Sys Rev Pharm 2020;11(12):35-41
A multifaceted review journal in the field of pharmacy

Implant Coating Materials to Increase Osseointegration of Dental Implant: A Systematic Review

Eri Hendra Jubhari, Irfan Dammar, Vinsensia Launardo, Yonatan Goan

Department of Prosthodontic, Faculty of Dentistry, Hasanuddin University, Makassar, Indonesia

Corresponding Author: erihjubhari@gmail.com

ABSTRACT

The literature review is intended to compare the various materials that several researchers have been used in the past ten years. Library searches are carried out electronically through the PubMed and Wiley databases to identify articles relating to the terms coating/implant coating, dental implants, and osseointegration, which are first traced using Medical Subject Heading (Mesh). The 81 articles were obtained from this literature search, but only 14 articles were considered eligible for inclusion criteria. Some coating implant materials identified and used by researchers include hydroxylapatite (HA), calcium phosphate, bisphosphonates, bioactive glass, and bioactive ceramic, ti nitride, bone stimulating factor, and fluoride have advantages and disadvantages and different coating techniques for each ingredient coating. HA Coating Material is still the most commonly used material because it provides better results and clinical properties. However, many clinical trials are still needed to obtain evidence base to ensure long-term success.

Keywords: Dental Implant, implant Coating, Osseointegration

Correspondence:
Eri Hendra Jubhari
Department of Prosthodontic, Faculty of Dentistry, Hasanuddin University, Makassar, Indonesia
Corresponding Author: erihjubhari@gmail.com

INTRODUCTION

The implant has been widely used in prosthodontic rehabilitation, i.e., to support the dental crown and has several advantages over conventional denture. To provide the successful treatment of implant placement, keeping alveolar bone thickness, facilitating phonetic function, managing osseointegration is the most crucial factor.[1] Osseointegration describe as a junction between living bones and the surface of an artificially anchored load bearing implant[2]. The quality of bone, distribution, and amount of bone present in the dental implant area are playing crucial role in the successful osseointegration. Two theories regarding osseointegration have been put forward by Branemark and Weiss[3,4]. The connective tissue layer or fibro-osseous ligament between the surface of the implant and the surrounding bone are two important things that differentiate the proposed system. Surgical techniques, materials, design, and surface texture of the implant are some of the factors that determine the presence of bone around the implant's surface. Optimal osseointegration depends on the characteristics of implant material, implant load, surgical technique used, and type of bone in implant site[5,6].

Titanium (also known as Ti) is the most commonly used material for dental implants because of its minimal toxicity, corrosion resistance, high mechanical resistance, and biocompatibility.[7,8] Recently, there are four commercially available pure grades of Ti and one alloy used for the manufacture of dental implants. Although for several years carbon-coated low-temperature-isotropic (LTI) implants show more significant potential for long-term success performance, Ti implants still show better biocompatibility results and long-term prognosis.[9,10,11] Ti-based implants remain the most commonly used type of implants because of their excellent properties and excellent long-term clinical results among PMMA, PFTE and carbon implants[12].

Dental implants surface quality divided into mechanical, topographic, psychochemical properties.[6,13] The implant surface's mechanical properties are related to the surface potential pressure and material hardness—topographic properties associated with surface irregularity (roughness). Physical characteristics primarily focus on surface energy and surface alteration. It can be concluded that a surface has high surface energy if the adsorption affinity is higher.[14]

Implant surface should be investigated to determine tissue reaction on the implant surface. In this review, the authors concluded that surfaces with moderate roughness (Sa = 1 – 2 μm) were considered to have clinical benefits over smoother or rougher surfaces. However, it is slightly different and not significant.

Although Ti implants have a high range of clinical success, various coating materials have been proposed[16]. An active surface coating should have the following properties: facilitate bone fixation, have a limit of irregularity in body fluids, and have therapeutic function.[10,11] If we use the Ti implant, the clinician should use sandwiched methods between implant and the bone surface as the coating material. The implant coating holds every pressure applied while transferring all loads throughout the implant. Utilizing calcium phosphate coatings have shown that the calcium phosphate ultrathin coating increases osseointegration, in contrast to the thick coating[3]. The thick coating prevents adhesion in surrounding tissue while weakening the internal structure, which can cause fracture and trigger failure of implant treatment.[3]

Various types of dental implant coating materials have been proposed. However, not all coatings give the same properties to prostheses. Another review focuses on the effects of loading and unloading on implants and their impact on bone integration systems. This systematic review will associate conventional Ti implants and implant coatings.[12,13,15]

Therefore, this literature review aims to examine various materials used by multiple researchers as implant coatings.

MATERIALS AND METHODS

Article selection

This systematic review considers whether the currently popular Ti surface is the best solution to patients in dental implant therapy compared to implant coatings.

Participants

The various types of implant coating materials compared to most commonly used Ti implants.

Intervention

Experiments to compare various implant coating materials need to be considered. Even the most recent coatings are involved, although long-term research is not widely available.

Outcome

Osseointegration and biocompatibility are the main characteristics sought in research. Adverse events such as implant failure after loading and delamination are also considered in the reviewed article.

The criteria in this review are several clinical studies, both in vitro and in vivo as well as together with randomized control trials (RCTs).

Search assisted by using PubMed, Wiley, and manual searches. The keywords used for this systematic review are "dental implants," "implant coatings," "osseointegration". Irrelevant articles are not included. The research also involves investigating radiographic assessment of the implant, risk of corrosion and implant placement in other bone structures of the human body.

Articles are selected if they meet the following criteria: evaluating various types of dental implant coatings, osseointegration potential, and the new coatings compared to conventional Ti implants. Firstly, the articles examined by its title and abstract determine whether the article was included/excluded. Next, the full text of the relevant article is further examined.

Data search strategies obtained 81 articles. A search strategy developed for each data. Primarily on a search strategy in Pubmed. The keywords used in data search are separated and also combined with AND or OR. Of the 81 articles, 67 articles were excluded because they were not relevant to dentistry.

RESULT

A PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow chart shows data identification, screening, data eligibility, and inclusion, presented in Figure 1.

Various material have been used as coating materials for dental implants with a core made of Ti such as carbon, bisphosphonates, bone stimulating factors, bioactive glass, bioactive ceramics, fluor, HA, calcium phosphate, and Ti nitride (TiN). Table 2 shows data regarding implant coating materials.

There are four articles reporting carbon coating as an implant coating material. Two articles are systematic reviews involving two other articles[15]. Carbon-coated implants are reported to have excellent chemical properties and stability between the carbon coating and the etching agent used yet also hemocompatible, histocompatible, biostable, and chemically stable both in vitro and in vivo. Surface properties and biological properties were found to be enhanced through implantation and removal of carbon immersion ions.[9] Direct carbon bonding makes it easier for adhesion and proliferation of osteoblasts on the surface of nickel-titanium alloys (NiTi)[15].

Bisphosphonates are another new type of coating material. Bisphosphonates have attracted research interest in dentistry because of their selective osteoclast inhibition and increased resultant net in terms of bone quality and resultant net changes in osteoblastic activity. However, the studies that supports the Ti implant's immersion is still fewer than others.[17] In the study by Yoshinari et al., osteoblastic cell activity and inhibitory effects have been investigated[14]. Bisphosphonates immobilization has been investigated by implanting Ca^{2+} and thin layered HA coating that provides both osteogenic potential and non-toxic, which manifests in osteoblasts[16]. Meraw et al. was conducted a study with a period of more than four weeks without any long-term or clinical studies available. Bisphosphonates showing an increase in size of osteoclast cells to compensate for their inhibitory activity. Therefore, the dose of anti-resorptive drugs should be determined, and the bone density around the surface of the implant depends on the concentration of bisphosphonates. Tyrosine phosphate is an enzyme in the formation and functionality of osteoclasts; therefore, it is one of the main targets of bisphosphonates. Ti.[17] Although the research has been performed, there are still some controversies regarding the use of bisphosphonate as an implant coating. Although, in short, subsequent studies conclude that there is early bone formation around the prosthesis, one thing that must be remembered is that bisphosphonates act selectively as an osteoclast inhibitor. Osseointegration is a dynamic process, depending on osteoblastic and osteoclastic activity; therefore, through inhibition of osteoclast activity, long-term implant success can be promising. In conclusion, bisphosphonates' effect as an implant coating is still unknown, and more research is needed before clinical research.

Bone stimulating factor (BSF) as a coating material for implants is quite innovative and interesting. The study results show that BSF has an excellent osseointegration process, and by applying this component as a coating, bone density in the peri-implant area and the biocompatibility of the prosthesis can be improved.[18] A study showed that implants coated with growth factors can increase bone healing potential after implant placement. Meanwhile, implants coated with bone morphogenic protein (BMP) can increase the bond strength on the surface of bone implants compared to control implants without BMP coating.[18] A study hypothesized that Ti implants coated with BMP-2 can trigger enhanced bone formation around the implant[18]. The researchers concluded that the number of bones formed was practically the same, but growth factors increased the range of bone formation in the peri-implant area. In conclusion, BSF is an innovative, promising coating because it offers both healing potentials after surgical implant placement while providing better osseointegration in the peri-implant region.

Bioactive glass and ceramics have also been proposed as surface coatings because they are innovative and useful for dental implants due to their glassy properties, thus helping to obtain better osseointegration from implants and also reduce corrosion in body fluids[10]. This thermal expansion can be reduced by increasing the content of silicon dioxide (SiO_2) in bioglass. In contrast, if the SiO_2 content is increased, the glass coating's bioactivity is significantly reduced[18]. The noxiousness of the coating is the limited use in the load resistance area. It was concluded that the coating material does not only consider functional if it meets the following two criteria:

1. Capable of withstanding the pressure of the load resistance at once
2. Maintain a strong bond with the surface of the implant with perfect function.

An in vitro research showed that bioactive glass fulfills both criteria even after several months of load resistance analysis[18]. Silicate glass also has a higher weight percentage of 60% so that it is capable of withstanding corrosion and coating thermal expansion[10]. Silica content with a weight exceeding 60% will undergo delamination and cracking. This can be overcome by partially replacing calcium oxide (CaO) with magnesium oxide (MgO), Na_2O and potassium oxide (K_2O) in bioglass compositions to adjust the thermal expansion between coatings and Ti-based alloys[18]. While, bioactive glass was applied as a dental implant coating by enameling technique with HA coating as control in other studies. Overall results show that the bioactive glass coating has the same success as the HA coating for obtaining osseointegration and bioactivity. This shows that the HA coating is not only an implant coating that provides good osseointegration. Nevertheless, required some research on bioglass for long-term results.[18]

OsseoSpeed (Dentsply) is a fluor nano-modified surface structure marketed to stimulate early bone formation. Monjo et al. that compared fluor-coated implant with TiOblast (Dentsply) was found that there is no difference about the biocompatibility of the implant. However, this induces more branched cellular morphology in the area of implant placement thereby triggering osteoblast differentiation.[19]

HA coating has encouraged a number of substantial interests because it increases osteoconductivity.[20] This type of coating material introduced as a combination of high metal strength with good bioactivity of the calcium phosphate compound (Ca_3 $(PO_4)_2$).[10,20] Although HA coating has been extensively studied and indicated as one of the ideal implant coatings, and the long-term prognosis is controversial[9]. Research on the morphology, composition, and structure of the coating and various relevant changes that occur during the implant coating indicate that coating will become thicker in the apical part of the implant, while imperfect lattices and changes in composition are also observed. Despite these results, researchers should not attribute these changes to implant failure in vivo[20].

Nitride compounds exhibit the same properties as Ti20. Osseointegration improvement is obtained by changing the thickness of the TiN layer and alteration of surface coating, in order to achieve neural response associated with nitrogen inside the coating.[21] Nitride coating shows the tolerability of the blood because it shows protein absorption and platelet retention similar to those obtained from medical elastomers control. A recent study to control Ti surface oxidation shows that although the oxidation layer increases bond strength, the very thick surface of the TiO layer causes difficulties for the bonding process. This shows that TiN coatings can control the formation of TiO layers and facilitate satisfactory bonding.[21] Other studies discuss the recent ways to coat Ti implants with TiN through the use of powder immersion reactions.

This will facilitate the formation of mechanically stable coatings, thereby improving chemical resistance and Ti wear. SEM studies for two months after implantation has shown that both coated and uncoated implants have and are osseointegrated with a comparable degree.[21]

DISCUSSION

The clinical success of osseointegration exceeds 90%. The purpose of studies discussed in this systematic review refers to new coating materials while providing promising chemical and mechanical properties and more cost-effective results. It can be concluded that the implant layer can improve implant properties while providing better physical and osseointegration properties. Although some of these implant coatings are considered to provide better results than others. Although the most commonly used and most researched material is HA coating, new materials such as bioglass and carbon coatings show promising results. Several types and classes of materials are used in various fields of dentistry. For example, coating materials such as bisphosphonates look promising theoretically but yield debatable results. It can be assumed that materials that play a good role in other fields of dentistry can be examined as an effort to propose a more suitable implant coating material.

CONCLUSION

Various materials have been proposed for implant coating. HA is the most widely used material because of its biocompatibility. Bioactive glass and TiN coating also show promising results and provide the same osseointegration results as HA material.

REFERENCES

1. Putra, A. S., Ramadhonie, R., & Rahajoe, P. S. (2018). Use of bones taken from the operated areas of impacted third molars as autografts for implant placement: cases report. *J Dentomaxillofac Sci*, *3*, 192-195.
2. Branemark, P. I. (1983). Osseointegration and its experimental background. *J prosthet Dent*, *50*, 399-410. https://ci.nii.ac.jp/lognavi?name=crossref&id=info:doi/10.1016/S0022-3913(83)80101-2
3. Bernard GW, Carranza FA, Jovanovic SA. (1996). Biological aspects of dental implants. Clin Periodont 687–689.
4. Weber, H. P., & Cochran, D. L. (1998). The soft tissue response to osseointegrated dental implants. *The Journal of prosthetic dentistry*, *79*(1), 79-89. https://doi.org/10.1016/S0022-3913(98)70198-2
5. Anil, S., Anand, P. S., Alghamdi, H., & Jansen, J. A. (2011). Dental implant surface enhancement and osseointegration. *Implant dentistry—a rapidly evolving practice*, 83-108.
6. Lekholm, U. (1985). Patient selection and preparation. *Tissue-integrated prostheses Osseointegration in clinical dentistry*, 199-209.

7. Cranin, N. A. (1982). The requirements and clinical performance of dental implants. *Biocompatibility of dental materials*. 149–160.
8. Demri, B., Hage-Ali, M., Moritz, M., & Muster, D. (1997). Surface characterization of C/Ti-6Al-4V coating treated with ion beam. *Biomaterials*, *18*(4), 305-310. https://doi.org/10.1016/S0142-9612(96)00130-5
9. Grabarczyk, J., Batory, D., Louda, P., Couvrat, P., Kotela, I., & Bakowicz-Mitura, K. (2007). Carbon coatings for medical implants. *Journal of Achievements in Materials and Manufacturing Engineering*, *20*(20), 107-110.
10. Yoshinari, M., Oda, Y., Ueki, H., & Yokose, S. (2001). Immobilization of bisphosphonates on surface modified titanium. *Biomaterials*, *22*(7), 709-715. https://doi.org/10.1016/S0142-9612(00)00234-9
11. Yoshinari, M., Oda, Y., Inoue, T., Matsuzaka, K., & Shimono, M. (2002). Bone response to calcium phosphate-coated and bisphosphonate-immobilized titanium implants. *Biomaterials*, *23*(14), 2879-2885. https://doi.org/10.1016/S0142-9612(01)00415-X
12. Bessho, K., Carnes, D. L., Cavin, R., Chen, H. Y., & Ong, J. L. (1999). BMP stimulation of bone response adjacent to titanium implants in vivo. *Clinical oral implants research*, *10*(3), 212-218. https://doi.org/10.1034/j.1600-0501.1999.100304.x
13. Jones, A. A., Buser, D., Schenk, R., Wozney, J., & Cochran, D. L. (2006). The effect of rhBMP-2 around endosseous implants with and without membranes in the canine model. *Journal of periodontology*, *77*(7), 1184-1193. https://doi.org/10.1902/jop.2006.050337
14. Le Guéhennec, L., Soueidan, A., Layrolle, P., & Amouriq, Y. (2007). Surface treatments of titanium dental implants for rapid osseointegration. *Dental materials*, *23*(7), 844-854. https://doi.org/10.1016/j.dental.2006.06.025
15. Schrooten, J., & Helsen, J. A. (2000). Adhesion of bioactive glass coating to Ti6Al4V oral implant. *Biomaterials*, *21*(14), 1461-1469. https://doi.org/10.1016/S0142-9612(00)00027-2
16. Lopez-Esteban, S., Saiz, E., Fujino, S., Oku, T., Suganuma, K., & Tomsia, A. P. (2003). Bioactive glass coatings for orthopedic metallic implants. *Journal of the European Ceramic Society*, *23*(15), 2921-2930. https://doi.org/10.1016/S0955-2219(03)00303-0
17. Mistry, S., Kundu, D., Datta, S., & Basu, D. (2011). Comparison of bioactive glass coated and hydroxyapatite coated titanium dental implants in the human jawbone. *Australian dental journal*, *56*(1), 68-75. https://doi.org/10.1111/j.1834-7819.2010.01305.x
18. Monjo, M., Petzold, C., Ramis, J. M., Lyngstadaas, S. P., & Ellingsen, J. E. (2012). In vitro osteogenic properties of two dental implant surfaces. *International Journal of Biomaterials*, *2012*. 181024. https://doi.org/10.1155/2012/181024
19. Baltag, I., Watanabe, K., Kusakari, H., Taguchi, N., Miyakawa, O., Kobayashi, M., & Ito, N. (2000). Long-term changes of hydroxyapatite-coated dental implants. *Journal of Biomedical Materials Research: An Official Journal of The Society for Biomaterials, The Japanese Society for Biomaterials, and The Australian Society for Biomaterials and the Korean Society for Biomaterials*, *53*(1), 76-85. https://doi.org/10.1002/(SICI)1097-4636(2000)53:1%3C76::AID-JBM11%3E3.0.CO;2-4
20. Oshida, Y., Hashem, A., Nishihara, T., & Yapchulay, M. V. (1994). Fractal dimension analysis of mandibular bones: toward a morphological compatibility of implants. *Bio-medical materials and engineering*, *4*(5), 397-407. https://doi.org/10.3233/BME-1994-4506
21. Oshida, Y. (2000). Requirements for successful biofunctional implants. In *The 2nd Symposium International of Advanced Bio-Materials* (pp. 5-10).
22. Hägi, T. T., Enggist, L., Michel, D., Ferguson, S. J., Liu, Y., & Hunziker, E. B. (2010). Mechanical insertion properties of calcium-phosphate implant coatings. *Clinical oral implants research*, *21*(11), 1214-1222. https://doi.org/10.1111/j.1600-0501.2010.01916.x
23. Iezzi, G., Scarano, A., Petrone, G., & Piattelli, A. (2007). Two human hydroxyapatite-coated dental implants retrieved after a 14-year loading period: A histologic and histomorphometric case report. *Journal of periodontology*, *78*(5), 940-947. https://doi.org/10.1902/jop.2007.060271
24. TAMURA, Y., YOKOYAMA, A., WATARI, F., & KAWASAKI, T. (2002). Surface properties and biocompatibility of nitrided titanium for abrasion resistant implant materials. *Dental materials journal*, *21*(4), 355-372. https://doi.org/10.4012/dmj.21.355
25. Cyster, L. A., Parker, K. G., Parker, T. L., & Grant, D. M. (2004). The effect of surface chemistry and nanotopography of titanium nitride (TiN) films on primary hippocampal neurones. *Biomaterials*, *25*(1), 97-107. https://doi.org/10.1016/S0142-9612(03)00480-0
26. Dion, I., Baquey, C., Candelon, B., & Monties, J. R. (1992). Hemocompatibility of titanium nitride. *The International journal of artificial organs*, *15*(10), 617-621. https://doi.org/10.1177%2F039139889201501009

Table 1. Titanium (Ti) degree Table 1. Titanium (Ti) degree

ASTM Degree	Types	Comments
Degree 1	Not Alloy	The purest, the lowest tensile strength, the lowest final tensile strength, the best ductility at room temperature. Highest impact strength and good resistance to corrosion
Degree 2	Not Alloy	Useful in chemical processing because of its high resistance to chemical environments, including oxidation medium, alkaline solution, organic acid, aqueous saline, and high temperature.
Degree 3	Not Alloy	Its modulus elasticity is similar to 1, 2, and 4 degrees. Could be considered as intermediate material among other degrees.
Degree 4	Not Alloy	Highest strength from degree 4 not alloy
Degree 5	4% vanadium alloy and 6% aluminum alloy	Most commonly used degrees. Alpha-beta alloy with excellent tensile strength, highest tensile strength, corrosion resistance and extraordinary ability.

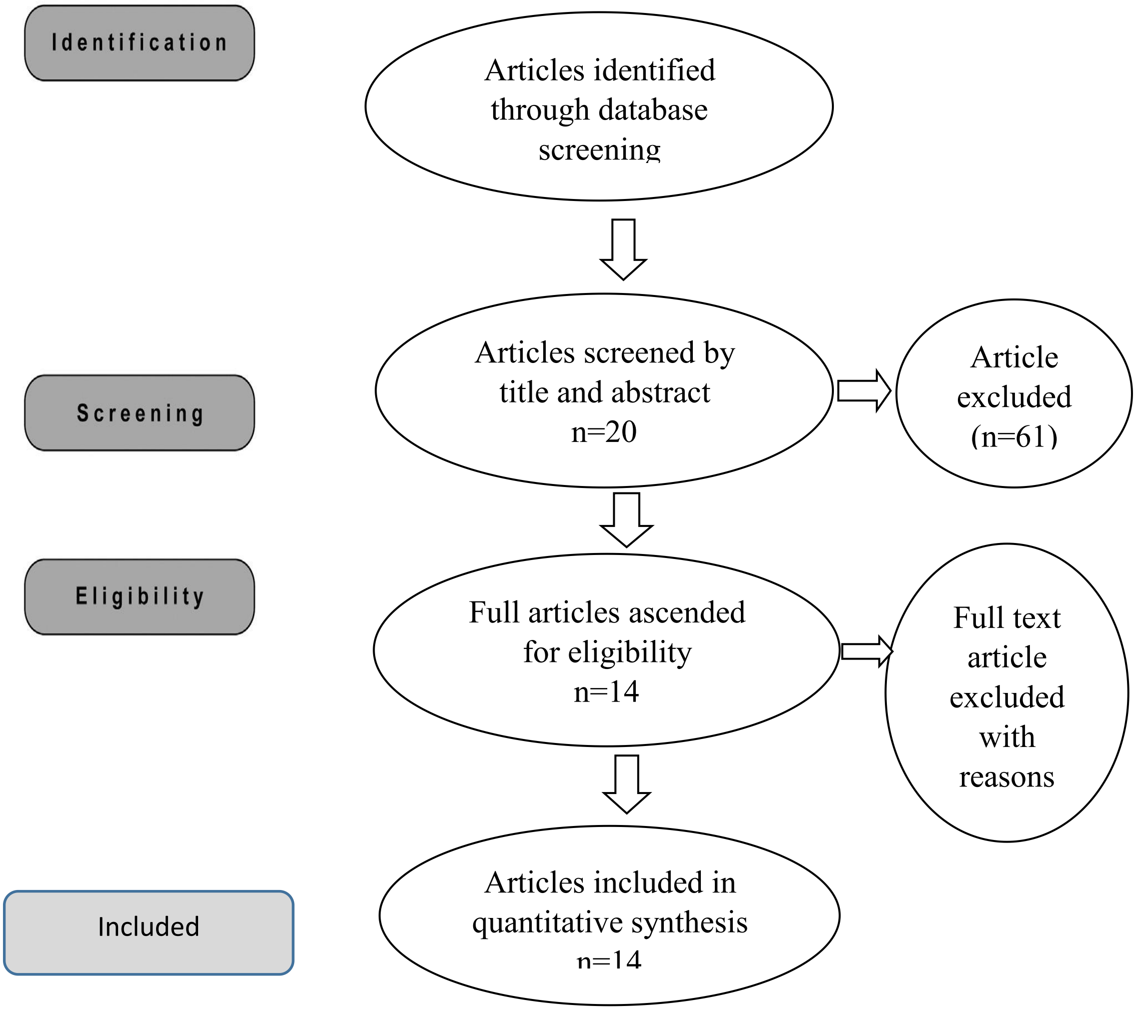

Figure 1. PRISMA Flowchart

Table 2. A brief summary of implant coating materials

Coating Materials	Product	Type of studies	Outcome
Carbon	Unavailable commercially, still investigated	• In vitro, • In vivo, • Clinical study	Improve biological properties and histocompatibility; the research still ongoing
Bisphosphonates	Unavailable commercially, still investigated	Long term study unavailable	Long term study unavailable
Bone stimulating factor	Unavailable commercially, still investigated	Animal and clinical study	Ongoing research
Bioactive glasses and ceramics	Unavailable commercially, still investigated	In vitro study	Ongoing research
Fluoride coating	OsseoSpeed	In vitro study	Selective osteoblast differentiation