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Research Article

Research Progress on Fluoride Solution Promoting the Survival of Replanted Teeth

Hui-Qin Yang[1, †], Wan-Yun Lin[1, †], Jun-Ling Guo[1], Ying-Yu Luo[1], Hui-Juan Hu[1], Minhaj Ahmad[2], Zhu-Ling Guo[1, 3, *]

[1]School of Dentistry, Hainan Medical University, Haikou, China

[2]School of International Education, Hainan Medical University, Haikou, China

[3]Department of Health Management Center, The First Affiliated Hospital of Hainan Medical University, Haikou, China

Abstract

Tooth replantation is an operation in which the lost teeth due to various reasons are treated and replanted in the alveolar socket. The key lies in the regeneration of the alveolar blood vessels and the regeneration of the alveolar bone. Fluoride has been proved to be a substance that promotes the growth of bone cells and has been widely used worldwide. Fluorine is a rare element that mixes with bone minerals during the osteogenic phase. It is a known non hormonal factor that can affect bone formation and has a bidirectional regulatory effect on bone formation. Long term low doses can promote bone formation, while high doses can cause osteoporosis or osteosclerosis. Osteocalcin can regulate bone metabolism, maintain normal bone calcification, inhibit cartilage calcification and irregular crystal precipitation. The mechanism of action of fluoride is that fluoride can stimulate osteoblasts to secrete osteocalcin, allowing more hydroxyapatite crystals to combine with it and precipitate in the bone matrix. Therefore, an appropriate concentration of fluoride solution can promote bone remodeling of alveolar bone and dentin. Through the effect of fluorine on bone cells, fluoride can be applied to tooth replantation surgery in order to improve the success rate of surgery. It was found that fluoride can regulate bone formation by stimulating the proliferation and differentiation of immature osteoblasts, ultimately affecting tooth replantation.

Keywords

Fluorine, Tooth Replantation, Dental Trauma

1. Introduction

Dental trauma refers to the damage of teeth or periodontal tissue or both (gingiva, periodontal ligament, alveolar bone) and adjacent soft tissues such as lips and tongue, which has a great impact on the pronunciation and diet of patients, and seriously affects the quality of life of patients. With the development of society and the increase of outdoor activities (outdoor games) of teenagers and children, the probability of dental trauma is also gradually increasing. According to the analysis of epidemiological data, maxillary incisors are the most common, followed by maxillary lateral incisors, and

*Corresponding author: 604569033@qq.com (Zhu-Ling Guo)

† Hui-Qin Yang and Wan-Yun Lin are co-first authors

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maxillary occurs mostly in the mandible. Males are more common than females. The high incidence period of permanent dentition trauma is 10-12 years old [1, 2]. Five million teeth are missing in sports injuries every year, mainly manifested as cracked teeth, incisional margin defects, pulp exposure, and serious cases including tooth fracture, dystopy, dislocation, and periodontal tissue tear. Among them, the more serious injury is complete dislocation of teeth, also known as tooth avulsion injury [3]. In other words, the teeth completely fall out of the alveolar fossa under the action of external force, resulting in the interruption of dental pulp blood supply and the complete exposure of periodontal ligament cells in vitro [4]. Avulsion injury of permanent teeth accounts for 0.5% - 3% of all tooth injuries [5]. After complete dislocation of teeth, pulp and periodontal ligament tissues are completely avulsed, and the integrity of gingival epithelium is destroyed, sometimes it's accompanied by the destruction of cementum and alveolar bone. Tooth replantation is a simple and effective treatment plan for completely dislocated teeth, as it does not damage adjacent teeth and can preserve the height of alveolar ridge. Timely tooth (within a certain period of avulsion) replantation can increase the possibility of pulp revascularization and periodontal ligament healing, and reduce the complications of dislocation injury [6].

After tooth dislocation, the periodontal ligament is in a dry state, which will lead to the loss of cell morphology and physiological function, and effect the replantation (which will have adverse effects on replanting). Therefore, the preservation of the dislocated teeth timely and effectively is particularly important. There are many media for the preservation of dislocation teeth, such as milk, physiological saline, IgG medium and Hanks equilibrium salt solution. And three main ways of healing are used after tooth replantation. The first one is the periodontal ligament healing which is the formation of normal periodontal ligament healing between teeth and alveolar. This opportunity is very rare, limited to short-term tooth dislocation in vitro, and the periodontal ligament is still alive without infection. The second is skeletal adhesion, which is the cementum and dentin of the root that are absorbed and replaced by bone. The clinical manifestation is that the tooth mobility is reduced, and the X-ray shows no periodontal space. There is the most common way of healing. Bone adhesion makes replanted teeth lose the functions of cushioning, stress dispersion and perception when they bear masticatory force [7]. The third is inflammatory absorption, which means there is inflammatory granulation tissue between the absorbed root surface and alveolar bone. Patients with tooth dislocation should properly preserve their teeth and go to the hospital within 30 minutes (better if tooth is kept in preservative medium) which can greatly improve the success rate of tooth replantation. Studies have shown that fluoride has a two-way regulatory effect on osteoblasts cultured in vitro by promoting growth and proliferation at low doses and inhibiting growth at high doses [8]. At the same time, fluoride has a certain effect on tooth mineralization. Fluoride can interfere with the metabolism of microorganisms, promote the morphological development of teeth, inhibit the demineralization of enamel and promote the remineralization of enamel surface, so as to improve the acid corrosion resistance and wear resistance of enamel. Many scholars have proposed the concept of oral fluoride storage, believing that fluoride ions can be stored in plaque, gingiva, cheek, tongue and other tissues, as well as in some fillings and restorations, and become fluoride ion storage and fluorine source in the mouth [9]. If the tooth surface contacts F^- for a long time, it will not only help to strengthen the tooth structure, but also improve its caries prevention performance.

2. Effect of Fluorine on Bone

2.1. The Relationship Between Fluorine and Bone

Throughout the life process, bone undergoes metabolism, that's the process of bone reconstruction. Bone remodeling is coordinated by bone formation and bone resorption. Osteoblasts (Bone forming cells) are the main functional cells of bone formation. The synthesis, secretion and mineralization of bone matrix are accomplished by osteoblasts, which are differentiated from mesenchymal progenitor cells in the inner and outer periosteum and bone marrow. Osteoclasts (Bone breaking/ Resorbing cells) are the main cells of bone resorption, which come from mononuclear macrophages and play an important role in bone development, growth, repair and reconstruction. Osteoclasts and osteoblasts are opposite, which coordinate with each other to maintain bone in proper shape and order. Osteoclasts have special absorption function, absorbing organic matter and minerals in bone tissue, while osteoblasts repair bone at bone resorption site. Osteoblasts and osteoclasts complement each and balance each other to maintain the normal tissue and anatomical structure of the bone [10]. Fluorine (F^-) is a rare element mixed into bone minerals during osteogenesis. It is a known non hormone factor that can affect bone formation. F^- has a two-way regulatory effect on bone formation. Long-term low dose can promote bone formation, and high dose can cause osteoporosis or bone sclerosis. In recent years, more and more researchers have reported the effect of fluoride on the activity of osteoblasts and osteoclasts. F- significantly activates osteoblasts, as evidenced by cell proliferation, cell body enlargement and enhanced the activity of alkaline phosphatase (ALP) [11]. ALP is a necessary enzyme for bone formation. The expression of ALP increases with the development of cell differentiation. Its function is to hydrolyze organic phosphorus to release inorganic phosphorus and act on the formation of hydroxyapatite. Osteocalcin, Bone Gla Protein (BGP) has the function of regulating bone metabolism, maintaining normal calcification of bone, inhibiting cartilage calcification

and irregular crystal precipitation. F^- can stimulate osteoblasts to secrete BGP (bone Gla protein), which makes more hydroxyapatite crystals bind to it and precipitate in bone matrix. Because the radius of F^- is the same as that of OH^- and has the same charge, it is easy to replace hydroxyapatite with fluoroapatite and deposit more F^- and apatite in bone matrix [11]. It is thus clear that the appropriate concentration of fluorine solution can promote the reconstruction of alveolar bone and cementum. However, the continuous stimulation of osteoblasts with high concentration of F^- leads to excessive BGP, which leads to the binding of too much fluoroapatite to BGP, resulting in abnormal bone crystal structure and bone damage.

2.2. Effect of Fluorine on Bone Cells

Some scholars believe that F^- has a direct effect on osteoblasts, while others believe that it has an indirect effect. That is, fluoride can act on OB indirectly by synthesizing some local growth factors. Numerous studies have shown that F^- directly acts on osteoblasts, but it shows two opposite experimental results of activation and inhibition on osteoblasts [12]. Results found that fluoride regulated the proliferation and early differentiation of osteoblasts in both directions, that is, small dose promoted and large dose inhibited. It can be inferred that the negative effect of excessive oxygen on bone health may be due to the inhibition of osteoblasts' survival. Fluoride is consistent in its late differentiation, which is a promoting effect. At the same time, the experiment proved that immature osteoblasts are more sensitive to F^- than mature osteoblasts, and the target cells of F^- action are immature osteoblasts, which can regulate bone formation by stimulating the proliferation and differentiation of immature osteoblast [13]. Studies on the effect of NaF on the functional expression of UMRI in osteoblast cells also obtained the same results as above. At the same time, experiments have proved that low concentration of selenium inhibits the toxic effect of high concentration of F^-, so fluorine and selenium can be used as opposite factors to regulate the expression of osteocalcin [14]. Other studies have confirmed that F^- can induce endoplasmic reticulum stress of osteoblasts, and it will affect the osteogenesis of osteoblasts [15].

The effect of F^- on bone has been widely studied. F^- has an effect on bone inorganic matter, bone cells and bone tissue structure. Although it has been confirmed that F^- has a dose-dependent effect on bone properties, the underlying mechanism is still unclear. Moreover, dose grade is not the only factor affecting bone properties there are some others too that can affect bone properties. Some epidemiological and clinical studies have reported that genetic factors play an important role [16]. Under a wide range of doses, some people do not respond to F^-, while others are very sensitive. Three inbred lines (A/J, SWR/J and 129p3/J) with different sensitivities showed different degrees of decline in bone mechanical properties under the same amount of enamel mineralization and F-exposure in tissues. The bone mechanical properties of the susceptible line (A/J) mice decreased significantly, while the moderately susceptible line (SWR/J) had only moderate changes, and the resistant line (129p3/J) was not affected. It indicates that genetic factors also have some influence on the bone properties in response to F^- exposure [17]. It can be seen that different concentrations and individual differences can affect the effect of F^- on bone.

3. Effect of Fluorine on Dental Hard Tissue

Dental hard tissue lacks the ability of self-healing. The content of hydroxyapatite in enamel is about 96Wt %, which has excellent biocompatibility and bioactivity, to be used as an inducer of bone and teeth. In dentin and cementum, hydroxyapatite (HAP) can exist inside and outside collagen fibers at the same time. Repair or regeneration of highly ordered and oriented HAP in the presence of collagen fibers is a difficult point in dentin and dentin repair and regeneration. The internal mechanism is too complex and there are too many influencing factors. Therefore, the tooth hard tissue damage is generally not promoted by fluoride solution. In the present experiment, more attention was paid to the study of synthetic materials for tooth restoration. The healing of reimplanted teeth is a complex process, which can be affected by many factors. Its essence is to form a new mineralized tissue on the surface of the root and alveolar bone, and embed the periodontal fiber in it, so that the tooth and alveolar bone are reconnected to a new physiological connection by means of periodontal ligament. To achieve good periodontal regeneration effect, it is largely dependent on the biological properties of the root surface and the growth of various cells in the periodontal tissue. There are many studies on tooth avulsion injury, mainly focusing on how to preserve the activity of periodontal ligament stem cells of completely dislocated teeth and the treatment of tooth surface. Periodontal membrane is the connective tissue between root dentin and alveolar bone. Periodontal Ligament Stem Cells (PDLSCs) have the ability of self-renewal and multi-directional differentiation, and can be differentiated into cementum, alveolar bone and periodontal membrane-like tissues, which mainly maintain homeostasis and periodontal regeneration. Compared with other mesenchymal stem cells, PDLSCs are easier to obtain in clinic and less ethically restricted. It has a good application prospect in periodontal regeneration therapy. However, oral local environment, including periodontal tissue, is often exposed to fluoride. The effects of fluoride exposure on the proliferation and osteogenic differentiation of PDLSCs are concentration and time-dependent. Different concentrations of fluoride have complex effects on the biological characteristics and functions of PDLSCs [18]. The proliferation test of PDLSCs in vitro proved the feasibility of PDLSCs in periodontal tissue regeneration [19]. In recent years, some scholars have tried to

add periodontal ligament stem cells as seed cells to the alveolar bone of dislocation teeth, and made some progress. However, based on the limitation of theoretical and clinical operation time, periodontal ligament stem cells have not been applied to the treatment of clinical avulsion tooth injury so far but in future it might be used for the treatment of clinical avulsion tooth injury [20].

After complete dislocation of teeth, it is often accompanied by serious injury of dental pulp and periodontal ligament. The alveolar fossa will become empty and often accompanied by alveolar bone fracture. The structure of alveolar bone is basically the same as that of other bones, with bone dense and cancellous, and its chemical structure is similar to that of cementum. The inorganic substance is mainly hydroxyapatite, and more than 90% of the organic substance is collagen. Alveolar bone is the most active part in the skeleton. It is reconstructed with the development of teeth, the replacement of deciduous teeth and the movement of permanent teeth. There are osteoblasts and osteoclasts on the surface of alveolar bone. When alveolar bone is damaged, osteoblasts play a role. As time gose by, osteoblasts gradually change from soft to hard, and finally calcified to form a new bone. They can cover the damaged area or reconnect the fracture. Osteoclasts are affected by many factors, such as age, health status, special diseases or environment. They will gather more or less on the surface of bone, and then local bone will be demineralized and dissolved, and the demineralized bone will be finally absorbed by the body. Alveolar bone grows with the growth and eruption of teeth. Fluoride can interfere with the metabolism of microorganisms, promote the morphological development of teeth, increase the maturation rate after tooth eruption, and then accelerate the development of alveolar bone. Fluoride mainly promotes the damage and repair of alveolar bone through its anti demineralization effect. Many studies have shown that low concentration of F^- can promote tooth remineralization more effectively than high concentration of F^-, and high concentration will lead to the loss of calcium and phosphorus in tooth hard tissue [21]. Therefore, the use of low concentration of fluorine solution can promote the repair of alveolar bone damage.

Therefore, the application of periodontal ligament stem cells in complete dislocation tooth replantation is still a research hotspot and direction and it is expected that we will come to the best conclusion to maintain a good dental health.

4. Conclusion

In this article, we discussed the impact of fluorine on dental replantation then the two important conclusions were drawn fluorine can affect bone formation, low doses of fluorine can promote bone formation, and high doses of fluorine can inhibit bone formation. At the same time, it has been found that the local environment of the oral cavity is often exposed to fluorine, and fluorine has an impact on the proliferation and osteogenic differentiation of periodontal ligament stem cells.

Abbreviations

ALP: Alkaline Phosphatase
BGP: Bone Gla Protein
OB: Osteoblast
HAP: Hydroxyapatite
PDLSCs: Peridontal Ligament Stem Cells

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Conflicts of Interest

The author declares that there is no conflict of interest.

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