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The era of future dentistry: Recent advances and future perspectives of restorative dentistry: A literature review

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Abstract
The important goal in dentistry is to provide best dental care to the patients. However, this may be attained with the help of a skilled dental professional and its team. Day by day, science is undergoing great revolutions that are leading the humanity towards a new era of dentistry. Clinicians with decades of expertise or the student of dental history can look back at the advances in dentistry and state clearly that the dental profession has experienced an exciting amount of technological growth. Yet in comparison to medicine, biomedical engineering, automotive and aeronautics, drugs, rapid manufacturing, electronics, and others, dentistry appears to be more than a decade behind in adopting or integrating new technologies on a widespread basis. This review article focuses on the various future perspectives of restorative dentistry and their clinical applications.

Keywords: nanotechnology, nano-dentistry, nano-composites, nano-ionomers, CAD-CAM

1. Introduction

In the early 1900's, dental decay was considered "gangrene" of the teeth, which mandated nothing less than extraction. This treatment approach was replaced by the extension for prevention restorative concept introduced by Dr. Black and practiced by others throughout the twentieth century as the microbiological model of dental disease took hold. Known as macro-dentistry, it promoted the complete removal of all carious tooth structure without regard for structural or biologic implications [1]. Patients throughout the world are showing an emerging interest in restorative dental materials, which enable natural teeth to be faithfully recreated with regard to their function and aesthetic appearance [2]. Nevertheless, in some situations, the destruction of tooth structure is inevitable and teeth have to be restored or replaced. As a result, dental restorations are still in demand, even today. The spectrum of dental restorations ranges from small restorations such as inlays and veneers to large restorations such as dental crowns and bridges [3].

1.1 Today's Vision: Tomorrow's Reality

We are already experiencing immense changes, and the 21st Century will excel even the immediate past for remarkable advances in the human condition. The biological and digital information revolutions are quickly converging with clinical dentistry as they are with medicine and pharmacy [2].

For example, can you think of a day your dentist will grow you a real tooth to replace one that has been lost? Prescribe medication tailored not only to your illness, but also your genetic code? Protect babies from dental decay before they even have teeth? It's not as far off as you imagine. The dental profession is at the threshold of new discoveries.

Restorative dentistry is conventionally one of the most fundamental aspects of dental treatment[5]. Developments in materials, equipment, and techniques have transformed both the art and science of restorative dentistry, and future advancements will certainly continue the evolution of this discipline. Dental amalgam, a restorative material that contains mercury, has been widely used for almost 150 years. In the past decades, the awareness and recognition of the environmental implications of mercury have increased and alternative filling materials have become increasingly more favored.

Technologies which may be practical for clinical application in the near future [3]:

- Establishment of stem cell banks which are readily accessible can make stem cell therapy a clinical probability.
- Procedures involving biological pulp implants and the respective implant storage banks.
- Mainstream tissue engineering specifically related to tissue regeneration in dentistry. This may involve cell printing and assembly on biological templates.
- Advanced and practical scaffold and growth factor delivery techniques.
- Amenable advances in biological micro scale and nano-scale technologies.

2. Nanodentistry

Rationalizing has become a current trend in the world of science and technology. Nanotechnology has made its way to become one of the most favorable technologies, and one which will change the application of materials in different fields. A nanometer is equal to one billionth of a meter or numerically expressed as 1,000,000,000th of a meter [4]. Nanotechnology is a branch of science that focuses on the study of handling matter on an atomic and molecular scale. The quality of dental biomaterials has been boosted by the emergence of nanotechnology. This technology manufactures materials with much better properties or by improving the properties of existing materials [6].

Nanotechnology is skillful engineering on a scale of less than 100 nm to accomplish desired design, functions and performance of end products. It engages the characterization and supervision of materials at the atomic or molecular level. At nano-scale, physical, chemical and biological properties are different from the properties at an individual atomic/molecular level and bulk matter. There are mainly four types of materials (metals, polymers, ceramics and composites). Nano-materials have been developed in all these four categories for practical applications in health care [6].

No synthetic material can be brilliant enough to respond to external stimuli and react like nature made tissues. There are mainly two key approaches (top down and bottom up) in nanotechnology for creating smaller or better materials and use of smaller constituent into more complex assembling. Top-down approach is based on solid-state processing of materials. Classic examples of top down processes are milling, machining and lithography. The “top-down” approaches like chemical vapor deposition (CVD), monolithic processing, wet and plasma etching are used to fabricate functional structures at micro and nano-scales. The “bottom-up” approach implicate the fabrication of materials via edifice up particles by harvesting atomic elements. Bottom-up processing is based on highly organized chemical synthesis and growth of materials. The perfect example of this approach is present in nature. Example, repairing of cells, tissues or organ systems and protein synthesis as well [6].

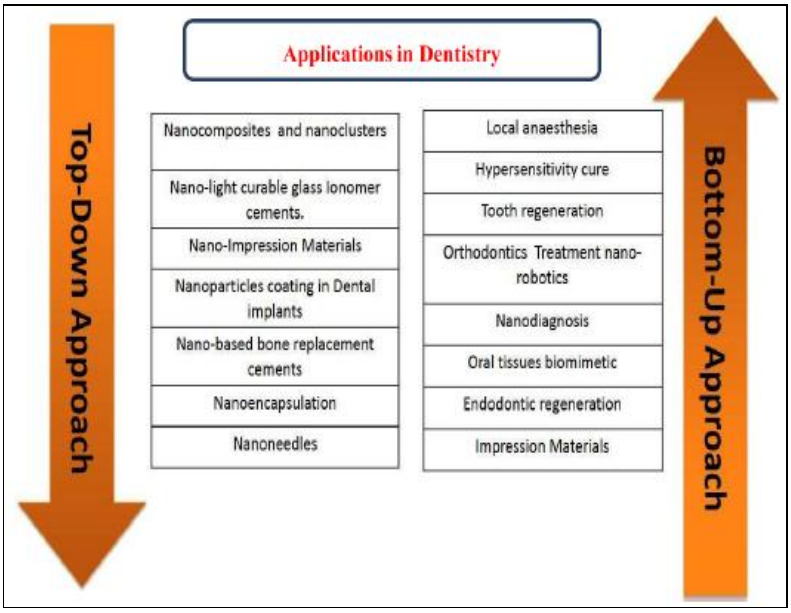

Fig 1: Applications of nanotechnology in dentistry

Current dental research involves gradual ingress into the preventive, diagnostic, reconstructive, regenerative, restorative, and rehabilitative domains. Near-perfect oral health will be possible through the aid of nano-robotics, nano-materials and biotechnology. A colloidal suspension carrying millions of anesthetic dental nano-robots would be able to induce local anesthesia before starting the dental treatment. The nano-robots get deposited on the gingival tissue. The dentist guide these nano-robots by moving toward the pulp via the dentinal tubules using nano-computer through the chemical differentials, temperature gradients, and positional steering and assist them to reach the dentin. As soon as they reach the pulp, the analgesic robots close down all sensation in the tooth. After the completion of the treatment procedure, the nano-robots may be ordered to re-establish all sensations and to exit from the tooth. This technique is advantageous as it is fast and totally reversible. Rapid and stable treatment for dentin hypersensitivity is possible by using dental Nano-robots, using local organic materials.

Toothpastes or mouthwashes containing the dentifrobots would inspect all gingival surfaces regularly and break down harmful materials and remove them [7].

Mouthwashes containing nanoparticles loaded with triclosan and silver nanoparticles have demonstrated plaque control potential and have shown high substantitvity due to the use of bio-adhesive polymers These nanocrystals also reduce implant surface roughness by depositing hydroxyapatite into the streaks present on the titanium surface and prevents plaque accumulation and peri-implant pathologies. Materials like Sapphire or diamond as part of a nanostructured composite are highly stronger than enamel and so can be used as tooth superficial enamel layer.

Nano-composite denture teeth made of Polymethylmethacrylate (PMMA) are nano fillers that are homogeneously distributed with excellent polishing ability, stain-resistant, have surface hardness with enhanced wear resistance and are superb aesthetics [8].

Current research is now focusing on reducing the polymerization shrinking. Carbon nanotubes have remarkable and exceptional mechanical properties as well as unique bioactivity. Reinforcing dental composite with carbon nano-tubes might facilitate to reduce such defects and provoke the advantages gained by excellent mechanical and biological characteristics [9].

Fig 2: Esthetic applications of resin nanocomposite restorative materials

Aesthetic applications of resin nanocomposite restorative materials

Suture needles are manufactured from Nano-structured stainless steel crystals. Cell surgery is made viable using Nano-tweezers. Dentition re-naturalization technique may revolutionarize cosmetic dentistry [10].

2.1 Nano Glass Ionomers (Nano-Ionomers)

More recently, nanotechnologies have been applied to the resin modified glass ionomers in the form of nanoparticles (Nanomers) and nanoclusters in fluoroaluminosilicate (FAS) glass. These nano-ionomers (Ketac™ Nano; 3M ESPE) have been available for clinical use since then [11]. The addition of nanoparticles resulted in the aesthetic improvement of the final restoration and polishablilty. It is important to mention that fluoride release property is not affected by the addition of nanoparticles due to its high surface area. The incorporation of resulted in higher mechanical values. The nano-filler components of nano ionomers also intensify some physical properties of the hardened restorative. Its bonding mechanism should be associated to micro mechanical interlocking provided by the surface roughness, most likely combined with chemical interaction through its acrylic/itaconic acid copolymers. Nano light-curing glass ionomer restorative blends nanotechnology originally developed for Filtek™ Supreme Universal Restorative with fluoraluminosilicate (FAS) [12].

The result of additives such as nanoscale hydroxyapatite (HA) and fluoroapatite (FA) on properties of glass ionomers is a hot topic. The bond strength was raised with addition of micro HA (5–10 μm) and whereas Nano-HA (100-150 nm) further improved the bond strength. Modification of existing glass ionomers using nano-materials is an active area of current research [6].

2.2 Endodontic Sealer

The applications of nanotechnology are not defined to filling materials but have been extended to endodontic applications. A bioceramic based nanomaterials (Endo Sequence BC sealer) containing calcium silicate, calcium phosphate, calcium hydroxide, zirconia and a thickening agent, has been developed recently. Nanoparticles have improved the handling and physical properties. Nano sized particles facilitate delivery of material from 0.012 capillary needle and adopt to irregular dentin surfaces. It sets hard in a matter of a few hours providing excellent seal and dimensional stability. Upon setting, it forms of hydroxyapatite; providing biocompatible and bioactivity [7].

2.3 Lose a tooth - grow a tooth

The applications of nanoscale scaffold materials for tooth tissue regeneration area are well established. For pulp regeneration, pulp stem cells were refined within the laboratory and grown in sheets on scaffolds. The scaffolds used were composed of nano-fibers of perishable collagen type I or fibronectin. Natural silk based mostly nanomaterials are getting used for varied tissue regeneration applications and have promising scope for dental applications. Collagen type I is the most plethoric fibrous protein found within the form of nano-fibers in dentin (~80%–90% of organic matrix) and bone. The tissue regeneration approached are not in sensible implementation at present, however more analysis is anticipated to beat the challenges to fancy tissue engineering products on market for clinical applications in near future.

Researchers have found that by shining a laser light directly into the remaining pulp, it can stimulate the stem cells within the pulp to begin producing new dentin. While the tooth would still need a cap to protect the delicate interior, the material inside the tooth would be natural, not manmade. This breakthrough would not only allow the body to begin repairing a process – severe tooth decay – that it could not before, it would also make teeth far more resilient than what current technology makes possible [13].

2.4 Amalgam restorations and future perspectives

Although adhesive dentistry and aesthetic restorative materials have had Important development, choosing the ideal material to restore dental structures is still controversy. Despite the long history and popularity of dental amalgam as a restorative material, there have been periodic concerns regarding the potential adverse health effects arising from exposure to mercury in amalgam. For that reason, yet as its progressively reduced use in daily practice due to patients' aesthetical demands, the amalgam has been showing within the context of public health services, which has raised some discussion concerning the indication of it and also its prolonged presence in academic teaching [14].

The United Nations Environment Programme (UNEP) has ceased discussions concerning an international agreement called the Minamata Convention on Mercury aiming to reduce significant environmental impacts on health caused by air pollution and mercury emissions and together with provisions that deal with several products containing that chemical element. Some of them will be banned as of 2020. Amalgam restorations haven't been prohibited, however the agreement provides for the gradual decrease in the use of that material without prohibitive measures or deadlines for ban.

Because dental amalgam is not one of the major contributors to mercury emissions into the air, if amalgam waste is considerably reduced with the best practices of waste management, it actually does not and will not contribute to world demand and/or pollution estimates attributed to the three kinds of mercury. Furthermore, the researchers failed to correlate amalgam restorations with adverse health effects and that they failed to show a legitimate link between amalgam in the oral cavity and systemic disease. Thus, with the necessary caution, sagacity and within the knowledge and based on supported studies, the teaching and use of dental amalgam may continue in clinical cases in which aesthetics is not the predominant factor.

2.5 Adhesive Dentistry

The increasing demand for aesthetic restorations by today's society has rendered adhesive systems essential in dental practice. Their various clinical functions and applicability make them a fundamental part of restoration therapy. No matter what the aim of the adhesive procedure, the systems are, by definition, "the materials responsible. for promoting a bond between the dental substrates and the restoration, thus acting as an intermediate material. The major challenge of these systems lies in providing appropriate bonding to the different tissues as these have very different compositions. If, on the one hand, the bonding to enamel can be satisfactorily achieved using the acid-etch technique, on the other hand, bonding to dentin is more complicated due to its tubular structure being humid; the properties of permeability and also the organic composition of its substrate [14].

Contemporary dentistry has firm foundations in the adhesive process which enables the bonding of artificial materials to the hard tissue of teeth. In restorative procedures, this biomechanical behavior is of the utmost importance to the creation of final structures that behave in a similar way to intact teeth. The creation of an interface between the tooth and the restorative material, described in the literature as a hybrid zone or layer, is The advances made in adhesive system research have sought to simplify as much as possible the clinical steps which could be influenced by the operator. Over the years, simplified systems have emerged to address this need. Another positive for the development of these systems has been the reduction in the procedure's clinical time. Thus the procedure carried out in three steps was reduced to two steps, followed by a further reduction, to just one step, and recently composite resins have made possible through the modification of the structure of tissue that makes up the dental element and their impregnation by means of resinous materials. Future perspectives include studies into the complete removal of water through the use of ethanol, the search for new substances that can inactivate the enzymes released in the adhesive process and the action of agents that act upon the demineralized dentin matrix by affording it better mechanical properties and longevity. There is a need for longitudinal clinical studies, rarely found in the existing literature, to confirm these procedures.

2.6 Dental Sculpture

CAD/CAM for dental manufacturing is growing at a fast pace. The laboratory profession discovered timely on what clinicians are slower to recognize-CAD/CAM works. It is quicker, more economical, predictable, consistent, and as correct as laboratory restorations, all with a high come back on investment. The development of computer-aided design and computer-aided machining method for the fabrication of inlays, onlays, crowns, and bridges has led us to the development of next generation of machinable ceramic restorations that can be delivered to the patient in a single appointment since these are made chair-side [5].

Merits of CAD/CAM technology

1. Designs, fabricates and places all ceramic restoration in a single patient visit
2. Restorations have demonstrated excellent fit, strength and longevity
3. Using CAD/CAM technology, a number of steps are simplified
4. The hassle of conventional impression, soft-tissue retraction and hemostasis for accurate record is eliminated

The systems for CAD-CAM restorations are cerec, celay, procera, cercon, lava, turbodent, DCS President, E4D Dentist

The marginal opening is the most important factor in enhancing the reliability of newly developed CAD/CAM systems. Milling is a crucial step to produce accurate restorations using CAD/CAM. Five axis milling devices showed highest accuracy as compared to four axis devices [5].

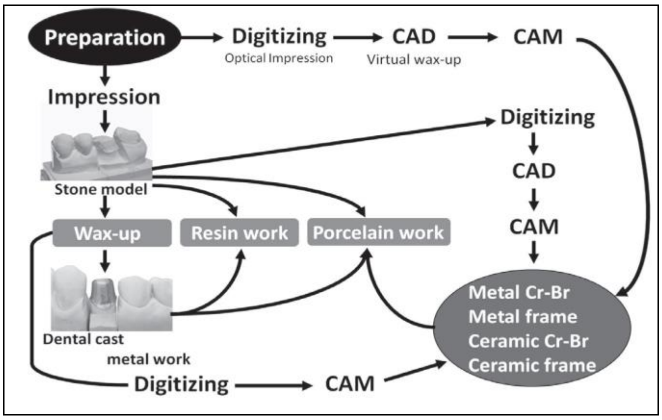

Fig 3: Current dental CAD/CAM systems for the fabrication of crown- bridge restorations

Current dental Cad/Cam systems using for the fabrication of crown- bridge restorations

When taking an impression using a conventional impression material in cases in which the marginal line cannot be seen directly because the marginal gingiva is overhanging, the shape of the marginal line can be transcribed. However, a shape cannot be measured by an intraoral scanner if it is not directly visible. If this problem can be solved, we may be completely free from impression taking of crowns and bridges as we are currently doing. In the currently available CAD / CAM systems, shape design by the CAD is done in a static state without considering contact sliding movements of the upper and lower teeth, and technicians perform manual adjustments to the model after milling with the CAM. Even in the more advanced CAD system, a virtual articulator is implemented into CAD software to simulate a conventional semi-regulating articulator. It is therefore impossible to design an optimal functional occlusal surface configuration for each individual patient. Therefore, if shape measurement by an intraoral scanner can be performed at ultrahigh speed, a series of states in which the upper and lower teeth slide in contact can be regarded as a record of the positional relationship between the upper and lower jaws, and the occlusal contact state of each patient can be simulated by a CAD system without a virtual articulator. It is expected that newly developed CAD software in the future will enable almost automatic design of an optimal occlusal surface form for each patient [5].

2.7 The power of stem cells

As bioengineered tooth crown formation requires the interactions of both dental epithelial cell progenitors and mesenchymal cell progenitors (as in natural tooth formation), the ability to bioengineer a tooth of specified size and shape can rely upon the ability first to identify, and then guide, the interactions of both types of cells. Methods to guide the interactions of epithelial and mesenchymal post-natal dental stem cells to form dentine and enamel layers characteristic of natural teeth requires modified scaffold materials and designs.
New research suggests that medications designed to stimulate cells can activate mechanisms that cause teeth to actually repair themselves. Research has found that certain types of drugs can actually stimulate stem cells within the dental pulp – the soft material that comprises the center of our teeth that's filled with blood vessels and nerves – into regrowing enough dentin (bony tissue) to fill a cavity [15].
Yen and Sharpe advised two techniques for tooth regeneration; the first of which involved growing dissociated tooth germs on a tooth-shaped scaffold lead to tiny, complex, tooth-like structures. The second method enclosed growing epithelial and mesenchymal (stem) cells, either from tooth germs or other sources, in organ culture and, through epithelial-mesenchymal interactions, forming organized teeth. Although many challenges stay, stem cell-based tissue engineering of teeth could be an option for the replacement of missing teeth in the future. A therapeutic choice that was impossible a few years ago seems an achievable goal today
Researchers have especially high hopes for Tideglusib, an experimental drug that has both an exceptional safety record and is remarkably cheap. The dentin produced by stimulating Tideglusib has the ability to completely integrate itself with the existing tooth enamel. This means that unlike a filling, the tooth isn't simply patched up, but regrown to restore it back to health. Currently, the research into the potential uses for Tideglusib has only been conducted using rats, but researchers believe that human trials could start by the end of the year [15].

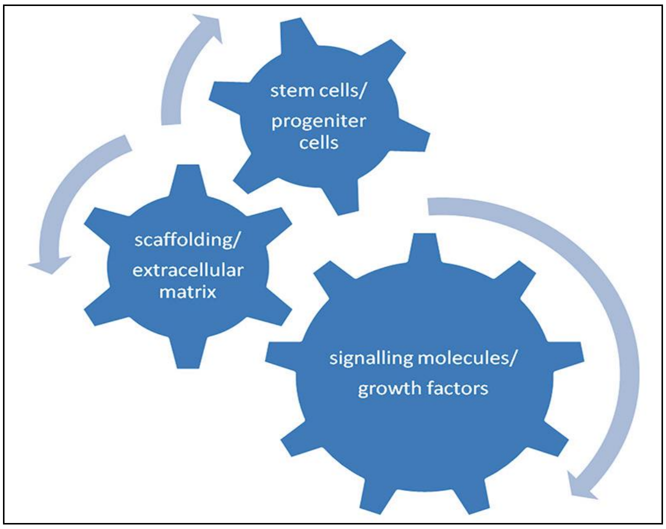

Fig 4: Tissue engineering

Tissue engineering

We have moved on from the surgical model to the medical model and are likely to move on to the biological model of care with stem cells. Regeneration of the dental tissues provides an attractive alternative to more traditional restorative approaches because the diseased tissue is replaced by natural tissue, which forms an integral part of the tooth. We clearly have an opportunity to move restorative dentistry to a new era, harnessing the biological activity of stem cells and tissue regeneration, but there is still a need to translate research into clinical realities [16].
One of the greatest challenges of this technique is that stem cells need to be stimulated in the right way so that it produces the right balance of hard tissue, dentin and enamel.

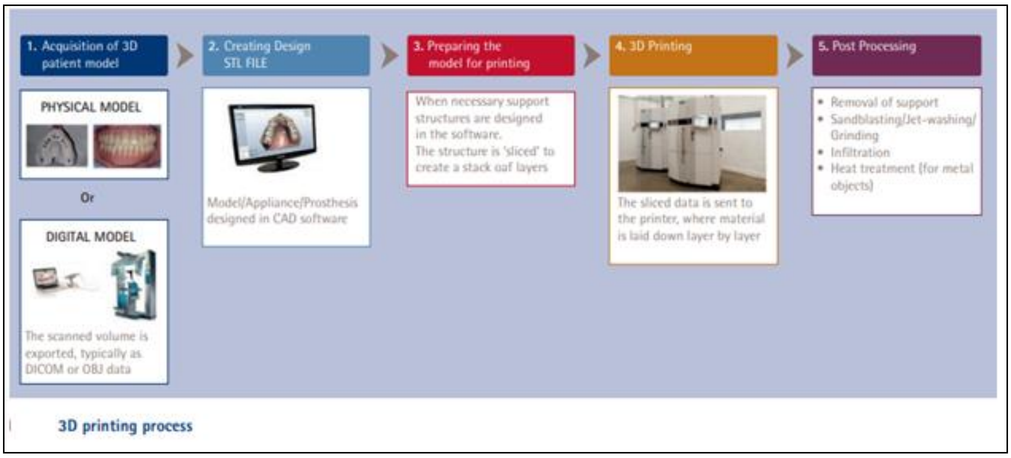

Fig 5: 3-D printing process

2.8 3-D Printed Teeth

3-D printing has provided several breakthroughs for the health profession however the advantages seen in medical specialty are going to be immeasurable. One example of those advantages is that the method of dental crowns. The current method involves taking a cast, making a temporary crown, and sending off the cast to a lab for the production of the permanent crown. In the future 3-D printing can expedite this process. By using 3-D printing technology, dentists may be able to assign the dental crown process. This would hopefully mean that crowns could be manufactured more quickly and maybe less expensively [17].
The trend towards the use of intraoral scanners implies that dentists need 3D printing so as to form a physical model of the scanned jaw. Although today, it is not always strictly necessary to print a master model at all, the 3D printed master model may be used for conventional aspects of the fabrication of a restoration, such as adding a veneering material, and we

are accustomed to seeing restorations displayed on a model – even if they have been directly fabricated digitally. Patient model information is also digitally archived, and only printed when required, easing storage needs.

3D imaging and modeling, and CAD technologies are hugely impacting on all aspects of dentistry. 3D printing makes it possible to accurately make one-off, complex geometrical forms from this digital data, in a variety of materials, locally or in industrial centers. Even now, everything we make for our patients can be made by a 3D printer, but no single technology is sufficient for all our patient's needs. The technology is already widely employed in orthodontics, where high-resolution printing in resin is already an entirely practical proposition, and similar technology is being used to print models for restorative dentistry and patterns for the lost wax process which is becoming increasingly important with the rise of intraoral scanning systems. Although 3D printers are becoming more affordable, the cost of running, materials, maintenance, and the need for skilled operators must also be carefully considered, as well as the need for post-processing and adherence to strict health and safety protocols. Despite these issues it is clear that 3D printing will have an increasingly important role to play in dentistry. The congruence of scanning, visualization, CAD, milling and 3D printing technologies, along with the professions innate curiosity and creativity makes this an surprisingly exciting time to be in dentistry.

3. Conclusion

The next generation of regenerative treatment techniques may involve the synthesis and assembly of bio proteins by the nano-robots. Where, these entities are simply injected to the desired location, and they weave up the collagen framework onto which the proteins are assembled, also are the possibilities where dental tissues are grown to specific requirements and transplanted on a regular basis. The possibilities are infinite and coveting. These ground breaking strategies may provide an innovative and novel biology-based new generation of clinical treatments for dental disease[3]. "No one can know for certain what the future of dentistry will hold. I think we will see an integration of dentistry into comprehensive health care and an increased focus on the link between oral health and overall health as we enter the 21st century. Computer-assisted technology for diagnosis and treatment, and gene-mediated therapeutics, which alters the genetic structure of teeth to make them impervious to decay, will likely play an important role in the future of dentistry.

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