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Ligaplants - A New Dimension in Implant Dentistry

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Abstract

Periodontitis is one amongst the various reasons for the loss of tooth. With the emergence of dental implant, replacement of natural tooth by fixed prosthesis got a new dimension. However, problems exist with implants as they lack periodontal ligament (PDL). A possible approach to the above-mentioned problems is tissue engineering of the PDL where similar cell culture is used around an artificial root and cells are being formed on the dental implants surface thus, acting as a natural tooth. This new dimension in the field of implant dentistry is known as LIGAPLANTS.

Keywords: Liga plant, Implant, Tissue engineering, Periodontal ligament (PDL).

Introduction

Periodontitis is one amongst the various reasons for the loss of tooth. It is the disease causing the destruction of the soft and hard tissues surrounding the teeth and, if left untreated, periodontal destruction may progress and ultimately lead to loss of teeth. Replacement of the missing tooth with implant has gained immense popularity in the recent years.

With the emergence of dental implant, replacement of natural tooth by fixed prosthesis got a new dimension. The natural tooth is connected to the bone through periodontal ligament (PDL), but when natural tooth is replaced by implant it becomes directly connected to the bone by osseointegration. This means that the implants are functionally ankylosed to the bone without PDL support.[1] However, problems exist with implants as they lack PDL, because any inflammation around them may cause serious bone loss contrary to that in natural tooth, where PDL is present. Replacement of a failed implant poses a challenge in achieving osseointegration in a healed bone site and can reduce the implant survival rate.[2]

A possible approach to the above-mentioned problems is tissue engineering of the PDL that is combined knowledge from material chemistry with cell biology and medicine. In tissue engineering of the PDL, similar cell culture is used around an artificial root and cells are being formed on the dental implants surface thus, acting as a natural tooth. This new dimension in the field of implant dentistry is known as LIGAPLANTS.

The implementation of such an implant offers potential for titanium implant devices that can maintain form, function, and potential proprioceptive responses to allow for a tooth replacement more similar to a natural tooth (Van Steenberg he 2000).[3]

Osseointegration and the need for Liga plants

Osseointegration can be described as a stable or immobile support of a prosthesis under functional loads. Albrektsson et al. defined osseointegration as the direct contact between living bone and implant at the light microscopic level.[1] Upon insertion of an implant, the bone tissue, which itself is the product of a long history of structural and functional adaptation to all kinds of intrinsic biological effects, is confronted with a physical event for which there is no prior preparation.[4] In vivo evidence for ultrastructural aspects of osseointegration substantiate the presence of a collagen-deficient zone of physiological origin.[4] However, various authors based on their studies mentioned several reasons for the failure of implants. Zembic et al., mentioned the loosening of abutment screws as a reason to failure.[5] Oliva et al., stated implants failed due to placement after simultaneous sinus elevation and patients being smokers.[6] Grassi et al., observed that implants failed after immediate loading.[7]

The success and longevity of dental implants are strongly governed by its surface characteristics. There are certain factors that successful implants must possess to accommodate the osseointegration. It should be biologically compatible to the surrounding hard and soft tissues and should be non-toxic. It should also be mechanically compatible to smoothly transfer the stress between the placed implant root and receiving hard tissue. Morphological compatibility must also be present to accommodate the surface roughness and promote bony cell growth.[5], [8]

As the previously mentioned characteristics of Osseo integrated implants does not fully comply with the abovementioned success criteria hence, search for a better alternative started, which lead to the idea of PDL regeneration around implants with the help of tissue engineering to combat the limitations and drawbacks of Osseo integrated implants.

Application of the previously discussed properties of periodontal ligament around implants is under process and is named Liga plant. The implementation of such an implant offers potential for Osseo integrated implant devices that can maintain form and function as that of natural tooth, load bearing capacity and transfer of stress of the PDL as well as potential proprioceptive responses to allow for a tooth replacement more similar to a natural tooth.

Tissue engineering

The emergence of tissue engineering was initialized in the 1970s by a Boston paediatrician, Dr. Green, who manipulated chondrocytes in an attempt to generate

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cartilage. The term was officially coined at a National Science Foundation workshop in 1988. However, it is unclear who used the term first.[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.[1]

It relies on the concept of using cells, biomaterials, and tissue-inducing factors either alone or in different combinations to accomplish tissue regeneration in vivo or in vitro for transplantation.[9]

Tissue engineering is a relatively a new approach in dentistry and are showing promising results. In this new dimension it is optimistic to see how tissue engineering can be of help in simulating the natural environment of the periodontium around implants, i.e., Liga plants.

Procedure of obtaining Liga plants

The procedure of obtaining Liga plant is through tissue engineering as mentioned earlier. The elements required for this procedure are-

- Matrix or a Scaffold
- Signalling molecules
- Cells

This can be done by both in vitro and in vivo. [10]

In vitro technique, the tissue is prepared in the laboratory. Here, biomimetic hybrid scaffolds for cell culturing is required. Cells are cultured in these scaffolds or matrix with the help of signaling molecules following which they are transplanted into the body.

Whereas, in in vivo technique, all the above-mentioned elements are placed in the tissue defect which later undergoes natural healing process in the body giving rises to regeneration. In another technique intrinsic healing activity is induced at site of tissue defect using these three elements.[10]

Preparation

The first step in this is the preparation of temperature responsive culture dishes. Here, N-isopropylacrylamide monomer in 2-propanalol solution is spread onto polystyrene culture dishes. Then the dishes are subjected to electron beam irradiation with an Area Beam Electron Processing System (ABEPS) and are rinsed with cold water to remove any foreign substance and then sterilized with ethylene oxide.

Secondly, cell culture and cells are extracted from tooth and periodontal ligament cells are isolated. From the middle third of the root periodontal tissue is scraped with a scalpel blade after extraction.

The harvested tissue is placed into culture dishes containing Dulbecco’s modified Eagle’s minimal essential medium, supplemented with 10% foetal bovine serum and 100units/mL of penicillin-streptomycin. [11]

Now, for the attachment of the cells to the dishes, cells are cultured in a humid atmosphere of 5% CO_2 at 37°C for 48 hours. The debris are eliminated by washing the dishes and the medium has to be changed three times per week.[12] For harvesting the cell sheet, periodontal ligament cells are placed on temperature responsive culture dishes (35 mm in diameter) at a cell density of 1×10^5 and cultured at 37°C supplemented with 50mg/mL ascorbic acid 2-phosphate, 10nM dexamethasone and 10nM ß-glycerophosphate that function as an osteo-differentiation medium.[11]

In the next step, PDL cells are cultured in a bioreactor. A hydroxyapatite (HAP) coated titanium pin is placed in a hollow plastic cylinder leaving a gap of 3mm around the pin. Through the gap culture medium is continuously pumped. Single cells suspension, obtained from human, is seeded first into plastic vessels under a flow of growth medium for 18 days.[11]

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The gene cells and protein therapy when used in the interphase of implant and periodontal ligament have been seen to help in ligament neogenesis and covers the implant surface, thereby giving rise to a new concept of oral implantology.

Precaution while preparing Liga plants

During the course of obtaining Liga plant various cell culturing techniques are implement, the prolonged cell culturing may favor the expression of non-pdl cell types. In order to preserve the cell differentiation state and to obtain adequate cell stimulation, the bioreactor are constructed to resemble the PDL situation during cell growth. Cells are positioned in a narrow space between the Liga plant and surrounding hollow cylinder, hence, it is anticipated that the PDL phenotype would be favored implicating a tight attachment of cells to the implant. So, the preparation of the Liga plants should have minute mechanical movements of the medium flow and space between the implants and the culture should be optimal. The duration of the surface treatment should also be optimal to obtain successful Liga plants.[11]

Other precautions while preparing Liga plant include-

1) Proper sterilization throughout the procedure to be maintained.

2) Proper culturing and cell growth is necessary, otherwise it may lead to the formation of non-periodontal ligament cell types.

3) Micromechanical movements of the growth medium is necessary for firm attachment of the cells to the implant.

4) Adequate duration of surface treatment must be maintained for the success of the Liga plant.[10]

Clinical importance

The periodontal ligament contains progenitor cells which maintain tissue homeostasis and the regeneration of the periodontium.

Tissues prepared in laboratory are cultivated with in vitro technique, following which they are transplanted into the body. Whereas, when all the cultivated vital elements are placed in a tissue defect and undergoes a natural healing process in the body giving rise to regeneration, it is called as in vivo technique. It induces intrinsic healing activity at the site of tissue defect using the three elements.[13]

As compared to conventional implants where one’s individual healing power was a factor in determining its success, Liga plants are a better alternative due to its aforementioned properties.

The presence of PDL cells in Liga plant distributes forces which are elicited during masticatory function and other contact movements to the alveolar process via the alveolar bone proper. Unlike conventional Osseo integrated implants where the artificial tooth is ankylosed in the bone, Liga plant gives the tooth some movement in the socket by acting as a shock absorber as well as providing proprioception. It also homes vital cells such as osteoblasts, osteoclasts, fibroblasts, cement oblasts, and most importantly undifferentiated stem cells which are osteoconductive in nature.[14]

The main entity is the presence of a periodontal ligament (PDL) to allow for a more dynamic role beyond the functionally ankylosed or Osseo integrated oral implant. 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 Osseo integrated implants.[15]

This will also help in decreasing the peri-implant diseases and provide the patient with a more natural feel along with several long-term benefits.

Properties of Liga plant

1. It allows movement of tooth in the socket by acting as a shock absorber.

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2. It also provides proprioception.

3. The PDL also has an important interaction with the adjacent bone, playing the role of the periosteum, at the bone side facing the root.

4. It contains vital cells such as osteoclasts, osteoblasts, fibroblasts, cement oblasts, cement clasts, and undifferentiated mesenchymal stem cells which are osteoconductive in nature.

5. These cells are all important in the dynamic relationship between the tooth and the bone.

6. PDL cells distributes forces, elicited during masticatory function and other contact movements to the alveolar process via the alveolar bone proper.

7. 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.[16], [14]

Advantages of Liga plants

1. It alleviates problems like gingival recession and bone defects of missing tooth site.

2. Mimics the anatomy of natural tooth roots in alveolar process.

3. Ligaplants become firmly integrated without interlocking and without direct bone contact, despite the initial fitting being loose in order to spare PDL cell cushion.

4. Amount of bone loss in peri-implantitis is reduced.

5. It resolves the problems of intrabony defects around the missing teeth.

6. Osseointegration was found around the implant surface, thereby depicting a firm communication between the two.

7. Initially after the placement of the Liga plant, it has a loose fitting so as to allow the formation of periodontal ligament around the implant surface. But later on, bone formation is induced and it attains firmness in spite of the absence of the direct bone contact.

8. Bone formation seems to be induced and movements of Liga plants inside the bone suggests an intact communication between bone and implant surface.

9. In its bone remodelling capacity (the presence of the PDL maintains/regenerate a good quality of bone).

10. The PDL offsets lateral and vertical tooth wear during the course of life.[17], [10], [15]

Disadvantages of Liga plants

1. The culturing of Liga plants should be done with caution i.e., the temperature, the cells that are used for culturing, the duration of the culturing and others.

2. The prolonged cell culturing may favour the appearance of non-PDL cell types

3. Proper maintenance of temperature, duration of culture etc. makes it a complicated procedure.

4. Due to limited facilities, the cost of this type of implant is high.

5. The factors affecting the host to accept the implant or the growth of PDL in the socket is unpredictable, which may result in failure of implant.[17], [10], [16]

Future perspectives

The notion for future research demands a combination of bioengineering techniques optimized with suitable adult stem cells as a potential candidate for the regenerative therapies allied with current dental implant design.

The future clinical utility of artificial PDL implies periodontal tissue regeneration, and thus providing an environment similar to natural teeth. A key concern has been the practical application concerning the feasibility and time consumption in the clinical setting. Ligaplants give a better long-term stability by simulating the optimal functioning of a normal human teeth with less inconvenience and discomfort. The advantages of Liga plants over conventional Osseo integrated implants can

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make them the next advancement in the field of implant dentistry.

Conclusion

In the recent era, dental implants have become ideal replacements for missing teeth. In the present scenario, most common dental implants are Osseo integrated implants. However, despite good success rates of Osseo integrated oral implants, failures do occur, which can be attributed to the bone loss due to excessive occlusal load and/or infection. 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 Osseo integrated implants.

With emerging technologies and ongoing research this far-fetched dream is now a reality with the introduction of Liga plant, which is the combination of the PDL cells with implant biomaterial.

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