swelling. Because it selectively blocks COX-2 enzyme and not COX-1 enzyme, it was suggested that the drug can be safely employed during orthodontic mechanotherapy, without causing negative effects on tooth movement.[8] This drug is no more prescribed due to risk of cardiovascular events. A recent study reported that nabumetone, belonging to NSAID group, reduces the amount of root resorption along with control of pain from intrusive orthodontic forces, without affecting the pace of tooth movement.

Acetaminophen (Paracetamol)

It is a weak COX-1 and COX-2 inhibitor that also reduces urinary prostaglandin levels after systemic administration and has shown no effect on orthodontic tooth movement in guinea pigs and rabbits.[9] Comparative studies and clinical experience have shown that acetaminophen is effective for controlling pain and discomfort associated with the orthodontic treatment.

Other NSAIDs

Yamasaki *et al*. administered indomethacin to rats and inserted a piece of elastic between their molar teeth. The appearance of osteoclasts in the interradicular septum of bone of the first molar was found to be inhibited by the indomethacin.[3] They also found imidazole, which is a specific inhibitor of thromboxane A2 synthesis but does not stop the synthesis of other prostaglandins, to have a similar effect. Sandy and Harris found that flurbiprofen inhibited the appearance of osteoclasts, but had no significant effect on tooth movement in rabbits.[6] Chumbley and Tuncay found that indomethacin reduced orthodontic tooth movement in cats by half and also asserted that tooth movement is inhibited in patients taking NSAIDs.[8] Mohammed *et al*. found significant inhibition of tooth movement in rats that were given indomethacin. However, they also found that AA861, a leukotriene inhibitor that causes an increase in the production of PGE2, inhibited tooth movement.[10]

Vitamin D

Vitamin D and its active metabolite, 1,25,2(OH)D3, together with parathyroid hormone (PTH) and calcitonin, regulate the amount of calcium and phosphorus levels. Vitamin D receptors have been demonstrated in osteoclast precursors.[11] In 1988, Collins and Sinclair demonstrated that intraligamentary injections of vitamin D metabolite, 1,25-dihydroxy cholecalciferol, caused increase in the number of osteoclasts and amount of tooth movement during canine retraction with light forces.[12] In 2004, Kale and colleagues observed that local applications of vitamins enhanced the rate of tooth movement in rats due to the well-balanced bone turnover induced by vitamin D.[13] Stimulatory action of vitamin D on osteoblasts can help stabilize orthodontic tooth movement. In 1976, Bran and colleagues reported that rats treated with vitamin D showed increased bone formation on the pressure side of the periodontal ligament after application of orthodontic forces.[14] In 2004, Kawakami observed an increase in the mineral appositional rate on alveolar bone after orthodontic force application; they suggested that local application of vitamin D could intensify the re-establishment of supporting alveolar bone, after orthodontic treatment.[15,16]

Fluorides

Fluoride is one of the trace elements having an effect on tissue metabolism. Fluoride increases bone mass and mineral density, and because of these skeletal actions, it has been used in the treatment of metabolic bone disease, osteoporosis.[17] Even a very active caries treatment with sodium fluoride during orthodontic treatment may delay orthodontic tooth movement and increase the time of orthodontic treatment.[18] Sodium fluoride has been shown to inhibit the osteoclastic activity and reduce the number of active osteoclasts.

Bisphosphonates

Bisphosphonates (BPNs) have strong chemical affinity to the solid-phase surface of calcium phosphate; this causes inhibition of hydroxyapatite aggregation, dissolution, and crystal formation.[19] Bisphosphonates cause a rise in intracellular calcium levels in osteoclastic-like cell line, reduction of osteoclastic activity, prevention of osteoclastic development from hematopoietic precursors, and production of an osteoclast inhibitory factor. Studies have shown that BPNs can inhibit orthodontic tooth movement and delay the orthodontic treatment.[20] Topical application of BPNs could be helpful in anchoring and retaining teeth under orthodontic treatment.

Hormones

Estrogens

Estrogen is considered to be the most important hormone affecting the bone metabolism in women. It inhibits the production of various cytokines which are involved in bone resorption by stimulating osteoclast formation and osteoclast bone resorption. It also inhibits osteoblasts' responsiveness to PTH.[21] Estrogens do not have any anabolic effects on bone tissue; they directly stimulate the bone forming activity of osteoblasts. Studies have shown that estrogens decrease the velocity of tooth movement.[22] Oral contraceptives, taken for long periods of time, can influence the rate of tooth movement. Androgens also inhibit bone resorption, modulate the growth of the muscular system, and may affect the length and results of the orthodontic treatment.

Thyroid Hormones

Thyroid hormones are recommended for the treatment of hypothyroidism and used after thyroidectomy in substitutive theraphy. Thyroxin administration lead to increased bone remodeling, increased bone resorptive activity and reduced bone density.[23] Effects on bone tissue may be related to the augmentation of interleukin-1 (IL-1B) production induced by thyroid hormones at low concentrations, cytokine stimulated osteoclast formation and osteoclastic bone resorption. The thyroid hormone increases the speed of orthodontic tooth movement in patients undergoing such medication.[24] Low dosage and short-term thyroxine administration are reported to lower the frequency of "force-induced" root resorption. Decrease in resorption may be correlated to a change in bone remodeling process and a reinforcement of the protection of the cementum and dentin to "force-induced" osteoclastic resorption.

Relaxin

Relaxin has been known as a pregnancy hormone. It is released just before child birth to loosen the public symphysis, so that the relaxed suture will allow widening of the birth canal for parturition. In 2005, Liu and colleagues showed that the administration of relaxin might accelerate the early stages of orthodontic tooth movements in rats.[25] Stewart and colleagues used gingival injections of Relaxin to relieve rotational memory in the connective tissues of maxillary lateral incisors that had been orthodontically rotated. In 2000, Nicozis and colleagues suggested that Relaxin might be used as an adjuvant to orthodontic therapy, during or after tooth movement, for promotion of stability, for rapid remodeling of gingival tissue during extraction space closure, for orthopedic expansion in non – growing patients, by reducing the tension of the stretched soft tissue envelope, particularly the expanded palatal mucosa, after orthognathic surgery.[26]

Calcitonin

Calcitonin inhibits bone resorption by direct action on osteoclasts, decreasing their ruffled surface which forms contact with resorptive pit. It also stimulates the activity of osteoblasts. Because of its physiological role, it is considered to inhibit the tooth movement; consequently, delay in orthodontic treatment can be expected.[27]

Parathyroid hormone

PTH affects osteoblasts' cellular metabolic activity, gene transcriptional activity, and multiple protease secretion. Its effects on osteoclasts occur through the production of RANK-L Recepor activator of nuclear factor kappa –B ligand), a protein playing a crucial role in osteoclasts' formation and activity.[28] In 1970s, animal studies demonstrated that PTH could induce an increase in bone turnover that would accelerate orthodontic tooth movement. More recently, an increased rate of tooth movements has been observed in rats treated with PTH, whether administered systemically or locally.[29] These results indicate that orthodontists should take note of patients being treated with PTH, as for example, in cases of severe osteoporosis.

Corticosteroids

Evidence indicates that the main effect of corticosteroid on bone tissue is direct inhibition of osteoblastic function and thus decreases total bone formation. Decrease in bone formation is due to elevated PTH levels caused by inhibition of intestinal calcium absorption which is induced by corticosteroids. Corticosteroids increase the rate of tooth movement, and since new bone formation can be difficult in a treated patient, they decrease the stability of tooth movement and stability of orthodontic treatment in general.[30] When they are used for longer periods of time, the main side effect is osteoporosis. It has been demonstrated in animal models with this type of osteoporosis that the rate of active tooth movement is greater, but tooth movement is less stable since little bone is present and there is no indication of bone formation. A more extensive retention may be required.

Prostaglandins
Experiments have shown that PGs may be mediators of mechanical stress during orthodontic tooth movement. They stimulate bone resorption, root resorption, decrease collagen synthesis, and increase cAMP. They stimulate bone resorption by increasing the number of osteoclasts and activating already existing osteoclasts. A lower concentration of PGE2 (0.1 μg) appears to be effective in enhancing tooth movement.[31] Higher concentration leads to root resorption. Systemic administration is reported to have better effect than local administration. Researchers have injected PGs locally at the site of orthodontic tooth movement to enhance the bone remodeling process and the pace of tooth movement. The main side effect associated with local injection of PGs is hyperalgesia due to the release of noxious agents.

Interleukin Antagonists
IL antagonists inhibit IL-1, produced by monocytes, macrophages, and some specialized cells, which are important for the inflammatory response, and IL-6 and COX-2. These drugs influence the inflammatory response following force application, reducing the pace of tooth movement and bone remodeling.

TNF-α Antagonists
TNF-α antagonists block TNF-α in inflammatory cytokinins released by activated monocytes, macrophages, and T-lymphocytes, which are essential for inflammatory responses following force application.[32]

Echistatin and RGD Peptides
Another approach made recently is local injection of integrin inhibitors like echistatin and RGD (Arginine–Glycine–Aspartic acid) peptides on rats to prevent tooth movement, thereby enhancing anchorage. Recent research has demonstrated decrease in root resorption following orthodontic force application after administration of Echistatin.[33]

Immunomodulatory Drugs
Most of these drugs used for treatment of Rheumatoid arthritis includes immunomodulatory agents like Leflunomide, TNFantagonists (Etanercept), interleukin antagonists (Anakinra).[34] Immunomodulatory drugs modulate nuclear factor kappa – Beta, tyrosine kinases in signaling pathway, IL – 6, MMPs and PGE2, all of which are essential for the bone remodeling process.

Immunosuppressant Drugs
Patients with chronic renal failure or kidney transplants and on immunosuppressant drugs can encounter some difficulty during orthodontic treatment. Drug consumed for prevention of graft rejection (cyclosporine A) produce severe gingival hyperplasia, making orthodontic treatment and maintenance of oral hygiene difficult. Treatment should be started or resumed after surgical removal of excessive gingival tissues once there is good oral hygiene. Whenever possible, fixed appliances should be kept to a minimum period with brackets and avoiding the use of cemented bands. Removable appliances in these cases are not recommended due to improper fit.[22]

Anticancer Drugs
These are used for the treatment of childhood cancers. There is every chance of observing disturbances in dental as well as general body growth and development due to the adverse effects of the chemotherapeutic agents. It is clearly stated that patients who had been on chemotherapy with busulfan/cyclophosphamide belong to the risk group for orthodontic treatment These drugs are known to produce damage to precursor cells involved in bone remodeling process, thereby complicating tooth movement.[34]

Anticonvulsants
Phenytoin
It induces gingival hyperplasia due to overgrowth of gingival collagen fibers, which involve the interdental papilla, making application of orthodontic mechanics and maintaining oral hygiene difficult. If used during pregnancy, it can produce fetal hydantoin syndrome characterized by hypoplastic phalanges, cleft palate, hare lip, and microcephaly.[22] Valproic acid has a potential to induce gingival bleeding even with minor trauma, making orthodontic maneuvers difficult. Gabapentin produces xerostomia, making oral hygiene maintenance difficult during orthodontic treatment.

Alcohol Abuse
Alcohol crosses the placental barrier and can stunt fetal growth or weight, create distinctive facial stigmata, damage neurons and brain structures, which can result in psychological or behavioral problems, and cause other physical damage (Fetal Alcohol Syndrome or FAS). The three FAS facial features are a smooth philtrum, thin vermilion, and small palpebral fissures. Chronic ingestion of large amounts on a daily basis may have devastating effects on a number of tissue systems, including skeletal system.[34] Circulating ethanol inhibits the hydroxylation of vitamin D3 in liver, thus impending calcium homeostasis. In such cases, the synthesis of PTH is increased, tipping the balance of cellular function toward the enhanced resorption of mineralized tissues, including root resorption, in order to maintain normal levels of calcium in blood. Davidovitch *et al*. have found that chronic alcoholics receiving orthodontic treatment are at high risk of developing severe root resorption during the course of orthodontic treatment.

CONCLUSION

Orthodontists have long observed that teeth move at different rates and individuals differ in their response to treatment. Some of the differences are caused by change in bone remodeling induced by drugs and systemic factors. All the drugs reviewed have therapeutic effects as well as side effects that influence the cells targeted by orthodontic forces. The value of a thorough medical history is increasingly significant as young and old alike are exposed to a greater range of therapeutic agents. Therefore, it is imperative that the orthodontists need to pay attention to drug consumption and history of each and every patient, before and during the course of orthodontic treatment, so that the best treatment strategy (including force control and appointment intervals) can be selected for each case. Acetaminophen, which does not have significant influence on the rate of tooth movement, can be recommended for controlling pain during orthodontic treatment.

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