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The Future for Clinical Dentistry

CE RENSON*, BDS, PhD, FFGDP(UK), DDPH, LDS RCS, FICD

ABSTRACT **Purpose:** The purpose of this review is to anticipate, as far as possible, the changes that will be experienced by dental practitioners in their day-to-day work in dental practice in the years ahead. **Method:** A review of the literature and of events of the past decade or so leads to the following conclusions. **Conclusions:** The years ahead will see important changes in patient empowerment. The word of the clinician is no longer treated with the deference of times past. Patients are asking questions and expecting informed answers. The management of elderly patients, in particular, will take up more of dental practitioners' time, as their proportion of the population increases. Other major changes affecting clinical dentistry will be stimulated by a search for an evidence base for our treatment of dental caries and periodontal disease, by advances in material science, by information technology (IT) and by advances in the new science of genomics. Equipment and techniques, which have been recently introduced and are presently used by relatively few, will be used by many during the next decade.

Introduction

The invitation to write this inaugural paper for the first issue of the Hong Kong Dental Journal has served to remind me of the last time I published an article in a Hong Kong Dental Association publication. In 1996 I was asked to write on *Current Trends in Clinical Dental Practice*. In that paper I reviewed almost one hundred papers which appeared to point authoritatively to trends that would affect the way that clinical dentistry would be practised in the future. Significant amongst those trends was an important attitudinal change affecting both patients and practitioners in relation to aesthetic and cosmetic dentistry. Additionally, I proposed that tooth tissue loss, caused neither by caries nor trauma but by dietary erosion caused largely, but not exclusively, by carbonated drinks would also occupy the time of practitioners more in the coming years. Implants would be used increasingly. I suggested that laser technology, air-abrasive technology, digital imaging radiographic systems, computer-aided design/computer-aided manufacture (CAD/CAM), and computer-assisted learning (CAL) would all play an increasing role in clinical dentistry. It is for you, the readers, to say to what extent my prognostications of seven years ago have been proved correct [1].

On this occasion the title that I have been asked to write to is *The Future for Clinical Dentistry* and I have interpreted that as a request to look more deeply into the years ahead and to prophecy what fundamental changes may lie ahead for dental practitioners. Some of those changes will involve, I believe, developments of materials and techniques already in use but some will involve techniques which many practitioners will find less than credible.

It would be manifestly absurd to attempt to cover the entire panoply of clinical dentistry in a single article. I will attempt to cover those aspects which, taken together, would engage the attention of the dental practitioner for much of his working day: the administration of his practice, planning and carrying out treatment for patients requiring restorative work, including periodontal care, the choosing of appropriate materials and techniques and finally a look at where research may be taking us in the rather more remote future.

Patient Empowerment and the Information Revolution

The years ahead will see important changes in patient empowerment. The word of the clinician is no longer treated with the deference of times past. Patients are asking questions and expecting informed answers [2, 3]. The management of elderly patients, in particular, will take up more of dental practitioners' time as their proportion of the population increases [4, 5].

Other major changes affecting clinical dentistry will

* Emeritus Professor of Conservative Dentistry, University of Hong Kong
Consulting Editor, Primary DENTAL CARE, Journal of the Faculty of General Dental Practitioners (UK), Royal College of Surgeons of England

Correspondence:
Professor CE Renson
El Ravanell 19,
Altea la Vieja 03599,
Alicante, Spain.
Tel : (34) 965848038
Fax : (34) 965848341
e-mail : renson@ctv.es

be stimulated by a search for an evidence base for our treatment of dental caries and periodontal disease, by advances in materials sciences, by information technology (IT) and finally by advances in the new science of genomics.

Equipment and techniques, which have been recently introduced and are presently used by relatively few, will be used by many during the next decade [6]. As an example of this type of change Monckton [7] found that between 1992 and 1997 the proportion of NHS dental practices in England and Wales which had computer facilities rose from 22% to 59%, the proportion generally accepted in the UK now is seventy per cent.

To date the influence of computers has been mainly in practice administration, record-keeping and, to an extent, on continuing professional education [8, 9]. Inevitably, primary dental care (PDC), like all other clinical disciplines, will increasingly use faster personal computers. The Internet will increase patient awareness and aid education and disease prevention. Clinicians will increasingly act more as guides to information sources about prevention and healthcare and less as a prime source of information. Lifelong learning or continuing professional development will be a must for all clinicians [10-12], not only to remain abreast of developments but also to stay level with their patients! There is already a determination that learning (and teaching) should be evidence-based and there will be an increasing emphasis on this prerequisite to clinical care with the passage of time [2].

Diagnosis and Treatment Planning

Increasing use of digital radiographs [13], laser technology and three-dimensional imaging will improve caries diagnosis [14, 15]. Storage of radiographs and three-dimensional views of study casts will be increasingly by electronic means. Clinical records will be created and maintained by voice-controlled computers. A computerised periodontal probe was first described fifteen years ago [16] and this will be commonly used in PDC.

A recent paper [17] comparing expert clinicians' assessments of periodontal disease risk versus a computerised tool, the Periodontal Risk Calculator (PRC) illustrates the value of this type of computer application. Risk scores determined using the PRC are accurate and valid predictors of future periodontal deterioration, as measured by actual alveolar bone loss and tooth loss over a period of 15 years [18]. The authors' observations suggest that use of risk scores generated for individual patients by *subjective* expert clinician opinion could result in inappropriate treatment for some patients and they support the use of an *objective* tool such as PRC. Dental practitioners will need the skills to access databases electronically to keep updated and to ensure that their treatments are evidence-based. Knowledge-based systems are already available and others are being developed [19, 20]

Developments in Periodontology

The past decade or so has borne witness to the most radical rethinking in much of clinical dentistry, none more so than in Periodontology. Advances in periodontal science and practice have radically changed the understanding of periodontal diseases and have opened new prospects for their treatment. The establishment of the aetiology and pathogenesis of periodontitis and subsequent understanding of the genetic and environmental susceptibility profile of affected subjects, and the recognition of the systemic implications of periodontal infections are the key research findings [21]. The use of randomised, controlled, clinical trials has provided a long awaited evidence base for periodontal treatment. Adjunctive antimicrobial therapy, regenerative periodontal surgery, periodontal plastic surgery, bone regeneration in the light of implant treatment, and soft tissue management at implant sites have radically changed clinical practice.

Today, periodontitis is considered to be an infection caused by a relatively small number of specific micro-organisms: *Porpbyromonas Gingivalis, Bacteroides forsythus (Tannerella forsythensis)* and *Actinobacillus actinomycetemcomitans* are the aetiologic agents of the most common forms of periodontitis [22-25].

Also of clinical relevance is the finding that severe periodontitis occurs in a subgroup of predisposed individuals rather than the whole population. This shift from a concept of universal susceptibility toward a concept of high-risk groups has led to the identification of characteristics associated with increased susceptibility [26, 27]. Today there is little doubt that smoking, systemic conditions and medications play a key role in an individual's susceptibility to periodontal disease [28-30]. It has also been established that a genetic component exists which regulates the inflammatory response and which affects severity of the disease and a lack of treatment response [31-33]. This has led to the concept that the infecting periodontal pathogens are able to cause clinically relevant periodontitis in susceptible individuals, and that this individual susceptibility is the result of the interplay between genes and environment.

Systemic effects of periodontal disease

Another key finding has been the discovery that periodontal infections may have systemic implications. Studies have demonstrated that severe periodontitis patients have alterations in some haematological parameters and in particular an increase in serum acute phase reactants. These changes are considered to be an indication of the fact that infection and inflammation of the periodontium have the potential to affect other organs and systems. Over the past ten years, a body of evidence has accumulated to suggest that aspects of oral health, particularly the extent and severity of periodontal disease, may be associated with an increased risk of coronary heart disease (CHD). This evidence should be seen against the background of a more general interest in the role of chronic infections in vascular disease. There have, for example, been suggestions of associations between CHD and a range of bacterial and viral agents, including *H. pylori, C. pneumoniae,* and *cytomegalovirus*, which are involved in persistent infections at various sites around the body. Reviews of the evidence for the causality of these relationships between CHD and specific organisms have been inconclusive [34]. However, a series of large-scale investigations has associated severe periodontitis with an increased risk for mortality, cardiovascular diseases, cerebrovascular diseases, pulmonary diseases and birth of premature low-weight babies [35-37].

Sequential treatment phases

The treatment of periodontitis has been radically modified by evidence gathered in randomised controlled clinical trials run over the last decade. The concept of an escalation of sequential treatment phases spanning from an initial, aetiologic or cause-related phase, to a surgical or corrective phase, and leading to a maintenance, recall or supportive care phase has been expanded by several key findings.

Despite the achievement of adequate oral hygiene, not all patients and sites seem to respond equally well to the delivered therapy [38]. This seems to be associated with subject characteristics such as smoking, genetic susceptibility, and concomitant systemic disease. Control of these acquired factors should now become an integral part of periodontal practice. Information management has become the key to periodontal treatment planning.

The use of systemic antibiotics in combination with removal of plaque biofilms by mechanical means has proven to be a significant tool for the suppression of specific components of the microflora such as *Actinobacillus actinomycetemcomitans* from the oral cavity of early onset periodontitis subjects infected with this bacterium [39]. The potential for antibiotic resistance, however, limits the application of some of the antimicrobial regimens to a few well-selected cases.

In the last decade there has been enormous progress in the discovery of the mechanisms leading to the reconstruction/regeneration of the periodontal tissues destroyed by the infectious process. New treatment approaches based on this new knowledge are reaching the stage of clinical application: biological molecular agents such as growth and/or differentiation factors have displayed considerable potential for the modulation of the periodontal wound-healing process to result in new cementum, periodontal ligament and bone formation. In parallel with these efforts, more traditional reconstructive/regenerative technologies, such as guided tissue regeneration and bone grafting have been extensively studied. Today predictable results from this type of treatment may be offered.

Surgical periodontal treatment

Advances and refinements in the surgical manipulation of gingival tissues, including the introduction of periodontal microsurgery, have opened new avenues in the management of soft tissue deformities of the gingiva. Aesthetically disturbing recessions associated with tooth malposition and/or toothbrushing can be predictably treated [40]. Likewise, excessive display of gingival tissue can be improved with careful resective approaches to obtain a more natural balance between the white (tooth) and the pink (gingiva) aesthetics. These abilities to manipulate the apico-coronal position of the gingival margin, along with the colour, thickness and texture of the gingival tissues, sometimes in combination with conventional restorative dentistry, have developed a new, increasingly important area of aesthetic dentistry. The ability to stimulate autogenous tissue growth will enhance a patient's recovery after periodontal therapy. The dentist, armed with the capacity to stimulate patient-specific regeneration of loss alveolar bone, gingival tissue and cementum will be able to restore an optimal level of periodontal health [41-43]. This type of tissue engineering will have a considerable effect on dental practice (see also under Genomics and Restorative Dentistry).

Developments in Dental Materials and Clinical Techniques

While it is true that dental amalgam is no longer a first choice for many practitioners or for many patients this economical material will continue to be used because of its cheapness, its adaptability and durability when properly applied. The relatively recent arrival of bifunctional primers such as 4-META and MDP, which enable bonding to be achieved between amalgam and tooth tissue, have ensured its continued use for some years to come. Bonding forms an immediate seal at the interface between restoration and tooth and prevents the percolation of saliva, bacteria and food thus obviating a secondary caries attack [44].

Concerns regarding mercury toxicity have led to the development both of mercury-free condensable silver-based and gallium-based materials. There are difficulties associated with the mercury-free silver-based condensable materials since although their mechanical properties are comparable with amalgam, they harden too slowly for clinical use. Gallium-based alloys are in clinical use but their results are inconsistent and exposure to water during setting produces clinically unacceptable expansion and poor corrosion resistance [45].

Composites

Composites have the disadvantage of polymerisation shrinkage and the shrinkage can stress dentine-bonding agents to failure, with associated percolation problems. Further, long-term exposure to moisture can soften the polymeric matrix and break down the silane bond which links the inert ceramic filler to the polymer. Both result in loss of filler that manifests as excessive wear.

The introduction of flowable composite resin is relatively new. These resins have lower viscosity due to less filler and they have been recommended for low stress-bearing restorations such as class V cavities. Examples of these resins include *Revolution (Kerr), Flow-it (Jeneric/Pentron) and FloRestore (Denmat)*. Their advantages include reduced moduli of elasticity and therefore improved stress dissipation, ease of manipulation, and polishability. The reported disadvantages are lower strength, lower fracture toughness and lower wear resistance. Manipulation difficulties due to "stickiness" on condensation in comparison with conventional composite resins is also a problem [46].

Recent innovations also include the composite resin *Artglass (Kulzer)*, primarily designed as a replacement material for porcelain in ceramo-metal crowns. *Artglass* is made up of a combination of conventional dimethacrylate monomers and new multifunctional methacrylate monomers which, on curing, produces an increase in the degree of monomer conversion and polymer cross-linked density [46]. Manufacturers have claimed improved fracture toughness due to decreased stiffness and improved resilience. Long-term clinical studies are needed to evaluate this.

The *Ormocer* (Organically Modified Ceramic) is a recently developed tooth-coloured filling material for use both in anterior and posterior sites, and has been proposed as an alternative to amalgam (e.g. *Definate, Degussa)*. Instead of a dimethacrylate-based matrix - as found in traditional composite resins and compomers - the matrix of the *Ormocer* is a ceramic polysiloxane. The manufacturers claim reduced polymerisation shrinkage, improved fluoride leaching, and better abrasion resistance and biocompatibility compared to traditional composite resins and compomers. However, long-term data regarding longevity are awaited [46].

Glass ionomers

The bonding ability and the fluoride-releasing ability of glass ionomers plus the improved appearance when compared with amalgam are properties that have served to retain a place for glass ionomers in the restorative materials armamentarium. However, the premature dissolution and wear of these materials have made them less popular over the years.

The active components of glass ionomers consist of an acid-soluble glass and a reactive polyacid. On mixing, the acid displaces metallic ions such as aluminium and calcium from the glass, together with fluoride ions. The cements set when the metallic ions cross-link the polyacid chains. In most contemporary cements these acids are polymers with simple active carboxylate groups and this simplicity limits their properties. Developments over the past few years have been aimed at improving their properties by changing the chemistry of the acids [44].

One approach has been to introduce phosphorous into the system in the form of poly(vinyl phosphonic acid). This has resulted in adhesive cements with a good resistance to early solubility (as in the *'Diamond'* system). Another has been to incorporate vinyl groups onto the acid. The vinyl (C=C) groups are similar to those found in all composite resins and, like the composites, in the presence of suitable initiating chemicals, exposure to blue light causes the vinyl groups to open and form cross-links. The setting of the cement is thus accelerated. These light-cured cements are more correctly known as 'resin-modified glass ionomers', and not only do they set more rapidly, but they resist early dissolution and possess greater resistance to in *vivo* wear. It is important to note that they contain water as one of their basic components, and when they are first mixed they form the same sort of chemical bonds to apatite as do conventional glass ionomer cements [47]. This is not the case for the materials known as the 'compomers' (more correctly known as 'polyacidmodified composites') which also use this technology. However, they contain no water and thus have to be bonded to tooth via a dentine-bonding agent prior to being light-cured. Once set, water slowly diffuses into these materials and further cross-linking of the polymeric chains formed by the light-curing reaction takes place via metallic ions released by the acid from the glass. However, this appears to have little effect on their properties other than allowing the release of fluoride ions [48].

Ceramics

Dental ceramics have many desirable qualities which include favourable aesthetics and biocompatibility, and many new ceramic materials and techniques have been introduced in recent years. These include high strength cores (e.g. *In-Ceram (Vita), Procera-Allceram (Nobel Biocare), Techceram (Techceram Ltd.),* heat pressed glass ceramic (e.g. *Empress, Ivoclar Vivadent*) and milled and CAD-CAM systems (e.g. *Celay* (*Celay Mikrona Technologie*), *Cerec (Siemens), DentiCAD (Bego), Dux (DCS Dental*) and *Sopha (Duret))* [46].

Until recently all-ceramic restorations have been used only in anterior sites where the aesthetics are demanding and they have not been sufficiently strong for use in posterior load-bearing areas. Recent development of stronger ceramics and better luting techniques, have resulted in all-ceramic restorations becoming realistic alternatives to ceramo-metal castings in posterior load-bearing areas. *Procera-Allceram* is an innovative ceramic, first described by Andersson and Oden in 1993 [49], which consists of a high strength densely sintered alumina core veneered with porcelain. The construction process involves making an impression of a prepared tooth and constructing a die which is then scanned to allow remote CAD-CAM construction of a densely sintered alumina core. This is then returned to the laboratory for the conventional porcelain build-up of the final crown. The aesthetics and the flexural strength associated with *the Procera-Allceram* system appear better than previous high strength core systems which have tended to have a high reflective value, difficult to mask with veneer porcelain [50].

The number of commercially available CAD-CAM systems continues to increase but the marginal fit of the final restorations remains a problem area [46, 51]. The *Cerec* system (*Siemens, Bensheim, Germany*) is an established CAD-CAM system which has undergone many improvements including new software, conversion to an electric turbine for better cutting control and improved ceramic blocks [52].

Other ceramics applications

Other developments in the application of ceramics include the development of the dentine-bonded crown, a conservative preparation technique recommended for minimally restored teeth requiring more extensive coverage than a labial veneer. The minimal preparation required is particularly suited to patients with microdontia (e.g. peg-shaped lateral incisors). Some difficulties may arise when trying to remove undercuts in more bulbous teeth with a minimal preparation. One of the major advantages of this technique is an aesthetic transition from porcelain to natural tooth structure. On the other hand, if the underlying tooth structure is significantly discoloured, this technique may be inappropriate.

Etching and silane treatment of ceramic are necessary to produce a durable ceramic-tooth bond. The high alumina cores of the *In-Ceram* and *Procera-AllCeram* systems cannot be acid etched due to their low silica content, and do not easily form silane bonds. It has therefore been recommended that their fit surface is sandblasted [46]. The silane-bonding agent may act as a wetting agent and is therefore still considered beneficial. Remaining enamel and dentine are etched and the dentine bonded before cementation with either a chemically cured or dual-cured composite resin-luting agent. The fracture resistance of dentine-bonded crowns may be enhanced by combining particular ceramics with luting agents [53].

CAD-CAM technology has also been used to produce titanium substructures for ceramo-titanium crowns and bridges. The external contours are milled and the fit surface is created by a spark erosion process. Individual components of the bridge are then laser-welded before final veneering with special porcelain. This technique eliminates the need for difficult casting procedures associated with the low density and poor thermal conductivity of titanium. The bond between titanium and porcelain may be an area of weakness and roughening of the titanium surface is also a potential problem [46].

Emerging Techniques used in Cavity Preparation

There is a range of innovative options for caries management that have so far failed to achieve wide acceptance.

The Atraumatic Restorative Treatment (ART)

The ART approach involves the removal of carious tooth tissue with hand instruments, followed by the restoration with an adhesive restorative material e.g. glass ionomer. This technique is particularly suited to areas where dental equipment is unsophisticated and/or not dependent on an electricity supply and has been used in Africa, Thailand, and China [54]. The ART technique was recently reviewed by Smales and Yip [55] who found problems with the high-strength glass ionomer cements, such as loss of sealant, non-retention in shallow cavities and fracture of multisurface restorations, they suggest the need for continued improvement in the design of hand instruments and in the properties of glass ionomer materials.

Chemo-mechanical caries removal.

The Carisolv method involves the application of a gel to identify and soften carious lesions. The caries is then removed by special hand instruments [56]. Drilling is only necessary to allow access to the carious lesion. The manufacturers have reported the mode of action to include chlorination of amino acids resulting in softening of the collagen in caries and facilitating removal.

Air Abrasive Technique

The air abrasive technique uses alumina particles in a high velocity stream of air to remove tooth structure. This technique was first described by Black in 1945 [57] and a commercial air abrasive instrument was introduced in 1951. Before further development could be carried out, the air-driven high-speed hand piece became available [1]. The re-emergence of air abrasion in the 1990's is attributable to improved evacuation and a recognition that the carious lesion should dictate the cavity preparation thus resulting in rounded internal cavity contours. Removal of amalgams is achieved by undermining restoration margins. One of the advantages of the technique is that anaesthesia is frequently unnecessary [58]. Disadvantages include the lack of tactile feedback and the time-consuming nature of the process compared to conventional drilling techniques. Face masks must be worn to prevent inhalation of the alumina particles.

Lasers

Though the first laser beam was generated in 1960, the use of lasers in dentistry was limited to a few laser wavelengths mainly because of concern about their potential for adverse thermal effects. The recent re-evaluation of lasers for soft and hard tissue removal has encompassed wavelengths from ultra-violet through visible to infra-red and has led to the FDA approval in 1997 of the Er:YAG (2940 nm) laser for hard tissue removal. This wavelength is absorbed well by water and hydroxyapatite resulting in efficient removal of both enamel and dentine [59] and also allows the use of water coolant to control temperature rises. Soft tissue use has been well documented in medicine and several wavelengths have gained FDA approval. Use of lasers for efficient chair-side bleaching of teeth has also been recommended.

Advances in dental materials are occurring rapidly. Adhesive dentistry will probably yield the greatest changes in the years ahead [60]. Many of the developments are dependent on materials with complex chemistry and need accurate operator techniques. The future lies in close collaboration between those developing the materials and techniques and the end-user, the dentist [46].

So far I have dealt with matters that concern the day-to-day work of the practitioner but what of the future for our colleagues in research – without them little progress would be made.

Dental Research and The Future

In writing about dentistry's contribution to biomedical research in 1999 I was able to point to the huge advances that dental researchers have made in recent years [61].

From a narrow concern with teeth and gums dentistry's researchers have encompassed all the oral tissues and more. The expanded horizons of research now include studies of viral infections, genetic anomalies, bone and joint diseases, oral cancers and acute and chronic pain conditions. Investigations which have led to achievements of importance to medicine as a whole include the development of a model *in vitro* system to measure the invasiveness of tumour cells and the development of antimetastatic drugs; the isolation of protein growth factors for bone; the identification of the precise region of immunoglobulin receptors responsible for hypersensitivity reactions; new vaccines against oral herpes virus infections; and anti-inflammatory and antienzymatic agents to counter the destructive effects of chronic inflammatory reactions. Dental scientists have carried out work of fundamental importance in the treatment of AIDS.

The mouth as a model

Ease of access to the oral tissues makes them excellent models for the study of infectious and other disease processes occurring elsewhere in the body. Studies of oral conditions have provided fresh insights into the interaction of pathogens and the immune system in many systemic disorders. Genetic and environmental factors that increase susceptibility or resistance to chronic disease, or that predisposes to congenital malformations have all been investigated by dental scientists. In the last decade dental researchers have demonstrated relationships between oral infections and low birth weight babies, diabetes, cardiovascular disease, pulmonary disease and stroke [34-37].

Dental scientists have pioneered research on the structure and properties of collagen, opening up new avenues of research including developmental biology, tissue formation and bone metabolism.

Dentistry is also making an important contribution to medicine's fledgling discipline – genomics [62] .

The analysis of the human genome, the increasing knowledge of protein construction and cellular function will give rise to enormous changes in the practice of all forms of clinical treatment, including dentistry. Huge strides are being made on an almost daily basis in relation to the analysis of bacterial genomes [63]. In 1999 Ferreti *et al* [64] reported the sequencing of the pathogen *Streptococcus pyogens*, the bacteria responsible for a wide variety of human ailments, including streptococcal sore throat, scarlet fever, acute glomerulonephritis, rheumatic fever, septicemia, toxic shock syndrome and nercotising fascitis (flesh-eating disease). The sequencing will broaden our understanding of how the organism causes disease. *Spyogens* contains more than 40 possible virulent genes, half of which were previously unknown.

The facility to determine bacterial genomes speedily will enable dental scientists to research and understand the cellular makeup of the organisms responsible for the initiation of caries and periodontal disease. Discovery of the specific bacterial nucleotide bases that cause dental disease will lead to the development of measures to counter these effects.

Genomics and Restorative Dentistry

Fundamental changes will occur in all forms of restorative dentistry. In describing the possibilities for cell-based restorative work Zuk *et al* [65] reported the success of their team in deriving stem cells from adipose tissue obtained from liposuction from which derived cells was subsequently possible to grow and differentiate adipogenic, chondrogenic, myogenic and osteogenic cells *in vitro*.

Using engineered skin and gingival cells, researchers at the University of Michigan School of Dentistry say they have produced complete bones that have the same hard outer coating, spongy interior and marrow core as naturally produced bone [66].

They used a developmental method to replace large areas of missing bone in living rats. This method could lead to less painful bone grafts in humans. In the developmental method, a tiny piece of skin or gingiva is removed, cut into even smaller pieces and placed in a culture dish. The cultured cells are then stimulated to secrete BMP-7, a protein that induces bone formation. The cells are seeded onto collagen sponges that are placed in the area where bone repair is needed. The method was tested on rats that had large sections of bone missing from their skulls. New bone was produced from the rats' own skin cells. The skulls were almost fully healed within four weeks.

It is reported that the new bone looks like naturally produced bone, and more experiments are planned to determine whether it functions like natural bone.

Using a patient's own tissues

Using a patient's own cells from easily accessed tissues that heal quickly is a major step toward an alternative to conventional bone grafts. If the implanted cells form bone directly, in addition to secreting BMP-7, these autografts would be useful in regenerating bone in many cases where few cells capable of forming new bone remain in the injured bone. Such lesions are difficult to treat by conventional treatment.

This ability to stimulate autogenous tissue growth also will enhance a patient's recovery after periodontal therapy. The dentist, armed with the capacity to stimulate patient-specific regeneration of loss alveolar bone, gingival tissue and cementum will be able to restore an optimal level of periodontal health [41-43]. This type of tissue engineering will have a considerable effect on dental practice during the next 25 years. The greatest effect will be related to the repair and replacement of mineralised tissues [67] and the promotion of oral wound healing.

Yeager [68], in a recent paper, speculates that as genetic researchers continue to study the specific genes that control the development and maintenance of teeth and their surrounding structures, implementing proteins will be located, and their tissue-building functions defined. Dentists will then be able to apply genetic engineering techniques to stimulate the body to repair itself, rather than making repairs with extrinsic materials. He forecasts that during endodontic therapy, dentists will be able to seed genetically developed pulpal tissue into the canal to grow and fill the chamber. A layer of epithelial cells could then be triggered to form dentine and enamel, to complete the biological restoration of the tooth.

We are on the verge of being able to mimic biological processes and to design nanoscale solutions to the biological problems that confront us each day.

Our colleagues of the future are likely to look back in wonder at our present primitive techniques as they apply the genetic solutions of tomorrow.

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