The adhesive revolution of restorative dentistry

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In many countries, the incidence of dental decay in the young is decreasing, and Hong Kong is no exception. However, there remains in the region, a number of restorative dental problems of some significance. These are tooth discolouration, fracture, and root surface decay. This article discusses these problems and the way in which their treatment is increasingly being undertaken by means of minimal-intervention adhesive techniques. The formulation of dental adhesive systems that are effective on a wet substrate has played a significant role in the development of modern dental practice. This development is briefly outlined, as are the principles underlying dental adhesion.

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Introduction

Restorative dentistry is concerned with the maintenance and preservation of the teeth. The field is distinct from oral and maxillofacial surgery, orthodontics, and children's dentistry, although there are areas of common interest. Restorative dentistry has a number of subspecialties which include conservative dentistry, endodontics (root-filling), prosthetics, periodontics, and in Hong Kong—public health. The way in which these subspecialties are taught and administered varies from country to country. Hong Kong currently follows the United Kingdom and Commonwealth pattern.

The 1980s and 1990s have seen great advances in the practice of conservative dentistry worldwide. Conservative dentistry comprises much of general dental practice, being the branch of dentistry that deals with the repair and modification of the teeth. Central to this change has been a reduction in the incidence of dental caries, which can be attributed chiefly to the use of fluoridated toothpastes and water supplies, and an increased awareness by patients of the advantages of good dental health. That is not to say that there is no dental decay in Hong Kong and there remains a reservoir of patients who need, but do not demand treatment. With the reduction of gross disease in the dentally-aware population, more work is now elective in nature, dealing with matters of poor appearance and impaired function as the result of occasional tooth loss.

There are a number of dental disorders for which treatment is commonly requested in Hong Kong. These include disfiguring tooth discolouration (a result of enamel fluorosis and tetracycline staining) and tooth fracture. The incidence of tooth discolouration in Hong Kong children is disturbingly high, occurring in approximately 17% of Chinese 12-year-olds.[1] Much of the enamel fluorosis is a result of an above-optimal level of fluoride in the piped water supply in the 1960s. Tetracycline staining is now uncommon in the West, and when it does occur, it is frequently the subject of medico-legal action. Tetracycline has been, at least until recently, widely prescribed to children in Hong Kong, because of its easy availability over the counter, poor prescribing practices by general practitioners and possibly through its addition to some Chinese traditional medicines.

From observation, the incidence of tooth fracture seems to be far higher in Hong Kong than that observed in European countries, where trauma and weakening of the teeth as a consequence of iatrogenic damage (the overcutting of cavities) is the principle cause. Here, the robust diet, where bones are commonly chewed, results in a relatively high incidence of fractured teeth. It is common practice to crown teeth that are at risk as a preventive measure. A further problem, of less impact in terms of overall incidence, but of particular relevance to southern China, is that of

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nasopharyngeal carcinoma. Treatment is by radiotherapy and the xerostomia that invariably ensues results in rapid and damaging decay of the teeth, the treatment of which poses particular problems.

Adhesion and tooth structure

The traditional "drill and fill" approach, familiar to anyone older than 30, is largely a thing of the past for the younger generation. The concept of minimal operative intervention and the conservation of tooth tissue—which is biologically not reparable and a very limited tissue resource—is at the forefront of the dentist's mind. In the early 1960s, a focus of dental research was the development of an adhesive system whereby restorative materials could be bonded to enamel or dentine without the need to destructively prepare or cut retentive cavities in tooth tissue. Barnacle adhesive was studied intensively because the manner in which these creatures can attach themselves underwater to rock is analogous to the intraoral environment.

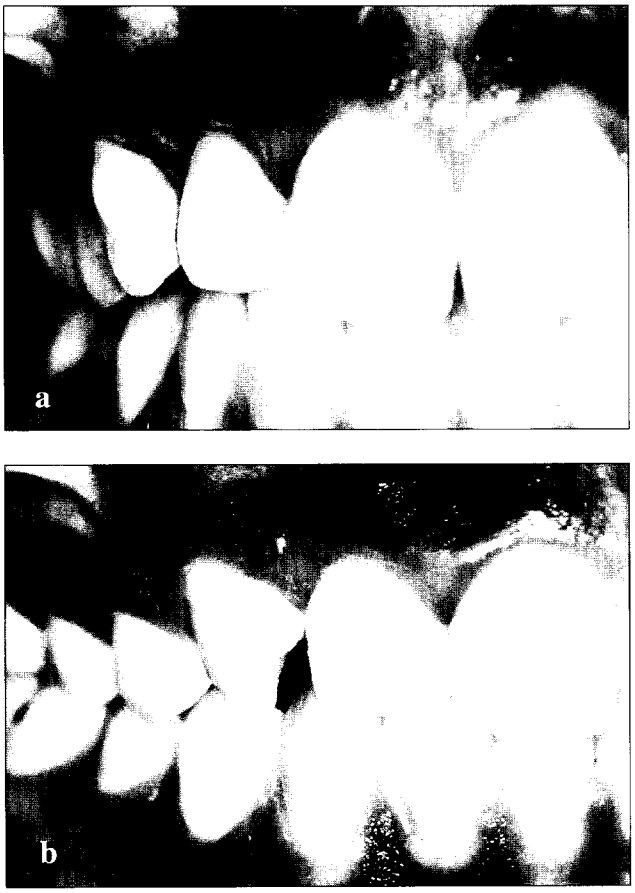
The complex resin that forms the basis for most commercial tooth-coloured plastic filling materials was developed initially from epoxy-resins in the hope that their glue-like characteristics could be used in the mouth. The highly cross-linked long polymer chains proved to be advantageous in a number of ways, such as limited condensation shrinkage, but chemical adhesion proved to be ephemeral.

The initial breakthrough was made in 1956, by a paedodontist, Buonocore,[2] who developed a purely mechanical technique for the repair of fractured incisor teeth. The method makes use of the microscopic structure of tooth enamel. Enamel is largely (96%) comprised of a myriad of interlocking fine prisms of hydroxyapatite (essentially calcium phosphate) that run uninterrupted from the inner core of the tooth, the dentine, to the outer surface of the enamel. When the surface enamel is treated with a dilute acid for approximately 30 seconds, the prisms dissolve differentially to a depth of about 30 μm, leaving a microscopically-roughened, porous surface. Unset, lightly-filled plastic resin can be applied to this roughened surface to be polymerised, either chemically or on command by the application of blue light. The set resin forms retentive tags within the enamel, similar to an interlocking jigsaw (Fig 1).

A restoration such as a crown, bridge, or veneer, made either of metal or porcelain with a roughened inner surface, may be fitted to the tooth surface with the unset resin as an intermediate layer. When set, the resin will lock into the restoration and the enamel of

Fig 1. Scanning electron micrograph showing resin tags on the fit surface of a composite resin restoration. These have been exposed by experimental dissolution of the underlying etched enamel, with acid. Tag length is about 20 μm.

Fig 2. Scanning electron micrograph of a resin replica showing fluid droplets on the surface of cut dentine in vitro. Field of view, 500 μm.



Figs 3a and 3b. A rotated upper right canine tooth, modified in shape to improve aesthetics, by means of acid-etch retained filled composite resin

Figs 4a and 4b. Discoloured upper incisor teeth rendered aesthetic by the provision of resin-bonded porcelain veneers

the cavity wall or tooth surface, bonding one to the other. Alternatively, lightly-filled bonding resin can be chemically (as opposed to mechanically) bonded to a highly-filled (glass, silica, or quartz) plastic, which itself forms the restoration. In a more recent development, resin adhesives have been used to reinforce the retention of silver amalgam fillings.

Buonocore was led to the special properties of etched enamel by the studies of Black,[3] who used the technique in the 1890s to study the micro-anatomy of enamel, specifically, the direction taken by the prisms in different parts of the tooth crown. It was from these studies that Black developed the first scientifically-based cavity designs, although these are now largely outmoded because of changes in the pattern of dental disease and advances in the dental equipment and materials used.

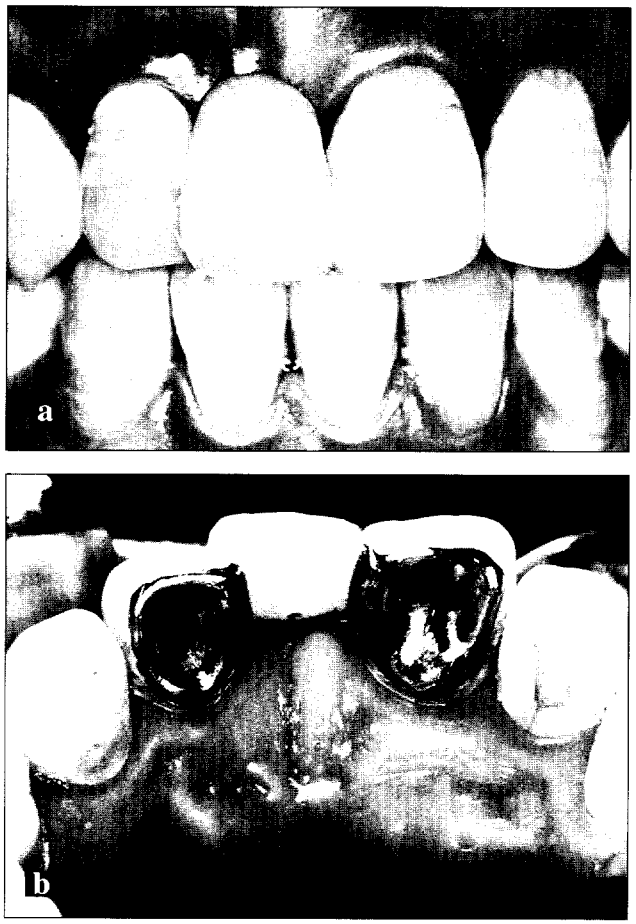
Once the outer enamel has been lost, the inner core of the tooth, comprised of dentine, is exposed. Dentine is dissimilar to enamel, being mesenchymal, rather than ectodermal in origin. It comprises more than 50% organic material, which is mainly collagen and tissue fluid. The fluid passes outward through the dentine from the pulp of the tooth, hence, the base of any newly cut cavity is wet (Fig 2). Dentine adhesives developed more slowly than enamel adhesives, largely because of the difficulty of bonding something to a wet substrate. Effective materials are now available that are as good as the enamel adhesives, having a tensile or debond strength of up to 25 MPa.

The adhesive technique involves decalcification of the dentine surface to expose a layer of interlacing collagen fibrils and the entrances of the dentinal tubules that lead to the dental pulp. Complex hydrophilic resins are used to perfuse this spongy complex. When set they form an intermediate layer of resin-perfused collagen, plus numerous rods of resin that extend down the opened dentinal tubules. This plastic-infused intermediate layer can then be bonded to the retentive inner surface of the restoration by means of a resin similar to that used for the more simple enamel bonding technique.

Clinical applications of adhesive dentistry

The first application of adhesive dentistry was in the treatment of traumatised teeth. Enamel is strong in compression but has a relatively low impact strength; it is brittle and prone to fracture. Large fractures are usually best repaired with artificial crowns but where the damage is relatively small, tooth-coloured, resin-composite, filling materials may be bonded to the fractured tooth. In some cases, it is possible to repair broken teeth simply by re-attaching the fractured portion.

Further uses for the technique were soon found. One of these was the use of relatively fluid lightly-filled resins to seal the chewing surfaces of childrens' back teeth.[4] These teeth contain pits and fissures that are so narrow they cannot be entered by a toothbrush filament and cleared of food and bacteria. These fissures are particularly prone to the typical early occlusal decay of youth. The resin sealant forms a protective coating on the tooth surface, effectively occluding the susceptible pits and fissures. In addition, patients often present with unsightly gaps between their teeth or with teeth rotated out of their natural position. These may require the use of orthodontic braces, which are attached to the teeth with resin bonding agents to realign the teeth. Often, an attractive result can be achieved simply by modifying the external contour of the tooth by the direct bonding of a plastic resin-filling material to its surface, with minimal destruction of sound tooth tissue (Figs 3a and 3b).



Figs 5a and 5b. Replacement of a lost incisor tooth by means of an acid-etch retained fixed partial denture. The artificial tooth is retained by means of two metal wings bonded to the palatal surfaces of the adjacent teeth.

The past decade has seen increased use of bonding agents in conjunction with traditional dental materials. Patients with dental fluorosis are now seldom treated with destructive full coverage crowns. The availability of adhesive techniques permits the placement of veneers—thin slivers of porcelain which are permanently bonded to the surfaces of the teeth (Figs 4a and 4b). Veneers are brittle and require delicate handling, but once bonded to the teeth they become much stronger and clinically functional. The procedure is painless because the minimal preparation that is required is made within the enamel. These apparently simple facings require skill in their fabrication by the dental technician, and represent a blend of science and art in ensuring the correct colour, contour, and fit.

For many years, replacement of a lost tooth required the construction of a denture or a bridge (fixed partial denture), which required the relatively destructive preparation for full coverage crowns of the teeth on both sides of the space to be filled. With the advent of adhesive resins it is often possible to bond the replacement tooth to the palatal or lingual aspect of the adjacent teeth by means of metal "wings" microscopically etched on their fit surfaces (Figs 5a and 5b).[5,6]

A further advance in adhesive dentistry has been the development, by means of complex glass and polymer chemistry, of adhesive restorative filling materials called glass ionomers. These may be used as true filling materials without the need for an intermediate bonding agent. The adhesion is chemical, rather than mechanical in nature, and is mediated principally by ionic bonds formed with hydroxyapatite crystals. When using glass ionomers as a filling material, it is not necessary to prepare complex cavities with tissue-destructive undercuts for retention. Adhesion is not the only advantage of this material. Special formulation of the glasses from which they are made allow fluoride ions to be released into the adjacent tooth tissue and the

overlying dental plaque. At other times, fluoride ions are "captured" on the surface of the filling from dietary and other sources.[7] The material thus acts as a rechargeable reservoir of fluoride and so effectively reduces the incidence of new caries, and recurrence of the treated lesion.

Glass ionomers are ideally suited to geriatric patients in whom the incidence of root surface caries is often high as a result of dry mouth, poor oral hygiene, gum recession, and the consumption of convenience foods rich in sugar.[8] As the population ages and retains its teeth, root surface caries and cervical lesions are being seen increasingly-glass ionomers are proving to be a material for their time. Another situation in which severely damaging root surface caries occur is when salivary function has been lost as a result of indirect irradiation of the salivary glands. Such patients include those who have been treated for nasopharyngeal carcinoma, which has a high incidence in Hong Kong and southern China.[9] The earlier glass ionomer materials were particularly susceptible to damage from dehydration[10] and so were not ideally suited to these patients. However, newer materials incorporating resin polymers show greater promise and are being tested clinically in the Faculty of Dentistry.

A further use for glass ionomers is in the treatment of dental decay "in the field" where electricity and complex dental equipment are unavailable. Here, the ability to place an easily mixed, adhesive material with cariostatic properties in a cavity prepared with simple, hand-held instruments, is likely to prove beneficial. The technique is known as the atraumatic restorative treatment (ART), and is being promoted by the World Health Organisation.[11] The Department of Conservative Dentistry is currently involved in establishing demonstration field trials in various Chinese provinces, and in other evaluations of the method.

Considering the somewhat unsophisticated adhesive systems used for prosthetic intervention elsewhere in the body, such as the use of acrylics for the cementing of replacement joints, it might be asked why the above adhesive systems cannot be used for the repair of other calcified tissues. Although research into a dental-compatible adhesive was hampered for many years by the innate wetness of tooth tissue, other aspects have been relatively straightforward. Calcified tooth tissue, although living, is largely acellular, and is isolated from the haemopoetic and reticulo-endothelial system. Hence, problems of phagocytosis, sensitisation, or rejection do not occur and it is relatively tolerant of foreign bodies.

The art and science of modern dentistry demands many skills-manual dexterity, diagnostic acumen, artistic flair, patient management, and business skills. It owes a significant debt to Black and Buonocore, and to numerous polymer chemists.

Acknowledgements

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