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The endodontic-implant continuum *by Aws Alani*

The recent advancement and popularity of implants has resulted in some questionable debate when compared to endodontics as a treatment option. This article details some challenges that can be faced when providing each treatment and highlights the now topical interface between them.

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Dentists are frequently faced with the challenge of teeth that require endodontic treatment and subsequent restoration. In some cases teeth may be considered unrestorable and require extraction and prosthetic replacement. Unfortunately this decision pathway can be subjective, influenced by multiple patient and oral factors. Indeed, the experience, training and skill of the clinician may play a role.[1] This interface has changed relatively recently with the emergence of predictable osseointegration, which has revolutionised the management of the part or completely edentate patient. Where there has been much discussion is the interface between the decision to endodontically treat and restore, or extract and place an implant-supported restoration.

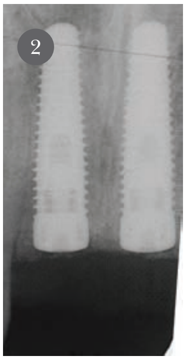
Failure: biological, mechanical and biomechanical

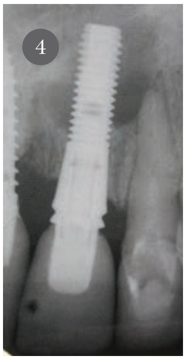
Upon loss of pulpal vitality teeth are more susceptible to a variety of disease processes that may be either microbial or linked to structural weakening of the tooth.[2–4] Where previously the focus has been on management of the established periapical lesion, efforts maybe better channelled towards procedures for protection of the pulp and so maintenance of vitality or potential for regeneration.[5]

Where pulpal or periapical disease is established, the coronal tooth structure may be significantly compromised. When assessing teeth for root canal treatment difficulty has arisen in the visualisation of the definitive restoration when treatment is complete.[6] As the mass of remaining tooth tissue is reduced the ability to retain a restoration diminishes and so does the likelihood of an optimal coronal seal, which has been shown to play a significant role in success.[7] Indeed, the prognosis of heavily restored teeth with previous history of failed secondary root canal treatment can be considered less favourable than an otherwise intact tooth requiring primary root canal treatment (Figures 1–3).

The real answer to a dynamic question that has cropped up in so many dentists' minds during their careers – 'is this tooth restorable?' – does not require a yes or no answer as any tooth can be 'restored'. The challenge faced by any restoration is time and thus longevity of the treatment provided. The need for an index measuring tooth restorability has long been cited.[8] This need has become more of a requirement as the quality of coronal restoration is now a significant factor in endodontic outcome.[7] Clinical data utilising previously developed tooth restorability indices are required to aid in tooth assessment and so improve endodontic outcomes.

When teeth present with previous primary root canal treatment and persisting disease, the clinician needs to balance all factors that can be improved upon from both endodontic and coronal restoration perspectives. The success rates of secondary root canal treatment are lower than primary attempts due to difficulties in negotiating and disinfecting a root canal system in which previous canal obstructions may be present, and due to the nature and location of root canal infection.[9] A further interface can manifest when the coronal restoration is optimal in contrast to poor root canal treatment and inaccessible persistent disease; consideration for apical surgery needs to be balanced against prognosis of the tooth and associated tissues post-surgery. Certain foresight is required as apical surgery will result in soft tissue trauma and pos-





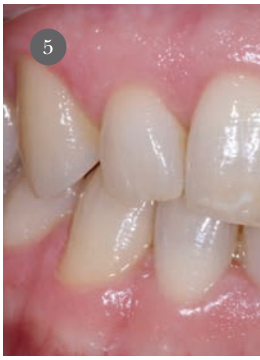


Fig 1 Root canal treated 11 and 21 subsequent to oro-facial trauma. Note the limited extra-coronal tooth tissue presenting with periapical health.

Fig 2 Due to repeated restoration failure both teeth were replaced with implants.

Fig 3 Final restorations placed on the 11 and 21.

Fig 4 Implants (11 and 21) placed in primary care. Both fixtures presented with peri-implantitis (21 peri-apical peri-implantitis). Also of note, the 22 presented with suboptimal root-canal treatment. Unfortunately the 21 implant required removal with remedial treatment provided for the defect. The 22 was root-canal re-treated optimally and retained.

Fig 5 Patient presenting with suppuration and mobility associated with the 21.

Fig 6 Radiographic examination revealed optimal root canal treatment but radiographic and clinical signs indicated restoration failure.

sible scarring in addition to an osteotomy site, which may compromise any prospective implant placement.[10]

If periapical surgery is attempted and the tooth reveals itself to be unrestorable, thus requiring extraction, guided tissue regeneration techniques can be applied prior to wound closure to optimise the site for future restoration.[11,12] The use of guided tissue regeneration (GTR) in the management of apical lesions during apical surgery has recently been addressed in a systematic review.[13] It was shown that large (>10mm) and through-and-through apical lesions would benefit from GTR as these lesions are more likely to result in incomplete healing. The positive effect of GTR on apical healing in these cases may improve bone mass but not necessarily quality for potential implant placement. Further to this, the immediate replacement of compromised teeth with implants at the time of abandoned periapical surgery is becoming more popular, despite a lack of high quality evidence on outcome.[14,15]

Where numerous teeth present with guarded prognoses, the assessment and appraisal of teeth adjacent to prospective implant sites is important for longitudinal treatment planning. Additionally, there has been some conjecture as to the association between the endodontic status of teeth adjacent to implants and peri-implant diseases (Figure 4).[16–18] In a retrospective study of 233 implants adjacent to endodontically treated teeth, vital teeth or lone-standing implants presented interesting results.[19] Implants adjacent to endodontically treated teeth had a 95% survival rate at nine months in comparison with 92% of those with no adjacent teeth and 99% adjacent to non-endodontically treated teeth. High-quality research seems to be required in this area where converting a tenuous association to causation may be difficult to achieve.

The replacement of teeth with questionable prognoses with implants is an accepted treatment pathway (Figures 5–9). The greater concern manifests when teeth that are restorable and amenable to endodontic treatment are extracted in favour of the implant option.[20] This practice can set a dangerous precedent as implants themselves can present with significant biological, aesthetic and mechanical problems that can be of comparable difficulty to primary or secondary root canal treatment.

One group of complications is peri-implant diseases, which are inflammatory processes resulting in either inflammation of the soft tissue around the implant or loss of bone. (Figure 10).[21] In a recent review the prevalence of these problems has been recorded in up to 43% of implant sites and 56% of subjects.[22] Management of this disease is difficult once it is established due to the inherent nature of the implant surface making optimal debridement difficult to achieve and a disease-free surface hard to maintain.[23,24] Indeed the presence of implant threads and the roughness of the surface are design features aimed at optimising integration; unfortunately these features are equally favourable for peri-implantitis progression.[21]

Implant threads are difficult to debride by patient or clinician and topographic features can promote biofilm development.[25] The optimal treatment regime for these diseases has yet to be realised. The efficacy of the non-surgical approach has been shown to be limited.[26] In comparison, a variety of surgical techniques have been advocated that have produced mixed results.[27] As the problem is relatively new and knowledge on its aetiology and progression is changing there is limited consensus on best management.[28]

Success and survival

Where there has been much conjecture is the comparison of 'success' between implants and root canal treatment. This comparison may seem spurious as root canal treatment aims to eradicate pathology in the form of peri-apical periodontitis whereas implant placement provides a means to restore an edentate space by way of successful physiologic osseointegration. These stark differences have not stopped comparisons for success between the two treatment modalities.

Success in endodontics has been measured through a variety of subjective, clinical and imaging methods. The most common mode of assessment has been the radiographic regression of a periapical lesion with associated bony infilling. This method of measuring success may seem harsh as the absence of complete radiographic regression of a periapical lesion may present on teeth that are symptom-free and functional. Indeed, a recent meta-analysis of outcome of primary root canal treatment identified strict (absence of periapical radiolucency)

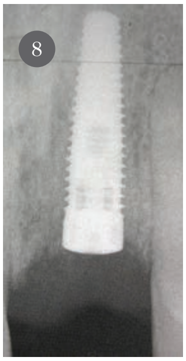


Fig 7 On periotome extraction horizontal root fracture was confirmed.

Fig 8 Implant placement in the 21 site was completed in a delayed immediate approach.

Fig 9 Interim implant restoration placed in the 21 site.

Fig 10 Patient presenting with peri-implantitis with suppuration on the 11 implant.

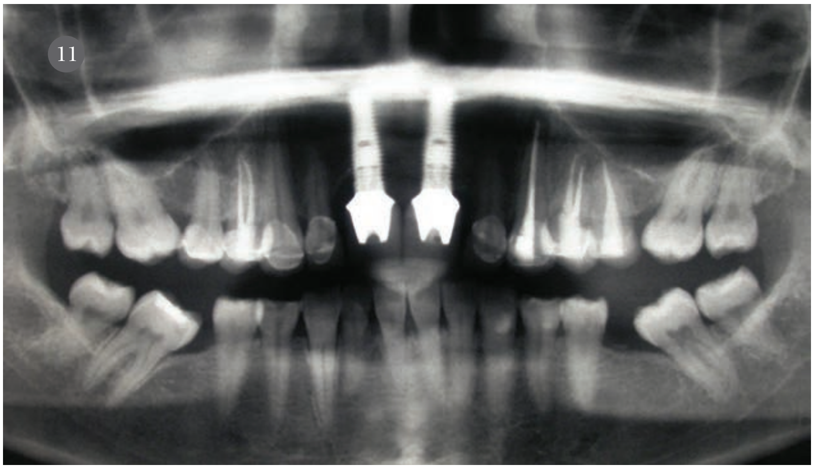
and loose criteria (reduction in size of radiolucency).[29] The success rates were found to be between 31–96%,and 60–100% respectively.[29] The pre-operative absence of a periapical lesion and an obturation with no voids extending to within 2mm of the radiographic apex with a satisfactory coronal restoration were seen to significantly improve the outcome of primary root canal treatment.[29]

The limitations of reliance on radiographic interpretation of disease regression need to be taken into account. Where histology, radiography and computed tomography have been compared for detection of periapical healing, radiographs consistently underestimated the size of the lesion.[30,31] As advanced imaging techniques, such as cone beam computed tomography, become more mainstream with potentially decreasing associated morbidity, current knowledge on outcomes of root canal treatment may change.[32]

The definition of success for either treatment option can be too stringent because the retention of either implant or tooth over a period of time is termed 'survival' and has been utilised to assess the two modalities.[33,34] This method can be open to interpretation as implants maybe retained long term with associated morbidities that may otherwise legislate further treatment. Similarly, root-canal-treated teeth may be retained in function with no significant progress towards healing.

Historically, criteria proposed by Albrektsson on success and bony remodelling for implants considered marginal bone loss of up to 1.5mm within the first year of placement to be acceptable and thereafter <0.2mm a year.[35] This can equate to 3.3mm of marginal bone loss at ten years, which could be considered significant by today's standards. A recent systematic review of survival and complication rates of single-tooth implants showed that 96.8% of implants were present at five years.[36] This favourable level of outcome needs to be tempered by the incidence of both biological and mechanical complication rates during this period. Nearly 10% of implants had associated peri-implantitis or soft tissue complications, with 6.3% exhibiting bone loss greater than 2mm. Mechanical complications included abutment or screw loosening (12.7%) and screw or abutment fracture (0.35%).[36]

As has been previously suggested, success for either treatment option is paradoxically different.[37,38] Short-term success rates for implants are considered very high whereas those for endodontically treated teeth tend to be more favourable in the long term, when there is an increased likelihood for late success as opposed to late failure.[39] A comparative study matched 196 single-tooth implants to 196 root-canal-treated teeth, comparing four different outcomes: success, survival, survival with intervention, and failure.[40] Interestingly, 73.5% of implants were considered successful in comparison with 82.1% of endodontically treated teeth. Failure was recorded in 6.1% of subjects in both groups. Implants required a significantly greater amount of interventions (18%), which varied from connective tissue graft and remedial surgery for peri-implantitis to screw loosening, although markedly fewer (3.6%) interventions for the endodontic group were noteworthy and included root canal re-treatment and apical surgery.



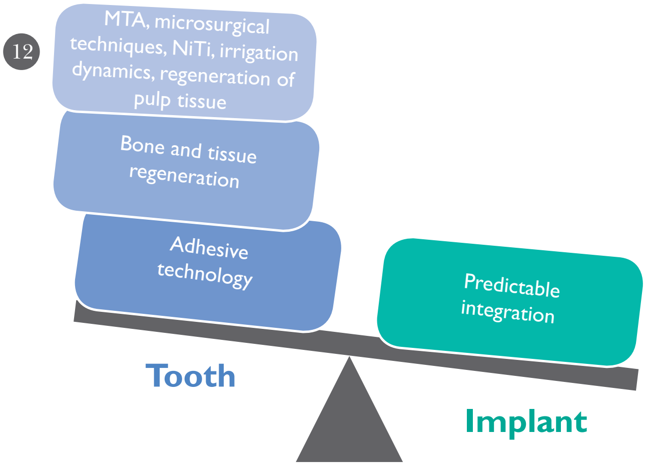


Fig 11 Dental panoramic tomogram of a patient that had undergone some cosmetic dentistry. Treatment involved the provision of implants, veneers and all-ceramic crowns. Radiographic examination revealed periapical lesions on the 22 and endodontic treatment that was provided subsequent to the cementation of both veneers and the crown restorations on the 14, 23, 24 and 25. Delayed responses to pulp testing were noted on the 12 and 13.

Fig 12 Is there imbalance in restorative dentistry?

Technological advancement: faster, happier, more productive?

Since Branemark's discovery of osseointegration there have been countless developments aimed at providing predictability and longevity. These developments were required as during the 1970s failure rates were greater than 50% in some cases.[41] These attempts differed conceptually and variations included topographic and morphologic designs, different materials, surface treatments and surgical protocols.[42] The current success of endosteal root-formed titanium implants has provided a platform for further research into all aspects of the osseointegration process. A recent review of the prosthodontic literature commented that a greater number of randomised controlled trials in commercially attractive topics such as dental implants were present than in any other field.[43]

What may also need to be considered is the quality of evidence in addition to the high risk of bias that is provided by manufacturers for changes in their designs and what long-term successes they will provide.[44] There are currently hundreds of implant manufacturers, all with their own product lines, surgical protocols and modes of restoration.[45] As new evidence emerges, companies tailor their products from year to year with the aim of providing the end-user with a newer, 'better' product. Such constant change seems strange as long-term high success rates of implants have been published for some time in addition to limited differences in success rates between different implant types.[46]

The constant turnover of new implant products may be fuelled by problems in the aesthetic zone, the need to place implants sooner after tooth extraction and also shortening the time to definitive restoration. As such, the rapidity of these changes may hinder implant maintenance in the long term, especially when considering an ageing population.[47] This aspect has been illustrated in a comparative study examining implant provision by maxillofacial surgeons treating patients with head and neck cancer between two time points 15 years apart.[48] In 1995, 30% of respondents were using 'Bonefit' implants (a previous Straumann product line), the popularity of which had disappeared by 2009 due to being superseded.[47] The repercussions of such changes on long-term maintenance, where implant systems become defunct, are difficult to predict.[42]

In comparison, endodontology has also undergone numerous changes and challenges, one significant threat being the 'focal infection theory' of the 1920s, which resulted in the wholesale extraction of non-vital teeth.[49] More recently, changes to NHS remuneration for root canal treatment present a challenge for primary care practitioners.[50] In contrast, the majority of implants are provided in a private setting. As such, it is probable that the context under which treatment is undertaken may influence practitioners' decision making.[51–53] Regardless of this, both treatment options have been shown to be cost-effective, depending on clinical presentation.[54]

Techniques used to achieve success in endodontics have been more or less constant over the past 100 years or so. The chemomechanical debridement of the root canal system under rubber dam isolation followed by obturation has been consistent but the methods and protocols in its delivery have changed with growing knowledge on the disease process. Chemomechanical debridement of the root canal system has become quicker but not necessarily more efficient with the advent of nickel titanium instrumentation. Sodium hypochlorite remains the mainstay in irrigation but methods in delivery and activation have seen significant progression.[55,56] Once preparation is complete there is now a plethora of obturation materials and techniques to fill the root canal system.[57] Despite such developments and accumulated experience there still remain cases resistant to treatment, with reported outcome rates not improving significantly over the last four decades.[29] New and innovative approaches tailored to current understanding of the disease process may be required to improve outcomes significantly in the future.[58]

The need for balance in restorative dentistry

As dentists part of our primary role is to preserve and conserve the natural dentition and, where indicated, extract those teeth considered to have a hopeless prognosis and, if required, restore the space. The maintenance of natural tooth tissue is important as restorations, however minimal, will inevitably require replacement in the future.[59] The conservative ethos has seemingly come under threat with the emergence of cosmetic dentistry in addition to opinions on replacing otherwise restorable teeth with implants.[10,20,60–63] (Figure 11).

Some authors have sought to compare endodontics and implants in the context of a choice of one over the other.[64–67] More recently, treatment planning algorithms have been devised to guide clinicians through the decision making process.[68,69] Unfortunately the treatment planning dynamic is seldom this straightforward. Balancing the clinical presentation with dentists' knowledge and technical abilities in addition to patient values and autonomy results in a decision-making process that shapes and defines itself. Research progression and technological advancement will also continually modify this pathway.

During the emergence of predictable osseointegration there have also been numerous significant milestones in other areas of restorative dentistry to treat those teeth previously considered of poor prognosis. These have seemingly had less exposure as management of teeth requiring remedial treatment may not seem to carry the same kudos as implant placement. As such, the balance between the utilisation of these techniques to retain teeth and extraction for implant placement seems uneven (Figure 12). Examples of these include the use of guided tissue regeneration in the management of a variety of periodontal defects.[70] Where limited tooth tissue is available the gradual evolution of adhesives may allow clinicians to restore teeth with limited extra-coronal dentine and enamel, or provide minimally invasive resin-bonded restorations to replace teeth.[71–73]

In some circumstances the retention of unrestorable teeth with the aim of optimising soft and hard-tissue healing while maintaining bone for future implant placement has been advocated (Figures 13–16).[74] This ethos has some substance as the placement of implants in either previously endodontically or periodontally infected sites can require thorough debridement, prophylactic antibiotics and tissue regeneration, and result in impaired bone-to-implant contact.[75] Where clinicians have previously separated endodontic procedures and implant placement, contemporary treatment planning should aim for a restorative continuum between the two modalities. Time invested in optimal root canal treatment, may aid future restorative planning, especially where an implant restoration is envisaged in the future.

There has been a recent movement towards recording patient-related outcomes within general healthcare and dentistry.[76] Indeed, similar oral health impact profiles have been shown in patients treated with either end-

Fig 13 13-year-old male presenting with a decoronated 21 as a result of trauma. A sinus was present buccally on the 21. Note the wide-open apex with sub-optimal root canal treatment and post-core restoration.

Fig 14 The post-core restoration was removed to reveal limited extra-coronal tooth tissue.

Fig 15 Radiographic completion of root-canal treatment. Mineral trioxide aggregate was placed in the apical 5mm with the remaining space obturated with fibre posts.

Fig 16 Utilisation of adhesive posts and composite to restore. The patient was made aware that the long-term prognosis of this tooth was guarded and that once he had completed growth an implant could be considered for the 21 site.

odontic treatment for a single tooth or those restored with a single implant crown.[77] The overriding message from all patients that participated in the study was that every effort in conserving and maintaining the natural dentition should be made wherever possible.[77]

Conclusion

Within a changing field, an approach that does not exhaust invasive options early in the restorative process is advisable. Where teeth are considered unrestorable the planning for tooth replacement needs to commence prior to tooth extraction. Despite high success rates of implants, maintaining balance when planning the treatment of a restorative case is important, especially when considering the conservative ethos in healthcare provision.

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