

KEY WORDS

Zirconia, tooth destruction, cosmetic, CAD/CAM, digital dentistry, endodontic, dental structural damage

LEARNING OBJECTIVES

- Clinical, technical, legal and consent problems with “digital dentistry”
- The potential for biologic harm from allegedly cosmetic dentistry particularly when based on unproven “digital dentistry” technology
- To encourage the practice of safer, proven, minimally destructive dentistry

AUTHORS

Robert D. Kelly BA BDentSci (Hons), MJDF RCS(Ed), FHEA

Dept. of Restorative Dentistry and Traumatology, King's College Hospital Dental Institute, London

Martin G.D. Kelleher BDS (Hons) MSc. FDSRCS, FDSRCS (Ed.), FDSRCS (Eng.)

Dept. of Restorative Dentistry and Traumatology, King's College Hospital Dental Institute, London

ROBERT D. KELLY, MARTIN G.D. KELLEHER

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IS 'DIGITAL DENTISTRY' DANGEROUS FOR TEETH? PROBLEMS ASSOCIATED WITH ZIRCONIA AND CAD/CAM RESTORATIONS

ABSTRACT

The increasing prescription of metal-free dental restorations has come about as a result of various patient demands and somewhat narcissistic expectations. However, some dental professionals have contributed to the rise in popularity of these materials and techniques. This article highlights the potential pitfalls of undertaking inherently destructive procedures, particularly when performed for questionable “cosmetic” reasons.

Metal-free full and partial coverage restorations have been a long-term ambition for some patients as well as for some dentists and for some manufacturers of dental products, technology and/or machinery. Many complex intertwined factors are probably involved in some dentists wishing to deliver more of these allegedly tooth coloured restorations to more patients, preferably ever more quickly and cheaply.

Fashions and other significant changes in society, including new media, have resulted in the demand for, and the provision of, so called “cosmetic” dental restorations. Increasingly some patients now seem to think of their teeth as a fashion accessory, partly due to an obsession with taking “selfies” to share on social media. Where the teeth in question are usually visible to others during normal social interactions reasonable requests for nicer looking teeth are entirely understandable. However, the worshipping

of “celebrities”, many of whom appear to have unnaturally big white teeth, coupled with questionable commercial advertising have resulted in an increased focus on the appearance of barely visible back teeth as well as front teeth.

In some popular, if intellectually vacuous, media, big white teeth predominate to such an extent that the mouth dominates the face. “Cosmetic” dentists and other fashionistas have jumped on this bandwagon – some due to pressure from their patients but others for understandable commercial reasons.

Unfortunately, certain dental clinicians when using digital dentistry to address “cosmetic” demands fail to emphasise sufficiently the desirability of preserving pulpal health and sound tooth structure.

Some clinicians and advertisements can be very economical with the truth about what is factually involved in patients having elective, full coverage indirect,

dentists buy key words from Google in order to increase their online profile for any interested patients with adequate disposable income.

However, many “consumers” remain blissfully unaware of the inherent biological dangers of having irreversible damage done to their natural teeth in order to use scanning and/or milling techniques. This involves exchanging much of their invaluable enamel and dentine,^{1,2,3} which have been well proven over millennia, for what many still consider to be *clinically* experimental dental materials, or rapidly machined restorations (Figure 1).

Is there sufficient evidence of efficacy, effectiveness and lack of problems for CAD/CAM techniques to be used on live teeth?

Many of the alleged improvements or speculative developments in relation to materials or techniques in dentistry have *not* been independently tested, using scientifically robust methods, in realistic clinical settings for an adequate length of time before being released on an unsuspecting public and gullible early adopter dentists by profit-driven dental corporations. In effect, these dentists then often do the human experimentation. Full and fair evaluation should include the longer-term effects on the health of the pulps and periodontal tissues as well as the success (i.e. not merely the survival) of new restorations. Detailed information of any partial failures such as chipping of any veneering material, or later fracture of the cores of those extensively prepared teeth should also be reported.

Recently, supposedly independent gurus or key opinion leaders (KOLs) have been promoting zirconia restorations, digital dentistry, CAD/CAM techniques and/or intraoral scanning for the provision of all-ceramic restorations with gushing enthusiasm. These promotions are usually presented at various dental conferences, but case reports sometimes appear in arms-length, barely concealed sponsored articles in largely commercial dental magazines.⁴ Even some peer-reviewed publications are reliant on “product positioning” in order to survive commercially. Allegedly scientific meetings are often subsidised by an accompanying trade show and social

allegedly tooth-coloured restorations. Any new technique or material should have been proven in appropriately controlled unbiased long-term trials to provide a significantly improved outcome to what it seeks to replace and have been proven not to produce collateral damage.

Some dentists perceive that the alleged benefits of such restorations being made using scanning techniques and computer-aided-design-computer-aided-machining (CAD/CAM) and not having any metal are good enough reasons for the unquestioning provision of multiple matching metal-free indirect restorations. Some believe that this a good way to satisfy the “cosmetic” demands of these selectively informed demanding individuals. Some fundamentalist dentists convince gullible patients that they have a “cosmetic dental disease” which digital dentistry can cure.

Some “dental consumers” can be overly influenced by algorithm targeted social media messages and images which abound on Facebook or Instagram, or on various dating sites about what constitutes an attractive smile. Other superficial “fashionistas” think of their teeth as being largely a fashion statement, which ought to be altered according to their latest whim.

The long-term consequences of pursuing destructive dental fashions

Somewhat narcissistic “dental consumers” can demand to have whatever they request in their pursuit of their “perfect smile”. Requests for changes in their dental appearance are often accompanied by a not-too-subtle threat to go elsewhere, perhaps to an apparently better “cosmetic dentist” if their dentist is reluctant to do their bidding. Their views are often based on their “research” with the help of the allegedly omniscient “Professor Google” using some key ad-words. Some marketing-savvy

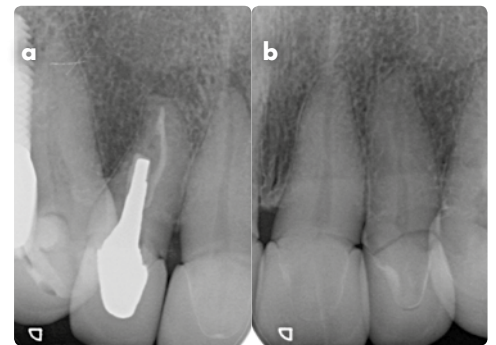


Figure 1 (a) and (b): Plain film radiographs showing upper incisors which were previously intact. Note the taper and outline of the cores showing the volume of sound tooth tissue destroyed for these full coverage ceramic crowns along with the periapical radiolucency at the upper right central incisor and near perforation by the post in the upper right lateral incisor

events, which often provide drinks and a buffet as some soft public relations by the relevant companies. In advance of attending such events, or some courses, sensible dental professionals are advised to spray themselves liberally with some powerful anti-bovine excrement aerosol.

The multiple effects of the internet on patients’ and dentists’ perceptions about dentistry

Dental soundbites and various mantras get pinged out into the moronosphere by various narcissistic dentists giving the impression that they have come from a properly trained expert. However, even mild criticism of blatantly damaging or inappropriate dentistry risks an orchestrated “howl-around” in various groups because some members of these fora have tribal – almost religious – beliefs and some have undisclosed links to the manufacturers of the materials or the technology involved.

The effects on healthy pulps of different threats

Selectively attacking a virtually intact tooth with a high-speed diamond bur to shape the tooth for a full coverage ceramic restoration poses a very different biologic threat to the health of a dental pulp to that which is involved when the pulp is threatened by caries. Caries is often

a slow process, during which time the invading bacteria and their by-products are detected early on by the pulpal defensive mechanisms and the invading bacteria are usually sent off on a wild goose chase around the amelodentinal junction. That diversionary tactic is just one of the clever defensive mechanisms which have evolved to allow the dental pulp enough time to lay down protective reparative dentine and thereby help to preserve the vitality of the pulp.

Unfortunately, a rapid assault with a high speed drill gives the pulps no warning at all before their enamel overcoat is rapidly stripped off them and millions of vulnerable dentinal tubules are opened up in minutes, thereby leaving them oozing dentinal fluid and allowing them to be attacked by bacterial, chemical and temperature challenges.⁵ When this unprovoked attack on a mainly sound tooth is then coupled with a weak, flexible, plastic temporary material, or a poorly cemented temporary restoration, this failure to seal adequately the suddenly exposed dentinal tubules allows extensive and uncontrolled micro-leakage to occur before the allegedly "permanent restorations" are ready to be fitted, usually a couple of weeks afterwards.^{4,6}



Figure 2: CAD-CAM milled all-ceramic restorations for the lower right second pre-molar and first molar tooth. Note marginal discrepancies and rapidly resulting secondary caries

Problems with the same visit indirect restorations

The simplistic claim that doing the preparation to provide the required one path of insertion for any indirect restoration, scanning it immediately and making and fitting the CAD/CAM restoration all at the same visit overcomes the significant biologic damage involved does not withstand scrutiny. That said, if there is no gingival inflammation or bleeding present to contaminate some aspect of the meticulous adhesive processes required, this approach is arguably better than leaving the electively exposed dentine being inadequately temporised for weeks while waiting for these allegedly "permanent" restorations to be fitted on their return from a remote laboratory. However, even with the same day approach a serious risk to the pulp's long-term health is the very real possibility of contamination of the prepared tooth/luting cement interface or the cement/restoration surface. This can be caused by contact with any crevicular fluid, blood or saliva before the bonding system has properly adhered to the prepared tooth or restoration surface at any time before the cementation material has set and thereby sealed off the now very vulnerable pulpal-dentinal complex (Figure 2).

Sadly, some electively incurred risks can get glossed over by some salespeople in

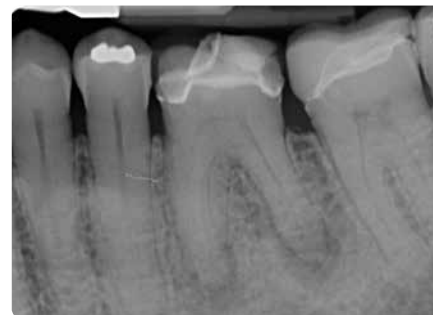


Figure 3: Note the destruction involved in producing this elective ceramic crown resulting in pulpal necrosis and periapical periodontitis of the lower left first molar tooth

pursuit of their understandable desire to sell their products to dentists, some of whom might have forgotten the basic principles of adhesion. Worryingly, some gullible dentists rely unquestioningly on the "knowledge" of a company representative selling them a particular dental material, machine or philosophy. Others, somewhat naively, believe every word uttered by an apparently independent "guru" who might be getting paid, either directly or indirectly, to promote that product, or a particular technique, or dental philosophy. This can be done by using a variety of slick computer generated images of irrelevant laboratory tests undertaken in idealised circumstances or by showing carefully selected clinical cases.

The 'BRAN' question and CAD/CAM: Benefits, Risks And Nothing?

Hippocrates is well known for his alleged (if unproven) exhortation to "firstly do no harm". Much less quoted is his pleading that "extreme remedies should be reserved for extreme diseases". A reasonable question to ask is: "are mildly crooked, worn or irregular teeth an extreme disease?" Most sensible people would answer "no". However, removal of 63%-72%^{1,2} of the structure of a sound tooth, which Edelhoff and

Sorensen have shown is the amount of tooth structure removed for an all-ceramic full coverage crown, certainly sounds rather extreme to most sensible people, particularly if done to cure someone of their supposed "cosmetic disease". Likewise, running the risk of having nearly a one in six chance of killing a previously intact tooth sounds extreme to many conscientious dentists. Such approaches are particularly worrying from ethical and legal perspectives, when, having elected to do irreversibly destructive preparations for allegedly "cosmetic" reasons, one then finds that significantly higher ceramic chipping problems have been reported with veneered zirconia restorations when compared to traditional PFM prostheses.³

Consent for computer assisted destructive (CAD) dentistry and the Montgomery ruling⁷

The risks of adverse outcomes of elective treatment – which can be aided and abetted by software manipulation to encourage patients to have it done for cosmetic reasons, can be considerable.

Undesirable outcomes range from the patient judging the appearance not to match their expectations, through ceramic chipping, to serious pain requiring endodontic treatment, through to fracture of residual cores or other long-term problems.

Following the Montgomery ruling in the UK Supreme Court,⁷ all options including their material risks of longer-term complications need to be discussed in advance of electively destructive dentistry.

This important judgement focused on full disclosure of all the relevant information about material risks by any treating clinician in order for any potential patient to understand these fully and thereby be able to give their valid consent.

The important issue here is the question of what a reasonable person would understand as a material risk. Losing somewhere between 63% and 72%^{1,2} of their sound tooth structure electively in order to have a metal-free all-ceramic crown would be regarded by most "sane" patients as a very material risk (Figures 1, 3, 4). Equally, the risks of serious pain, or requiring expensive and complicated endodontic treatment afterwards, or possibly losing an electively weakened tooth later on, would be seen by many patients as being "material" (Figure 5a and 5b). Most members of the legal profession would concur.

If the notes do not reflect that all these material risks were *fully understood by the patient* in advance of them having irreversible CAD-CAM inspired procedures for cosmetic reasons, the whole question of their consent being *valid* for that elective interference with their bodily integrity is likely to be called into question.

How successful are veneered zirconia restorations?

The literature is full of half-truths about the alleged success of veneered zirconia or all-ceramic restorations. Even serious ceramic chipping from zirconia, which will obviously ruin any "cosmetic benefits", frequently gets described as



Figure 4: This 75-year-old patient had milled CAD-CAM 'cosmetic restorations' completed on her upper left teeth one year previously. Note how little is left of the upper left molars due to the gross tooth destruction, the open margins and inter-dental contacts as well as the caries cervical to these elective restorations. This OPT illustrates the consequences of one or more of the three sources of failure mentioned in the text

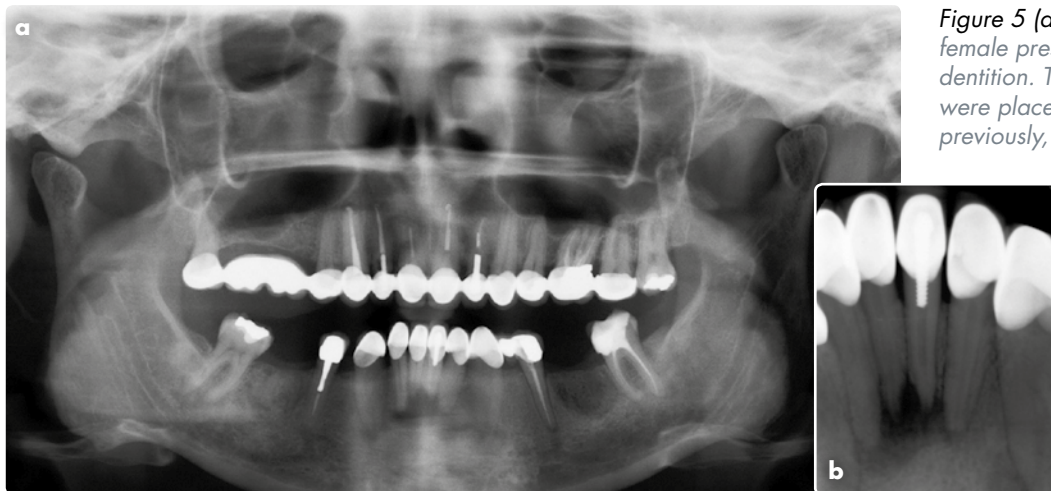


Figure 5 (a) and (b): A 53-year-old female presenting with a failing dentition. The original restorations were placed approximately 15 years previously, but the patient recently had the lower restorations replaced. Her initial complaint was of pain localised to the lower anterior teeth. Fig 5 (b) shows an intra-oral radiograph of the lower anterior teeth. CAD-CAM restorations are not likely to be any less destructive or less problematic in the longer-term

a "complication" rather than as a frank failure (Figure 6). Various authors^{8,9,10} have warned about the influence of some commercial companies in ensuring that the reporting of ceramic chipping off zirconia or of other failures is minimised.

Objective reliable information is highly desirable to help responsible dentists to inform patients properly in advance of preparing teeth extensively for these elective "cosmetic" full coverage crowns. This is particularly important when there are alternative, well proven minimally destructive strategies, techniques and materials available to solve many aesthetic problems. Such biologically more sensible techniques do not involve anything like the extensive dental destruction required to obtain a single path of insertion and/or to gain enough space for veneered zirconia, or other all-ceramic crowns to be used.

"Digital dentistry" ought not to be touted as "the great new thing in dentistry" without drawing adequate attention to the downside potential of damaging dental tissues in order to treat clinical problems, which could be dealt with more sensibly. Bleaching and/or alignment of crooked teeth and/or "additive dentistry" using bonding techniques are often preferable to doing irreversible subtractive dentistry. Many biologically aware dentists and material scientists have expressed alarm

at the lack of long-term valid clinical evidence being made available before these materials or techniques are used more extensively.^{9,11,12}

Bridge design and material considerations

Generally speaking, adhesive bridgework, provided there is sufficient enamel present, is well proven^{13,14} and is preferable to destroying tooth structure for conventional bridgework. However, if enamel is missing, or teeth are heavily repaired and one really needs to extensively prepare such teeth to provide conventional bridgework, then the well proven, well-made metal-ceramic restoration is still a better proven option than utilising still speculative full coverage, porcelain veneered, zirconia crowns or bridges.³

Fixed-fixed full coverage bridgework on tilted teeth requires one path of insertion. Consequently, the abutment teeth have to be prepared even more extensively, resulting in more structural damage as compared to a cantilever or fixed-moveable bridge design. Direct cantilever or fixed-moveable bridges allow for independent movement of the abutment teeth but also leave much more of the sound tooth structure for long-term load bearing purposes.

Unfortunately, the advent of "digital dentistry" and zirconia has coincided

with a resurgence in the fashion for stupidly destructive fixed-fixed designs which incur all the well reported risks that cantilever or fixed-moveable designs have largely avoided for more than 40 years.

Devout fans of zirconia fixed-fixed bridges seem to have developed a convenient amnesia about basic principles of bridge design and furthermore turn a blind eye to the chipping that has been reported to be nearly three times that of porcelain fused to metal.³ One classic study by Roberts showed that some fixed-fixed bridges had a ten times higher failure rate than those done with a fixed-moveable design.¹⁵ That study predated the development of adhesive bridgework.

Adhesive dentistry works best when sound enamel and intact marginal ridges are still present and when independent movement of the supporting teeth can occur with various occlusal changes being programmed by the periodontal ligament mechano-receptors. This capacity for adaptation by patients to changes in their occlusion was elegantly described in the UK by Anderson in 1962.¹⁶ Dahl and others (1982¹⁷ and 1983¹⁸) described the changes, which occurred using a partial coverage bite-raising splint in 20 patients prior to crowning their worn teeth. The adaptive capacity of patients to changes in their occlusion underpins many of the modern treatment

approaches to managing tooth surface loss where the anterior vertical dimension can be changed readily by adding direct resin composite to worn teeth rather than subtracting further sound tooth tissue.¹⁹

Given all of these changes in thinking and development of ways of adding composite and bonding metals and ceramic materials to teeth to solve various problems, which have been reported extensively by a wide variety of authors, it seems puzzling why those old-fashioned subtractive techniques are now being promoted in order to use intra-oral scanning, zirconia, or CAD/CAM.²⁰

Unfortunately, if patients sue for any reason, the patient's notes rarely, if ever, record that the patient understood in advance about those additive rather than subtractive alternative approaches were available to them instead of having zirconia or other all-ceramic full coverage crowns. If they did really understand things fully it seems very curious indeed that their clinical notes do not record with their signature that they preferred the elective removal of about two thirds of their sound tooth structure. More curiously, most dental notes do not contain a patient's signature certifying their desire to have the same-appointment elective restorations made by CAD/CAM, that they understood about the possibility of having subsequent pulpal pain or possibly needing expensive and unpredictable endodontic treatment. Ambulance chasing lawyers are often very helpful in pointing out these pertinent issues of lack of obvious "Montgomery consent"²⁷ when they are pursuing a claim on behalf of some disgruntled patient.

Structural and load-bearing aspects of tooth preparation for full coverage restorations

Most of the strength of anterior and posterior teeth is in the marginal ridges and provided these remain intact the load bearing capacity remains very high. Electively cutting through the marginal ridges of teeth grossly reduces their stiffness.²¹ Elective preparation of a tooth for an anterior or a posterior full coverage all-ceramic, veneered zirconia, or porcelain fused to metal crown, results in massive destruction with the stiffness and strength of the residual core being hugely compromised.^{1,2}

No structural engineer would suggest elective removal of up to two thirds of any load bearing structure as a sensible approach if the expectations were still to get the same long-term performance out of the remaining one third of that structure. Likewise, no sensible orthopaedic surgeon would be persuaded by some flash digital imaging software to electively remove two thirds of a sound knee or a hip and still expect long-term function. Sadly, some unthinking dentists seem to think that many patients with largely intact front teeth who, quite understandably, request a nicer looking smile probably suffer from "hyperenamelosis" or "porcelain deficiency disease" which can require various amounts of tooth reduction in order to cure them of their "cosmetic disease problems".⁶

What is often glossed over is that all ceramic crowns require even more extensive occlusal and interproximal clearance than do porcelain fused to metal restorations. In reality it is often the sound structure of people's teeth that is being destroyed unnecessarily to compensate for the inadequacies of current scanning technology and materials used to provide these superficially attractive restorations.

Endodontic problems with the use of veneered zirconia

Iatrogenic pulpal insults are almost an inevitable consequence of elective tooth preparations for full coverage ceramic



Figure. 6 (a) and (b): Fig (a) demonstrates ceramic chipping adjacent to an occlusal endodontic access cavity preparation on the upper right first permanent premolar tooth, while there are obvious ceramic fracture lines evident on the upper right canine, which has been restored with a post-retained restoration. Fig (b) demonstrates staining following an attempted composite repair of the upper left premolar tooth. The patient reported that the teeth distal to those shown in the photographs had elective 'cosmetic' restorations and were subsequently lost due to pain and failed endodontics approximately 18 months earlier. One ethical or legal question: 'Is that responsible dentistry?'

veneered restorations of any type and are responsible for a proportion of previously pulpally healthy teeth subsequently requiring at least conservative endodontic management.

The dentine-pulp is a dynamic and extremely complex system with capabilities to protect, defend and repair itself when required to do so following mechanical, thermal, chemical, bacterial or iatrogenic attacks.^{22,23} The dental pulp sustains insults on a daily basis during functional activities and is frequently in a cycle of repair and regeneration following episodes of caries, trauma or mechanical intervention. However, when a certain threshold is exceeded – for example following rapid or dry tooth preparation, often followed by bacterial micro-leakage contamination, irreversible pulpal pathology can ensue.

Full coverage ceramic veneered restorations often obscure the original pulpal anatomy, which guides the clinician in accurate location and detection of root canal orifices²⁴ and thereby makes endodontic treatment more difficult and hazardous. A combination of problems means that the provision of endodontic treatment often requires specialist endodontic treatment with illumination, magnification and a lot of experience to increase the chances of the root canal treatment being successful. This

extra time and material costs of multiple burs spent in attempting to cut through extremely hard zirconia can significantly add to the treatment duration, complexity and costs. This tedious process inevitably destroys residual sound tooth tissue in attempting to locate the root canals. There can be significant medico-legal dangers when unexpected pain and specialist endodontic costs are involved.

Patients sometimes ask if the endodontist has seen many similar cases and/or if the root filling problem has been caused by the allegedly “permanent cosmetic crown”. The issue of “duty of candour” can then become quite interesting. Tensions can arise between an endodontist who, understandably would wish to protect their referral base and still discharging their duty of being candid with any enquiring patient.

Particular problems exist when undertaking endodontic treatment following the provision of fixed-fixed bridgework using veneered zirconia where each abutment must be prepared to provide a common path of insertion for that bridge. Making the residual cores nearly parallel to one another in order to get one line of draw for the fixed-fixed bridge design frequently hazards any innocent nearby pulp horns, as does bacterial micro-leakage occurring from inadequate temporisation between appointments.

The very real risks of inducing further iatrogenic endodontic related damage can require cone-beam computed-tomography (CBCT) to try to diagnose, investigate and fully inform patients of various treatment options, as well as highlighting to the patient in advance that endodontic therapy at that stage can be unpredictable, even if performed by an experienced dentist or specialist endodontist.

In summary, one might reasonably ask the question: “If general dentists are not especially good at getting out of the endodontic problems afterwards, why do they do things to teeth that cause these in the first place?”

Does getting some patients and/or themselves into future difficulties sound like it involves smart thinking e.g. by utilising zirconia for fixed-fixed bridgework or just because they had the in-surgery machinery, or perhaps because that dentist “did not do implants” or perhaps because “the patient could not afford implants” or just because the dentist “did not believe in adhesive bridges”?

Any logical analysis of all of these potential problems leads one to the inescapable conclusion that it was the decision to elect to cut mainly sound teeth aggressively in order to use

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intra-oral scanning, zirconia or CAD/CAM techniques that have created those avoidable risks. In most cases a smarter biologic approach using alignment and/or minimally destructive or additive composite techniques would have avoided problems.

Increased endodontic problems associated with full coverage crowns

The dental literature suggests that up to 20% of teeth prepared to receive a single unit restoration become necrotic afterwards.²⁵⁻³¹ When teeth are crowned for conventional fixed-partial-denture abutments (aka "bridges") reported death of teeth ranges from 3%-38%.³²

Cheung et al (2005)³³ reported that 32.5% of bridge retainers in a Chinese population showed signs of pulpal necrosis. One interesting explanation for that "outlier" figure may be that some Chinese medicines contain tetracycline, which discolours any developing teeth and virtually all the stable tetracycline orthophosphate is found in the dentine. The particular combination of risk factors – young age, tetracycline discolouration in the dentine coupled with dubious temporisation, possibly all acting together, might well help to explain the high number of pulpal necrosis reported by Cheung et al (2005).³⁰

Jackson et al (1992)²⁷ reported that just fewer than 6% of teeth required endodontic treatment following placement of an indirect restoration when followed for up to 6 years. Bergenholtz (1991)²⁵ who evaluated crowned teeth clinically and radiographically reported an incidence of 10%-15%. Saunders and Saunders (1998)²⁹ reported a figure of about 19% in a radiographic study of patients that had been referred to two Scottish teaching hospitals.

Time for re-intervention or extraction of crowned teeth

Biological complications (recurring caries and pathologies of endodontic origin) are the most common causes of failure for teeth restored with indirect restorations.^{29,32} In a recent study by Burke and Lucarotti,^{33,34} the authors examined approximately 1.2m crowns placed over a 16-year period within the National Health Service (England and Wales). The results demonstrated that teeth restored with indirect restorations perform poorly in younger patients. The authors attribute this to "the crown preparation and the attendant removal of the enamel which provides stiffness to the tooth", ultimately resulting in "catastrophic" failure.³³

Predictably enough, for all the aforementioned reasons, all-ceramic and metal-ceramic restorations had more re-interventions when compared to all-metal restorations.^{31,33,34} Those authors further demonstrated that crowns placed on younger patients (those <40 years

of age) required more interventions, many of which necessitated earlier extraction of the tooth, when compared to when crowns were placed in older individuals.^{33,34} One explanation for that could be that removal of sound tooth structure is a lot less extensive when doing all-metal crowns. Furthermore, metal crowns are more likely to have been done on posterior teeth and could have been done on teeth that had been affected by caries previously, rather than for those being done on front teeth some of which might well have been done for supposedly "cosmetic" reasons.

So what actually happens to the pulp when teeth are prepared for full coverage ceramic crowns?

The initial reaction of the dentine-pulp complex to any invasive/operative treatment is inflammation,^{35,36} with increasing severity of the inflammation as proximity to the pulp of the preparation increases.³⁷ The particular relevance of this is that endodontic damage is determined by the location of the pulpal horns and the thickness of the residual dentine when a tooth is prepared to receive a full coverage zirconia veneered with ceramic restoration. Rapid destruction of sound tooth tissue puts the pulp horns and the cervical regions particularly at risk in immature teeth. It is relevant to note that enamel is only 0.7mm thick in the cervical region and an unprovoked attack with a bur quickly exposes the cervical dentine. Doing that has a huge impact on the health of dentine-pulp complex, partly because there is an increase in

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both the number of dentine tubules and in their diameter as compared to the more coronally positioned dentine.^{38,39}

As the dentine gets grossly reduced its permeability increases towards the dentine-pulpal complex and therefore so too does the risk of greater pulpal inflammation.³⁹ Non-biocompatible or ineffective luting materials have also been suggested as a major risk factor.³⁶ Reduction of the remaining dentine thickness can allow bacterial micro-leakage directly to the pulp and further hazard the pulp's vitality.^{37,40,41}

If the temporary crown or bridge material breaks, or the temporary crown de-bonds, or its cement leaks at any time, this can easily result in the electively wounded tooth (or teeth) having to endure a sustained period of bacterial, chemical or thermal insults while awaiting the allegedly permanent restoration(s) to be fitted. That realistic scenario is being played out daily in busy dental practices does not make much biologic sense to anyone who really cares about patients' long-term pulpal health. A recent prospective study determined that a not so insignificant number of teeth (9%) became necrotic in the interval between preparation for a fixed prosthesis and fit.⁴²

Irresponsible advertising and unwarranted claims

Manufacturers and their acolytes claim that digital dentistry techniques can be used in minimally invasive dentistry all the way through to full-mouth rehabilitation. It is certainly true that this technology has vastly improved the accuracy and speed of delivery of implant supported and retained restorations. However, unlike teeth, dental implants do not contain vital pulp tissue and there is nearly always lots of space available for large amounts of ceramic to be utilised following the loss of a tooth or teeth. Unfortunately, the reason why implant(s) had to be placed can often be tracked back to aggressive over-preparation of the now absent tooth for a full coverage ceramic veneered crown or fixed-fixed bridge. There is scarcely any long-term independent clinical evidence that using scanning techniques and milling technology produces restorations with better form, function, durability or aesthetics when compared to the traditional porcelain bonded to metal restorations made using conventional clinical and laboratory techniques.

That then poses the question: "how useful is digital dentistry in conventional fixed prosthodontics involving vital natural teeth?" The pulpal and structural problems risks involved seem so great that its routine use simply cannot be recommended based on sound biological or bio-engineering principles.

Conclusions

- The more elective the restorative procedure is the wider the safety margin needs to be, as these restorations do not have to be provided.
- Patients need to understand *all* options available to them including the potential risks and benefits of those in order for their consent to be valid.
- Minimally invasive techniques to restore/replace a missing tooth needs to be discussed prior to embarking upon more "subtractive" treatments.
- Until such a time as CAD/CAM technology has been proven in independent, long term, trials to deliver significantly better, more reliable and durable restorations than conventional restorations it appears that "seamless digital dentistry" can be viewed largely as a trendy selling point, used by slick sales-oriented personnel or "cosmetic fashionistas", to deliver prostheses which involve taking significant biologic and mechanical risks for very little long-term patient benefit.

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