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Periodontio-Integrated Implants: A Review

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ABSTRACT: Though the fields of regenerative dentistry and tissue engineering have undergone significant advancements, yet its application to the field of implant-dentistry is lacking; in the sense that presently the implants are being placed with the aim of attaining osseointegration without giving consideration to the regeneration of periodontium around the implant. This review describes the PDL integrated implants and its importance.

KEYWORDS: Periodontal Ligament, Tissue engineered Cells, Ligaplants.

I. INTRODUCTION:

Implantology has become an indispensable part of mainstream dentistry in the present era of dental practice, helping dentists all over to improve the quality of life of the large population of patients. It is well-known fact that professor Branemark's work in developing the osseointegrated dental implants constituted the dawn of an era of the "evidence-based dentistry."[1]

Since, the description of the process of osseointegration by Brånemark et al., dental implants have become ideal replacements for missing teeth.[1] The term osseointegration was later defined by Albrektsson et al. as the direct contact between living bone and implant at the light microscope level.[2]

This means that the implants are functionally ankylosed to the bone without periodontal ligament (PDL) support. Over the years, many strategies have been explored to improve the osseointegrative property of the implant, be it the surface modifications to improve the mechanical, physical, and chemical characteristics of the implant, by modifying the shape and design, altered surface topography to control cell behavior, nanostructured surface coatings or the addition of biomimetics (growth factors) to the implant surface.[3,4]

Though implants are an ideal way to replace a missing tooth, still lacking is the presence of the periodontal ligament, as in the natural teeth. This soft, richly vascular, and cellular connective tissue permits forces, elicited during masticatory function and other contact movements to be distributed to the alveolar process via the alveolar bone proper. It acts like a shock absorber, giving the tooth some movement in the socket. It also provides proprioception. The periodontal ligament also has an important interaction with the adjacent bone, playing the role of the periosteum, at the bone side facing the root. It homes vital cells such as osteoclasts, osteoblasts, fibroblasts, cementoblasts, cementoclasts, and most importantly, the undifferentiated mesenchymal stem cells. These cells are all important in the dynamic relationship between the tooth and the bone. Therefore, strategies to generate dental implants with associated periodontal tissues have become a new approach in tooth replacement therapies.

Therefore, an innovative approach is mandatory to create "periodontio-integrated implants" i.e., an implant suspended in the socket through periodontal ligament as opposed to functionally ankylosed osseointegrated implants.

PERIODONTIO-INTEGRATED IMPLANTS VERSUS OSSEOINTEGRATED IMPLANT:

The biomechanics of force distribution in implant-supported prostheses is qualitatively different from natural teeth abutments. The essential difference is caused by the dynamic role of PDL, which permits micro-movements and acts as a shock absorber.[5]

In cases of osseointegrated implants, there was no fibrous capsule. High-resolution microscopy revealed an afibrillar interfacial zone (cement-like layer) at the boneimplant interface to which alveolar bone was attached. The interfacial layer at the titanium-bone interface is rich in noncollagenous proteins (proteoglycans and glycoproteins), as well as certain plasma proteins[6.]

Thus, osseointegrated dental implants exhibit a rigid bone-implant interface that lacks the plasticity and biological remodeling that natural tooth possesses, which in turn is responsible for the decreased amount of mobility under functional loading and the transfer of excessive destructive stresses to the surrounding bone that consequently results in marginal bone resorption[7].

On the other hand, PDL integration of dental implants, accompanied by formation of periodontal-like ligament, demands new cementum construction on the implant surface together with complete development of periodontal attachment. The later should include functionally oriented PDL fibers and Sharpey's fibers inserted into both the newly formed cementum layer and alveolar bone[8]. This ligament-like tissue is equivalent to the PDL found in gomphosis that acts as a buffer to occlusal loads, allowing for bone remodeling and permitting curative orthodontic movements of malpositioned dental implants.

TISSUE ENGINEERING: FOUNDATION OF PERIODONTIO-INTEGRATED IMPLANT

Tissue engineering has emerged as a new and ambitious approach that utilizes biodegradable polymers to make scaffolds into the cells to produce tissues in the presence of growth factors.[9]

Tissue engineering as defined by Langer and Vacanti is an interdisciplinary field that applies the principles of engineering and life sciences for the development of biological substitutes that restore, maintain or improve tissue function.[10]

The main requirements for producing an engineered tissue are: The appropriate levels and sequencing of regulatory signals, the presence and numbers of responsive progenitor cells, an appropriate extracellular matrix or carrier construct and an adequate blood supply.[11]

Because periodontal ligament-derived cells have multipotential characteristics, these cells are harvested and utilized as sources for the regeneration of periodontal tissues containing bone, cementum and periodontal ligament. Clearly, a tissue-engineering approach for periodontal regeneration will need to utilize the regenerative capacity of these cells residing within the periodontium and would involve the isolation of such cells and their subsequent proliferation within a three-dimensional framework. Recent advances in mesenchymal stem cell isolation, growth factor biology and biodegradable polymer constructs have set the stage for successful tissue engineering of many tissues, of which the periodontium is considered a prime candidate for such procedures. Sonoyama et al. demonstrated the possibility of constructing the entire root/periodontal complex by inserting a hydroxyapatite/tricalcium phosphate block coated with periodontal ligament-derived mesenchymal stromal cells into the tooth sockets of mini-pigs.[12]

Another possible option for periodontal ligament regeneration is gene therapy that comprises the insertion of genes into an individual's cells in order to promote a specific biological effect and requires the use of vectors or direct delivery methods to transfect the target cells.

Lin et al. reported the use of autologous rat PDL cells derived from molar tooth root surfaces to regenerate PDL tissues of titanium. They used matrigel, a three-dimensional matrix scaffold to facilitate organized rat PDL regeneration at the titanium-implant alveolar bone interface. In yet another study ligaplants were used for the tooth replacement. It involved both animal experiments as well as human clinical investigations. One of the interesting facts in his research-work was that PDL fibroblasts could be harvested from hopeless teeth of mature individuals and cultured in bioreactors to preserve their state of differentiation but therapeutic success could only be achieved when a high proportion of cultivated cells should organize into a new PDL.[13]

INTERPHASE OF IMPLANT AND PERIODONTAL LIGAMENT TISSUE:

The development of a regenerative PDL depends on site specific signaling, which in turn is mediated by an anatomic code, written in expression patterns of homeogene-coded transcription factors. So, the homeoproteins influence the synthesis of cell surface and signaling components, and signals from the cell surface feedback to modulate homeogene expression, whereby cell identities are established according to the anatomic site and tissue type. Homeogene Msx2 has in fact been considered in the segregation of mineralized bone versus non-mineralized PDL. For the inhibition of mineral formation of PDL, a role of asporin (an SLRP protein that is present in the extracellular matrix) has been introduced[14]

PERIODONTAL REGENERATION BY PDLSCS CELL SHEET:

MSCs are the most widely investigated cell type for cell-based treatment because of their characteristics such as multi-differentiation capacity, immunomodulation, anti-apoptosis, angiogenesis, and cell recruitment [15]. Besides these MSC characteristics, PDLSCs possess a unique potential to form cementum.

Cell sheet engineering is a unique tissue engineering method to obtain cells in a sheet format, which allows collection of the cell sheet without destruction of extracellular matrix

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components secreted from cells. . PDLSC transplantation is now considered one of the promising regenerative approaches for periodontal tissues.

CONSTRUCTION OF DENTAL IMPLANT BEARING PERIODONTAL TISSUES BY PDLSCS:

Dental titanium implants directly integrate with the bone and lack several important functional structures associated with a natural tooth, such as cementum and PDL. These attachment structures, normally associated with teeth, could function collectively as a buffering structure against the forces of mastication to help protect the implant from traumatic mechanical load. Moreover, the direct interface between oral epithelium and titanium implant presents higher risks of bacterial invasion and consequential inflammatory peri-implant mucositis and periimplantitis.

LIGAPLANTS:

Implants with PDL are placed in the extraction socket of the missing tooth, thereby facilitating the surgical procedure. Natural implant anchoring might also be compatible with further growth and development of the alveolar bone housing, and it may allow tooth movements during orthodontic therapy. Ligaplants have the capacity to induce the formation of the new bone, when placed in sites associated with large periodontal defects.[16]

The ligaplants system mimics the natural placement of natural tooth roots in alveolar bone. Without interlocking and without direct bone contacts, they become firmly integrated into the bone despite the initial fitting being loose in order to spare the PDL cell cushion. Despite decisive advantages of ligaplants as tooth replacement than dental implants alone, their preparation is complex and caution must be made about the temperature, duration of the culturing, and the cells obtained from cultures as other non-periodontal cells are formed if the culturing fails. Extended culturing is required to obtain a cushion of adequate thickness. Also the high cost of the implant reduces patient cooperation. The factors affecting the host to accept the implant or the growth of PDL in the socket is also unpredictable, which may result in failure of the implant.

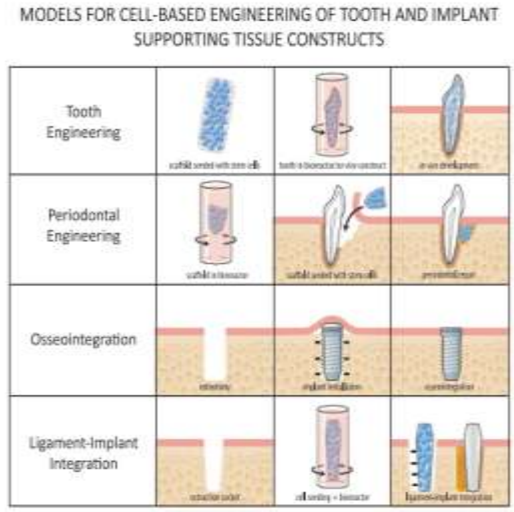

Fig. 1. Stem cell-based therapies in the bioengineering of teeth, periodontium and alveolar bone structures. In the situation of the formation of a tooth–implant interface, periodontal ligament stem cells offer the potential to form tooth–ligament–bone interfacial complexes.

II. CONCLUSION:

Although it has been revealed that generating a periodontal-like tissue around implants is possible, still a predictable and feasible method for producing dental implants with periodontal-like ligament has not been innovated. A major concern being the rational application of stem cell based tissue-engineering technology in clinical practice. Besides, the costs and time required from a practical standpoint for such tissue engineering applications is significant. Yet, this revolutionary approach to develop periodontio-integrated implants; however, opens up exciting possibilities for both periodontologists and oral implantologists and offers many interesting possibilities of utilizing ready-made, off-the-shelf biological tooth replacements that could be delivered to serve as hybrid-material-living oral implants.

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