IN BRIEF

- A long-term view of crown provision is essential (ten years or more)
- Meeting the patient's expectations is a critical measure of success
- The patient's ability to tolerate treatment and maintain the restorations is a key factor when planning treatment
- One's own ability to provide high quality crowns requires honest reflection in every case
- The damage to tooth tissue when providing crowns is considerable and should be weighed against the benefits
- Control of the environment to minimise disease and damage is a fundamental part of the treatment plan
- The biological and biomechanical safety of the restorations is taken as a prerequisite

3

Crowns and extra-coronal restorations: Considerations when planning treatment

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Considerations when planning treatment is the third in the series of crowns and other extra-coronal restorations. Articles or chapters on treatment planning in restorative dentistry can make pretty dry reading, often built around a list of factors that might influence your decision-making. In truth though, planning and placing crowns or other extra-coronal restorations cannot be distilled into a series of lists. The decision-making involved requires experience, subtle understanding and a flexible approach, none of which come easily.

CROWNS AND EXTRA-CORONAL RESTORATIONS:

1. Changing patterns and the need for quality
2. Materials considerations
3. Pre-operative assessment
4. Endodontic considerations
5. Jaw registration and articulator selection
6. Aesthetic control
7. Cores for teeth with vital pulps
8. Preparations for full veneer crowns
9. Provisional restorations
10. Impression materials and technique
11. Try-in and cementation of crowns
12. Porcelain veneers
13. Resin bonded metal restorations

No crowns can really be regarded as permanent. If we lived for long enough, wear and tear, disease and the realities of intra-oral existence mean that even the most carefully constructed and cemented crown would probably eventually fail. We should though expect to get many useful years from our crowns, and should plan to have a situation we can recover, if and when they eventually fail. This article aims to address the issues of planning, both by planning to avoid failure and also by planning to cope with failure. It will address both the treatment plan itself and the planned delivery of treatment (these are subtly different things), and it aims to set the scene for the more detailed and specific analysis of treatment planning and delivery issues within the rest of this series of articles.

Learning is most effective when you learn from your mistakes, but this can be a painful process, both for patient and operator. Here we will use examples where mistakes have been made (some quite close to home) to illustrate the points we are trying to make. Take a few moments to look at the illustrations of the two cases shown, and read the text in the boxes.

Many of the cases that fail miserably suffer from decisions made right at the beginning. In other cases the decisions are sound but the execution is the problem. These two cases were abject failures at several points and illustrate, perhaps in a rather extreme way, some of the fundamentals of planning. One was done in a dental hospital, the other in a practice. Bad planning and bad execution were contributors in both. We will refer to these two cases as we go through.

THE LONG-TERM STRATEGY: WHAT WILL THIS DENTITION BE LIKE IN 10 YEARS?

A long-term strategy is different from a treatment plan. It is tempting easy to focus immediately at the level of the tooth, discussing its crown height, pulp vitality or its role in the occlusion. Whilst these detailed 'close focus' issues are all critically important if a crown is to survive, they are not as important as making a decision about treating the tooth in the context of the rest of the dentition, and about managing the rest of the dentition in the context of the individual.

Look at Case 1 (see box overleaf). This failed for many reasons, including poor technical outcomes and perhaps insufficient attention to hygiene and diet. But as you look at the first radiograph, ask yourself this question: 'if this patient attended my surgery now, what condition would I expect this dentition to be in, in 10 years time?' The answer might be 'edentulous', it may be that there will be a couple of remaining teeth and an overdenture, but the answer probably is not 'the same as it is now'. Given the widespread caries and the lack of remaining sound tooth tissue, tooth loss here was always very likely. Had this been acknowledged right at the beginning, rather than trying to save and re-crown every tooth (and on a 'close focus' tooth-by-tooth basis this seemed quite possible no doubt), then a reasonable end stage would have been reached more quickly, more efficiently and less traumatically. Who knows, implants may not have been necessary if the transition to edentulousness had been planned, or a couple of overdenture abutments had been identified at the start. If you ask yourself: 'What

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CASE 1

In 1989 this patient had all of her lower teeth crowned.

Two years later there was evidence of caries around the margins of several of them (Fig. 1).

A further decision was made to root treat all of the teeth, initially with a view to restoring them with crowns and this treatment was started a short time later, initially leaving the crowns in place (Fig. 2).

The root treatments were undertaken, but within a year they began to fail because, among many other reasons, it was proving very difficult to ensure a coronal seal (Fig. 3), in fact it is doubtful whether this biological pre-requisite to successful endodontics had been considered at all.

As no progress was being made (things were actually getting worse), the decision was made to revert to an overdenture (Fig. 4).

Within another year even the overdenture abutments became mobile and infected (Fig. 5) and in the end they too were removed, leaving the patient with a denture which she could not wear.

The end result, a further 2 years down the line, was the placement of four implants and a very successful lower implant retained fixed prosthesis (Fig. 6).

The whole case cost several thousand pounds to manage, much of which was used to provide treatment which soon failed.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

will this be like in 10 years, or 20?' and can answer, a sensible strategy for how you want to get there can be developed.

Essentially this is gambling, a game of odds. You cannot possibly hope to know what things will be like in 10 years, can you? Perhaps not, but as a professional you are better placed to assess the 'form' of the dentition than anyone else. Often, it is unwise to develop your final strategy straight away, before you have seen the response to basic preventive measures such as hygiene and dietary management. Increasingly we find that the 'one off' treatment plan is actually inappropriate, as it was in the case in Figure 7 where isolated coronal restorations and bridgework have been provided in an environment of generalised toothwear. This clearly warranted fuller investigation and an overall management strategy. Taking your time and planning in stages, will often improve your chances of winning this game of odds.

With a strategy in place, it is now time to ask some more specific questions, starting with some issues relating to the patient as a whole before finally moving on to technicalities associated with the patient's mouth and teeth.

CASE SELECTION: THE PATIENT

Can I meet the expectations of the patient?

The first fundamental issue that you need to resolve with the patient is whether your expectations and theirs converge. It is all very well being able to sell something to your patient, but you have to be able to deliver and, in the long term, 'expectation modification' can be a key skill. The issue of expectations most often arises in terms of aesthetics (see Part 6 in this series) though there are issues in other areas too. We know that patients' expectations for tooth retention are increasing all the time,¹ and this applies as much to treatment decisions on individual teeth as it does to the dentition as a whole. Where you really feel that expectations cannot be met or modified it is better to make an appropriate referral at the beginning than risk later retribution.

Will the patient be able to tolerate the treatment and then maintain the restorations?

Planning some restorations based on the technicalities of pulp state, angulation, crown height and so on is all very well, but if the patient cannot lie flat for more than 20 minutes, or cannot open their mouth beyond 2 centimetres, actually providing treatment may cause you some problems. It is surprisingly easy to forget to think these things through before lifting a handpiece. Physical limitations, such as neuromuscular or skeletal disorders, may also prevent patients from maintaining their restorations, no matter how devoted they are to good hygiene. Furthermore, it is not simply the state of hygiene you encounter when you see the patient for the first time that matters, it is also how you see them being able to cope in 5 or 10 years. This may not be an issue for young or middle-aged patients,

Fig. 7 'isolated coronal restorations and bridgework with generalised toothwear'

but for an increasingly dentate and demanding group of older adults it is highly relevant. The treatment planning strategy of 'shortened dental arch' (SDA) is built around the differences in the ease with which different types of tooth can be maintained and cleaned. Anterior teeth are easier for the dentist to access for treatment and long-term maintenance and for the patient to clean. Molars on the other hand are difficult. They have multiple roots with furcations between them, as well as fine and curved root canals. Their inaccessible location means that, if there are real problems cleaning, these are the teeth most likely to suffer. SDA gives priority to the anterior and premolar teeth to ensure that limited resources are targeted to the teeth which have the best chance of long-term survival, and which will provide adequate mechanical and aesthetic function.

My own skills: Can I do this to a high enough standard?

This can be a difficult question to face up to but it is a question that should be answered honestly. Tackling a complex case requiring multiple coronal restorations with an excess of bravado and a lack of insight and understanding of the potential pitfalls can lead to disaster. Good restorative work is more than being able to cut some shapes and stick on crowns. Dentistry is difficult. The knowledge and experience, not to mention the technical skills that are required to make the complex judgements necessary to plan and then carry out treatment take a long time to acquire. Other factors, which enter the equation and may affect the outcome, include the availability of adequate treatment facilities, materials and appropriate technical support. Ultimately the decision is yours, but there is usually more than one treatment option and simpler alternatives may be more successful in the long-term.

Can I justify the damage I am going to do to the patient's teeth?

Look at Case 2 again (see box overleaf). This is a case where a decision was made to place crowns on perfectly sound teeth. Admittedly, the clinical work was poor, but the resultant damage was almost terminal for the teeth. This was a planning failure every bit as much as a clinical failure. It is easy to be seduced by the technical possibilities and to forget the biological realities when creating a treatment plan. In a recent review of patients visiting a UK dental hospital, 19% of all crowned teeth without root fillings had evidence of periapical

CASE 2

This 18-year-old female patient attended Newcastle Dental Hospital requesting treatment to improve the appearance of her upper anterior teeth which were chipped as a result of trauma with UL1 (21) having been root filled and discoloured (Fig. 8). She was placed on a waiting list for conservative management involving the provision of a labial porcelain veneer to UL1 (21) and incisal composite restorations to UR1 (11), UR2 (12) and UL2 (22).

Inevitable delays with treatment at the Dental Hospital led to the patient seeking treatment elsewhere. She did, however, return to the Dental Hospital some 5 years later with PJs of poor quality on all the upper anterior teeth and irreversible pulpitis in UR2 (12) and UL2 (22) (Fig. 9). A further treatment plan was formulated involving endodontics to UR2 (12) and UL2 (22) followed by replacement crowns for the upper anterior teeth. Once again, Dental Hospital waiting lists resulted in the patient obtaining treatment elsewhere. A further 8 years later, she was referred back to the Dental Hospital by her latest dentist who was suitably horrified by what he found! The results of 13 years of treatment were six poor crowns with carious margins, unrootfilled or inadequately root-filled teeth, short or perforating posts and several teeth of very doubtful prognosis (Fig. 10). In summary, an unnecessarily mutilated dentition.

Fortunately, remedial treatment from her own dentist was possible in this case and the result is much better than could have been hoped for initially (Fig. 11). This is also a very good illustration of what can be achieved in the General Dental Services under ideal circumstances although it is important to note that the treatment required a further 17 visits over a 9-month period, including two surgical procedures, and the longevity of the restorations remains unpredictable.

Fig. 8

Fig. 9

Fig. 10

Fig. 11

pathology.² For a number of technical reasons it is very difficult to get an accurate indication of just how often teeth die as a result of crown preparation, but this finding and other published evidence suggests it is probably a fairly common occurrence, unless the technical quality of the work is of a very high standard.^{3,4} Furthermore, the tooth itself is often weakened by preparation, and fracture of the tooth at gum level is not uncommon. Crown preparation on virgin teeth is not something to be undertaken lightly.

What is the main lesson to be learnt from Case 2? We have already stated in the introduction that all crowns may eventually fail but the poor standard of clinical work in this instance has certainly resulted in unacceptable early and damaging failure. The message is clear that if there are simpler, less invasive, but effective means of achieving the desired result, as there were in this case, these should always be considered before embarking upon more complex treatments which may actually accelerate the loss of the dentition.

CASE SELECTION: THE MOUTH AND TEETH

The oral environment: Can I, and the patient, control the environment to minimise the risk of disease or damage in the long term?

It is tempting sometimes to want to crack on and do the difficult, skilled and lucrative technical things, to see the final result, and to witness the transformed smile. The new crowns though are only as good as their environment. Sometimes it takes a lot of time to sort out the environment, for little immediate reward. At other times you just have to work within a difficult environment; for example it may be rather difficult to stop a bruxist from grinding and you may need to plan around this. Usually you have to accept less than perfection, often much less, but plaque control, caries risk and the occlusion are at the heart of successful crown work. All can be managed to some degree. If you should be in any doubt about the importance of managing the environment, look again at Case 1 where neither plaque control, nor caries management were properly dealt with. The result was time consuming and expensive failure.

Is the plaque control good enough?

Little needs to be said about plaque. We know that it is a fundamental factor in both caries and periodontal disease. In simple terms, plaque around restorations is likely to shorten their life. Tooth cleaning is a surprisingly complex process, and sometimes we forget this or even trivialise it. Helping people to find the skills to keep their own teeth clean is probably the least trivial thing dentists do.

It is truly remarkable that any form of operative dentistry should be considered in an environment like this (Fig. 12), let alone the provision of crowns that have been carefully contoured to follow the aberrant gingival margins! The pres-

Fig. 12 'poor oral hygiene and crowns'

Fig. 13 'deficient margins and recurrent caries'

Fig. 14 'deficient margins with good plaque control'

ence of marginal deficiencies in an environment where plaque control is inadequate can result in rapid caries progression and potential tooth loss (Fig. 13). Contrast this situation with Figure 14 which illustrates poor open crown margins but where caries is minimal. Again, this quality of treatment cannot be condoned but the saving grace has been the patient's maintenance of a high standard of plaque control.

It is the dentist's responsibility to provide the highest standard of technical work possible, but also to communicate to the patient the importance of good hygiene and maintenance. The patient's responsibility is to follow that advice on the understanding that they may directly influence the longevity of their dental restorations. The fact that they may have made a considerable investment in terms of time and expense for their dental treatment represents a powerful incentive to comply with future preventive measures.

Has the risk of caries in the future been addressed?

Caries risk is directly related to both plaque and diet, and also (in the case of root caries) to the presence of a partial denture.⁵⁻⁷ The oral health profile of most western populations is such that our crown patients of the next few decades will,

Fig. 15 'root caries and attempted repairs'

Fig. 16 'de-bonded anterior post crown'

for the most part, be a steadily ageing band.¹ Caries management is an issue at all ages, but in this cohort root caries is likely to be an increasing threat. This is a wretched disease to deal with. The best crown in the world, with an undetectable margin, perfect occlusion and stunning aesthetics will still fail if the risk of root caries is not addressed. In this case (Fig. 15), the risk of caries around the upper anterior restorations has clearly not been properly addressed with root caries and progressive periodontal destruction resulting. Treatment has involved the mechanical repair of caries at the crown margins (and in some areas the repair of the repairs) with little or no emphasis on prevention. The solution for managing root caries is biological not mechanical. It requires simple communication about hygiene and attention to some 'little things' in the diet, such as the odd teaspoon of sugar in regular cups of tea or coffee, biscuit nibbling and a range of other apparently innocuous activities which patients may not associate with a problem. If you are in any doubt as to how important this is, just scan Case 1 again. The dentist has at his or her disposal a full armamentarium of approaches, including hygiene and dietary advice and the appropriate use of fluorides and varnishes. Caries, particularly root caries, is preventable. If your crowns fail because of caries it is partly a failure of your own management.

Has the risk of damage from the occlusion been minimised?

A few basic checks and a little thought and care should eliminate the risk of problems in the large majority of cases. It is important that you know where the contacts are on the tooth you are to treat, especially those that are involved in guiding the jaw movement in lateral and protrusive excursions. It is also important to know which other teeth are involved in guidance, and whether the tooth you are about to prepare is a deflective contact or interference to guidance. These may sound complex but are readily checked and there is rarely a problem. Tech-

niques for occlusal examination and adjustment are dealt with in Part 5.

Figure 16 shows a de-bonded anterior post crown. Many kilos of zinc phosphate must be used and many unnecessary hours spent re-cementing such restorations. Often the blame is put on a short or non-retentive post (which this tooth shows), but in our experience a large proportion dislodge because inadequate care is taken to ensure that it is not providing all of the anterior guidance. Look at the profile of the palatal surface of this crown, it is bulky and convex and it is difficult to believe that this complied with the natural pattern of guidance provided by the adjacent natural teeth. Although the post is not long, the contour of the guidance surface must have been a contributory factor. Any anterior tooth is likely to provide some element of protrusive guidance and you can and should spend a few moments thinking about how to manage this right at the outset. Again details are given in Part 5.

The nature of the opposing tooth contacts is also important in terms of the material used for the occlusal/palatal surfaces of coronal restorations. In this case (Figs 17,18) there is already an ongoing toothwear problem caused by erosion and the provision of upper anterior crowns with porcelain palatal surfaces, which have been adjusted to make them even more abrasive, is not a good example of planning and the potential for further wear is self-evident.

The tooth: Are the foundations biologically and biomechanically sound?

The periodontal tissues

A tooth with any amount of attachment loss can be crowned, but where the disease is advanced and uncontrolled it is a hopeless investment. The major issues though do not surround the risk to

Figure 17,18 'worn dentition with porcelain abrasion'

your crown from periodontal disease but the risk to the periodontal tissues from your crown. Poor crown margins can certainly result in gingival problems (Fig. 19), as can an incorrect emergence profile. All crown margins should, ideally, be placed supragingivally to avoid problems related to gingival inflammation. Where a subgingival margin is indicated, it is essential that the margin be placed within the limits of the sulcus and that the biologic width is not encroached upon (Fig. 20). The biologic width is a band of approximately 2 mm of supracrestal connective tissue attachment and junctional epithelium around every tooth. If a restoration encroaches upon or eliminates this 2 mm band of attachment, an inflammatory response occurs and attachment loss, apical migration and pocket formation may result. Contrast the healthy gingivae associated with the supragingival crown margin on tooth UR1 (11) in Fig. 21 with the subgingival margin on tooth UL1 (21). Marginal position is something to be planned in advance, and as a rule of thumb it is wise to minimise encroachment into the sulcus.

Apart from encouraging periodontal problems, the subgingival placement of margins can also make accurate impression recording difficult or impossible. In Figure 22 subgingival margin placement has led to gingival inflammation, either as a result of biologic width encroachment or poor marginal fit resulting from obvious difficulties with impressions, as in Figure 23. Poorly contoured temporaries can also result in problems with impressions because of poor gingival condition (Fig. 24). The replacement of such restorations with well fitting and contoured provisional restorations may need to be a planned first step prior to definitive treatment.

Is the endodontic state stable enough to allow a crown to be planned?

Managing the endodontic state can be a particularly difficult problem, in fact we have devoted an entire article to the subject (see Part 4). Generally speaking though, for vital teeth the issues are quite straightforward. The pulp is a living tissue and everyone's life is easier where it remains a living tissue. Pulp protection is fundamental to crown provision. Non-vital or pulpally involved teeth that are not already filled also usually make for a relatively straightforward planning decision, as the infection clearly needs to be managed. There are very few, if any, circumstances where a crown should be placed over a tooth with an infected pulp where no attempt at endodontic treatment has been made.

The greatest clinical quandary arises with teeth that have already been root treated, but without a long-term resolution of the pathology, or where the technical quality of the root filling is dubious. Data from the UK suggest that most root treated teeth would actually fall into the latter category.^{2,8,9} Endodontics can be difficult enough at first attempt, but a technically satisfactory result is even more difficult where an unsatisfactory attempt has already been made. Re-treatment decisions have to be made on a

Fig. 19 'gingival inflammation related to anterior crown margins'

Fig. 20 'biologic width'

Fig. 21 'biologic width encroachment'

Fig. 22 'subgingival margins and gingival inflammation'

Fig. 23 'poorly fitting anterior crowns resulting from inaccurate impressions'

Fig. 24 'poor temporisation'

tooth-by-tooth basis and will be influenced by your own skill as an endodontist, or the access to a specialist in this demanding discipline. These are the foundations though, and you would think twice before replacing a roof where there is dry rot in the rafters.

Part 4 of the series covers these issues in some detail, including ways of restoring the core of the tooth using the root canal for retention.

Is the tooth itself strong enough to receive and retain a crown?

A number of basic factors should be considered before preparing any tooth for a crown. The extent of an existing restoration will influence the strength of the remaining tooth tissue and adequate retention of an extensive restoration is important to prevent complete coronal breakdown, even with a crown in place. The patient who enters the surgery with a crown containing an inadequate core or fractured tooth (usually neatly wrapped in tissue paper) is unfortunately a common scenario.

A properly constructed core with appropriate retentive features on a sound, disease free tooth can usually prevent this situation. Previous endodontic treatment will also affect the strength of the remaining tooth tissue, particularly where access cavities and coronal destruction are extensive. Parts 4 and 7 in this series cover the issues of core build up in detail, but decisions about the need for a core are an integral part of the planning process.

Will the preparation be retentive enough?

Adequate clinical crown height is a critical factor for the retention of full coronal restorations. Unless you plan to increase the occlusal vertical dimension, teeth with short clinical crowns will be even shorter and potentially very unretentive following crown preparation. This is particularly relevant for the restoration of worn teeth and although recent improvements in adhesive dentistry have increased the options for enhancing retention, mechanical retention by appropriate tooth preparation remains essential for predictable success and longevity of coronal restorations. Specific design features to optimise retention as well as crown lengthening will be covered in Part 8 in this series.

Is there enough space for my restoration?

Tooth wear not only results in problems of retention but also in providing adequate

occlusal space for your restoration. As we have just discussed increasing the occlusal vertical dimension can obviate the need for occlusal reduction on the preparation and can provide additional length that will improve retention, and often allows for improved aesthetics as well. Clearly, such an approach will involve extensive restorations and could involve the whole of one or both arches. However other strategies are available to make space.

The easiest way to provide sufficient clearance is to reduce the height of the opposing tooth, but whilst simple, this is often not advisable. Another approach, which is conservative of tooth tissue, is to make a local temporary increase in vertical dimension to promote axial orthodontic tooth movements (eg a Dahl appliance, or an occlusal composite build-up). The patient needs to be informed that the required tooth movements can take several months and you have to be careful to ensure that the built-up teeth are being loaded axially. This approach is being used increasingly on supra-occluding restorations by at least one centre.¹⁰

Occasionally space can be created anteriorly by adjusting the posterior teeth to eliminate deflective contacts, which repositions the mandible distally.

None of the above options should be undertaken lightly, but a detailed consideration falls outside the remit of this series. All of these techniques are well described in a recent article by Dyer *et al.* (2001), which provides a useful introduction to contemporary methods of managing space and problems of reduced crown height.¹¹

What next? The staged treatment plan

Although a clear vision of the finished treatment is indispensable at the outset we sometimes find that the initial plan is inappropriate and changes have to be made. This is because one or other of the questions listed above are answered in a different way from the way you expected. Perhaps hygiene continues to be a problem, or perhaps it improves unexpectedly, maybe the core breaks down or you find a root crack during endodontics. It pays to keep flexible, and to review the plan at key stages as you progress. Failure to do this can leave you committed to a course of action which may become increasingly difficult to sustain and which may fail much sooner than anticipated.

It is always worth discussing the alternative treatment options with your patient before starting work. In this way a change of plan can be made at an early stage rather than carrying on regardless and subsequently having to explain an expensive failure later. Anticipating problems is one of the key skills of the experienced restorative dentist and contingency planning is an essential element of any complex treatment plan.

Conclusion

In the course of this article we have posed seven key questions to ask yourself before you finally

plan treatment and pick up a handpiece. Success with crowns and other extra-coronal restorations depends on many interacting factors; technical issues related to tooth preparation, the relationship with the pulp and periodontal tissues and occlusion have been introduced and will be covered in greater detail later in this series. However, the emphasis has been on planning for the future rather than providing a short-term fix for single teeth in isolation. The needs and expectations of the patient

are key elements in the treatment planning process as is the importance of minimising further damage to the dentition and reducing the risk of disease in the future. These essential factors could perhaps be summarised in one overriding question before embarking on a course of treatment: 'will this patient's oral health be better off when I have finished?'. If there are any doubts about the answer to this question, the plan should be modified and an alternative approach considered.

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