Peri-implantitis and the prosthodontist

A. Dawood,*[1] B. Marti Marti[1] and S. Tanner[1]

In brief

- Peri-implantitis is a poorly understood condition which is difficult to manage and better prevented with careful control of all phases of treatment.
- Many aspects of prosthodontic treatment have an impact on peri-implant heath with far reaching potential consequences.
- Prosthodontic procedures such as impression taking, temporisation, and cementation may have long term consequences as a result of contamination of the implant surface.
- The use of low cost generic components, inappropriate materials, and poor decisions made in the laboratory may all impact upon peri-implant health.

Peri-implantitis has been described as progressive crestal bone loss around a dental implant. The condition is poorly understood, and is challenging to manage; it is commonly and widely attributed to issues with the implant, the implant surface, surgical technique and oral hygiene. The effect of prosthodontic stages of treatment on the postoperatively established state has not been adequately investigated. It is the authors' contention that the manner in which the implant is restored contributes significantly to prognosis and peri-implant disease experience, and that the role of prosthodontic aspects of treatment in the causation of peri-implantitis may be seriously underestimated. The prosthodontist has a clear role and responsibility in the avoidance of future peri-implant problems by ensuring that implants are restored in an entirely biologically and biomechanically sound manner. The number of implant treatments carried out year-on-year is rising apace, with more and more implants being restored in general dental practice. With the rapid emergence of lower cost dental implant systems and a broadening range of generic restorative options and components for well-established systems, there is an increasing need to consider and understand how the implant restorative process may have a negative impact upon the peri-implant tissues, and how this effect may be minimised and peri-implant health promoted and maintained by paying attention to detail throughout the entire process.

Introduction

For many general practitioners and prosthodontists referring to surgeons for implant placement, it may seem that they are dealing with an already established state which will not be impacted upon by subsequent prosthodontic treatments. However, this is not the case; the role of prosthodontic aspects of treatment in the causation of peri-implantitis may be seriously underestimated.

This article is not intended to be an epidemiological survey of disease experience but is a reflection of 25 years of implant dentistry in a single practice, and the treatment outcome of thousands of patients who have received dental implant supported restorations within the practice or elsewhere, or who have been referred with implant problems.

Over this time the authors have seen a multitude of implant systems restored using different approaches within their practice, and also by referrers to the practice who have used alternative restorative components, materials and methodologies. It has become clearly evident to the authors that the manner in which the implant is restored contributes significantly to prognosis and peri-implant disease experience, and that the individual providing the restoration also has a clear responsibility in ensuring the long-term health of the peri-implant tissues.

[1]Dawood and Tanner Dental Practice, 45 Wimpole St, London, W1G 8SB, UK
*Correspondence to: Dr A. Dawood
Email: andrewdawood@hotmail.com

Refereed Paper. Accepted 5 July 2017
DOI: 10.1038/sj.bdj.2017.755

Definition and prevalence

Peri-implant disease is usually described as peri-implant mucositis when inflammation is confined to the peri-implant mucosa (Fig. 1a), and peri-implantitis (Fig. 1b) when the inflammation is accompanied by loss of crestal bone tissue.[1,2] These conditions around implants may be thought of as being analogous to gingivitis and periodontal disease in relation to teeth.

Before considering the prevalence of a disease it should be clearly defined; the rate at which bone loss takes place is a critical part of the definition of peri-implantitis.[3] It is therefore disappointing and unsettling to find that there is no clear-cut definition for a condition that may have a dramatic effect upon our patients, their implants and our practices.

'Normal' bone remodelling around implants has been described to be in the order of 1 mm during the first year of function and further loss of less than 0.2 mm each year subsequently.[4,5]

In 2008 Zitzmann & Berglundh reported that the prevalence of peri-implantitis varied widely in the literature, from 6.47% to 28%, depending on the criteria adopted to define peri-implantitis, the follow-up time, and implant variables.[1]

Official journal of the British Dental Association.

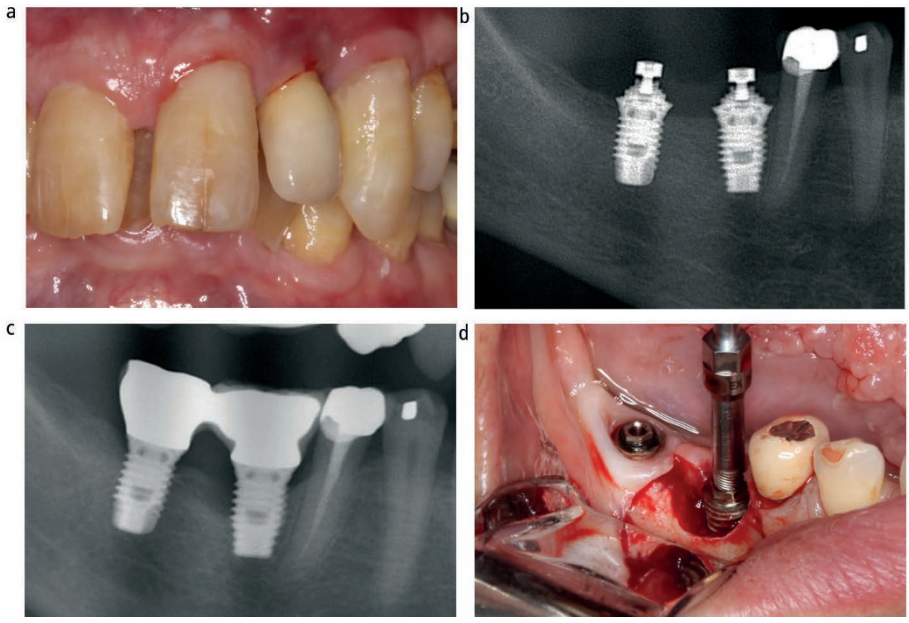

Fig. 1 (a) Peri-implant mucositis; cleaning is poor and there is gingival inflammation present in association with the natural central incisor tooth and the lateral incisor implant unit. (b-d) Progressive bone loss associated with an implant with peri-implantitis. There is an interval of 2.5 years between the radiographs. An implant retrieval tool is being used to remove the failing implant

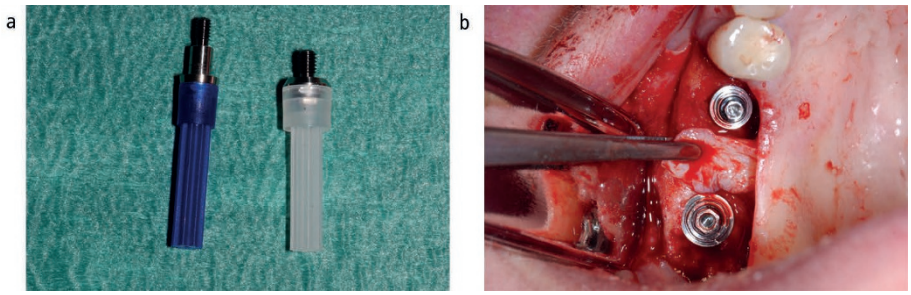

Fig. 2 Titanium 'Multiunit' abutments fitted at time of dental implant surgery for a one-time connection

Fransson *et al.* diagnosed 40% of implants with progressive bone loss,[3] whereas Roos-Jansaker *et al.* found 6.6% of their long-term followed-up implants to suffer from peri-implantitis.[6] In the opinion of Jemt and Albrektsson even the lower range of these figures may be overstating a problem, which may simply represent normal bony remodelling, and which may also be associated with the particular design and topography of each individual implant.[7]

A brief review of the literature indicates that peri-implantitis is poorly understood,[8] may be difficult to avoid,[9] and is difficult to treat.[10] There has been a great deal of attention given to the effect of patient health,[11] smoking[12] and the presence or pre-existence of gum disease,[13] implant type,[14] implant surface,[15] and quality of the bony site,[16] all factors which may contribute to susceptibility or disease progression. Recent opinion considers the possibility that peri-implantitis may be a manifestation of an immunologically-mediated foreign body reaction.[8] This is certainly worthy of careful investigation, however peri-implantitis generally takes place at the crestal margin of the implant; if it were immunologically-mediated, then why would it not appear along the entire length of the implant? Meanwhile, prosthodontic treatment takes place at the level of the implant platform or the abutment, and the prosthesis is connected at this crestal level. The authors thus feel that prosthodontic treatment must have enormous implications for peri-implantitis experience, yet the long-term impact of this is poorly documented.

Whatever criteria are used to define the condition, it is clear that more and more of our patients are receiving implant treatments,[17] and these treatments are being delivered by an increasing number of practitioners[18] with varying degrees of experience. This means that peri-implantitis is a condition, which will inevitably be widely encountered and will need to be managed in general and specialist practice. If even a small percentage of patients are affected there is the potential for this to compound exponentially to create a burgeoning problem.

Most studies reported in the literature have taken place in carefully controlled environments in universities or specialist centres, using implants from long established manufacturers. Considering the large number of systems available, few implant systems are well described in the literature. In the studies that are reported, reference is rarely made to the prosthodontic procedures that have been carried out or the restorations that have been provided on the implants, and with the exception of studies relating to the delivery of screw- or cement-retained restorations, few studies link the presence of disease to this aspect of the overall treatment.

Despite this lack of focus on the prosthodontic aspects of treatment, even the simplest implant reconstruction is a multi-part process, each step having the potential to subtly or markedly affect outcome and future peri-implantitis experience.

Peri-implantitis may be more frequently encountered when planning is poor, restorations are poorly designed and manufactured, implants and implant components are poorly engineered, and surgery poorly executed; for these cases, the dentist involved is unlikely to proudly report the treatment outcome, and so there is an inevitable absence of literature which explores the outcome of treatments which have taken place outside of carefully controlled environments.

Consent and risk management

With so much information freely available on the internet, patients might reasonably expect to be informed of the availability of scientific evidence supporting the use of a particular type of implant or prosthesis, particularly if they are to be the recipient of a newly-launched component. Patients appear to have a perception that implant treatments are robust, and permanent – a lifetime solution to their dental problems. This may well be the case in an elderly patient, but many younger patients with this rose-tinted view may eventually be disappointed.

Official journal of the British Dental Association.

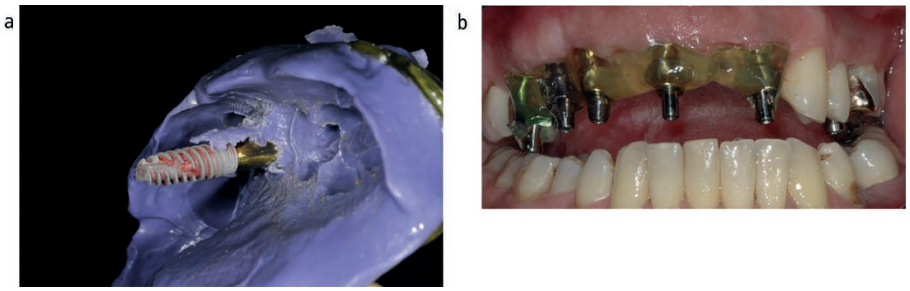

Fig. 3 (a) In this case impression material has extruded into an extraction site and onto the implant surface, motivating the author to remove and replace the contaminated implant. (b) Use of a low viscosity resin material to link implant impression copings – another potential contaminant

There is no shame in acknowledging that peri-implantitis is a poorly understood condition that may be difficult to avoid and impossible to treat. After all, patients requiring dental implants have usually lost their own teeth through disease. An implant-supported restoration may be an alternative to a fixed bridge or a removable prosthesis; it may be seen as a replacement for a missing or failing tooth; but it is a poor substitute for a healthy tooth.

Proper informed consent is an essential prelude to any medical intervention. Patients must be informed of the potential for future problems, the need for maintenance and the anticipated longevity of an implant-supported reconstruction. Described at the outset our patients perceive this information as an explanation; later on, if given for the first time, the same information is perceived as an excuse. A frank and open discussion is needed in order to gain consent, and this consent process should be documented.

The first prosthodontic phase

Abutment connection

There is evidence[19] that avoiding the repeated connection and disconnection of components at fixture head level will reduce bony remodelling; this would seem intuitive as every time a titanium or zirconia component is removed from the fixture head, a hemidesmosomal connection[20,21] is severed and needs to be re-established. The use of an abutment is particularly important when the implant is deeply placed.[22] While careful and purposeful repeat activity at the fixture head may be avoided, this interface must be treated with respect and unnecessary insult to the tissues or contamination of components avoided. Each treatment stage and the components and materials needed should be planned in advance, aiming to minimise the number of procedures.

It would seem to make a great deal of sense to provide a one-time connection of a sterile implant abutment at the time of implant placement or at the time of second stage implant surgery if at all possible, such that a definitive abutment is fitted and further access to the implant, and any interference with the tissue cuff surrounding the abutment and fixture head, is avoided as far as possible (Fig. 2). The use of a prefabricated abutment for screw retention, fitted at the time of surgery, is well documented.[23] Prefabricated abutments for cement retention may also be used to provide support for a temporary crown at the time of surgery, but their use might involve an increased level of tissue manipulation or surface contamination when abutments are prepared intra-orally or if impressions are made of the abutment in place.

In the period immediately after implant surgery, stability of the wound is important. Saliva ingress and plaque formation on a healing abutment or an abutment may possibly trigger bony re-modelling at this early stage. If the implant itself lies exposed, for example, in an extraction site or beyond the bone crest, then it too may be vulnerable to contamination, and this issue may extend to biomaterials placed in close proximity to the implant.

The use of a preoperative chlorhexidine rinse[24] and the need to begin oral hygiene procedures over the implant site within a few days of surgery is normal practice for the author. However, the surface of the implant may itself possibly be contaminated by the use of a substantive chlorhexidine rinse.

Impressions and temporary restorations

Whether restoration of the implant begins at the time of surgery (if immediate loading is carried out) or following a conventional healing period, making an impression with a dental impression material or using resins, composites or adhesive bonding agents will all put potentially contaminating dental materials in proximity to the implant platform or definitive abutment. Contamination of the implant or abutment surface, particularly of a high energy, rough surface with a low-viscosity dental material (Fig. 3) may have the potential to preclude uniform osseo- or tissue integration, and so their use must be carefully constrained. Clearly, if such materials are used at the time of surgery there is more scope for contamination, particularly if the rough surface of an implant is exposed, or if retraction cords are used and tissue is retracted beyond the implant platform, or if material remnants are left behind.

If the rough surface of an implant extends all the way to the implant platform then contamination at the level of the platform may in turn lead to lack of integration followed by bacterial colonisation, which may act as an initiator of, and focus for peri-implant disease. Implants having a machined collar may be less prone to contamination; the machined collar acting as a 'fire-break', distancing potential contaminants from the deeper, rougher and more adsorbent surface.

Connection of a machined titanium or zirconia definitive abutment at the time of surgery not only avoids or minimises later disruption of the adjacent delicate tissues, but means that restorative procedures take place more superficially, minimising insult, and also as it happens making the experience more comfortable for the patient. Used, cleaned, and sterilised titanium healing abutments may harbour contaminated remnants[25] that have the potential to negatively impact peri-implant tissues. The practice of reusing healing abutments or abutments is not acceptable despite being considered by some to be a cost-effective measure in dental practice.[26]

Laboratory phase

A robust relationship with an experienced technical team will help to ensure that treatment progresses purposefully and positively, minimising steps towards the definitive restoration. Although interaction with the technical team is most important and gives the clinician access to experience that extends beyond the confines of their own practice, the clinician must remember that they carry the burden of responsibility for the restoration (and the implant that supports it) for many years to come, and that the biological

Official journal of the British Dental Association.

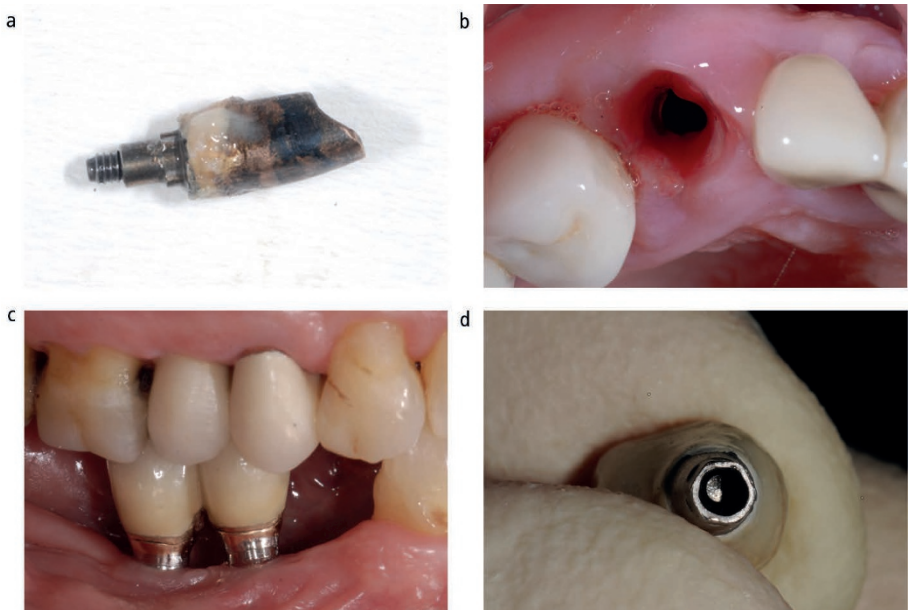

Fig 4 (a and b) Gold abutment removed from implant. Note the accumulation of plaque on the abutment surface and the inflamed peri-abutment tissue; (c) The lack of tissue integration with a gold abutment leads to recession as the biological width re-establishes apically; (d) A gold abutment which has been made using the lost-wax process will have a poorly engineered surface

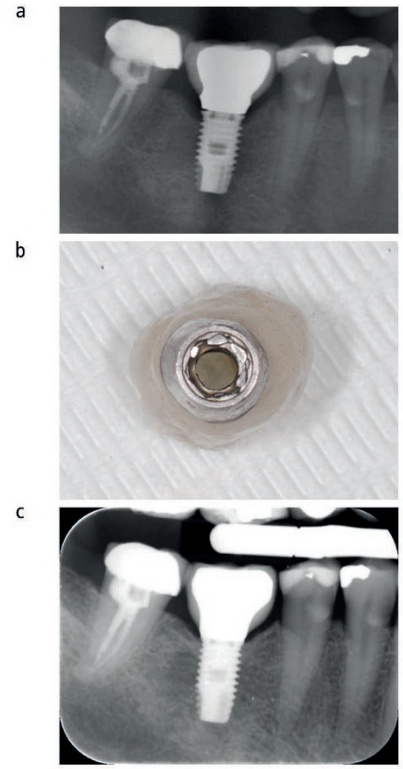

Fig. 5 A patient returned for review having been provided with a screw retained porcelain bonded to milled cobalt chrome implant crown, fitted directly to the implant. Note (a) the poor fit and (b) the poorly engineered fit surface of the crown; (c) The crown was removed and a screw retained porcelain bonded to zirconia abutment was provided; note bone gain around zirconia abutment one year later

consequences of actions taken in the dental laboratory become owned by the clinician. Parameters such as material choice, abutment selection, the use of prefabricated or custom components, and the use of potentially less precise (in-house computer aided design – computer aided manufacturing [CAD-CAM]) technologies, or cast or machined non-implant grade materials all have biological and clinical ramifications which are harder to appreciate when an impression sits on the laboratory bench. The restoration must be made to the clinician's prescription as some technical decisions which may have important biological consequences may be absolutely contrary to convenience or ideal aesthetics, for example, the subgingival extension of porcelain or resin materials.

Abutment material selection

Titanium and zirconia are implantable biomaterials.[27] Gold alloys and porcelain bonding alloys such as gold alloys and cobalt or nickel chromes have poor biological properties[28] and would ideally not be placed into the tissues (Fig. 4ac). An experimental study in dogs carried out by Abrahamsson *et* al.[28] showed that no proper soft tissue attachment formed where gold abutments were used.

The fit of a cast abutment cannot be as good as the fit of a milled pre-fabricated or custom abutment, even where a pre-formed gold abutment has been used in the lost wax process,[29] as the casting process and subsequent processing will inevitably damage the engineered surface (Fig. 4d). As reported in the literature,[30] and also in the authors' experience, loosening of the abutment screw is also more common for these abutment types.

With the growth of digital manufacturing, the wide availability of generic components, and the increasingly more common use of 'in-house' low cost milling units, there is a pressure on the dental team to use parts which may not perform as intended in the long-term; the stability of screw connection has not been reported for these types of components, where poor fit and poor biological properties may all impact upon the tissues (Fig. 5).

Abutment material selection is a clinical decision, which should be influenced by the technical team, but not dictated by the technician.

Planning for screw or cement-retention

Screw retention of implant crown and bridgework facilitates retrievability, and completely eliminates the risk of subgingival cement extrusion. However, lack of precision can result in poorly fitting bridge substructures, or tight contacts between adjacent implant restorations, generating high-level standing loads with the potential to hasten component fracture and possibly contribute to crestal bone loss.[31] Cement retention may make it more straightforward to accommodate implant placement where the screw-axis of the implant would otherwise emerge inappropriately,[32] but evolving CAD-CAM technology makes possible the creation of angled screw channels, making the need to use cement retention less important for some systems[33] (Fig. 6).

Where cement retention is unavoidable, placing the restoration/abutment margin supragingivally will reduce the potential for cement extrusion into the tissues and even in aesthetic zones may still be practical, by using zirconia abutments and appropriate cements/adhesives, and/or designing the contour such that only the most visible part of the interface is designed to be at or just below the gingival margin (Fig. 7a).

Repeated trauma to the tissues caused by frequent debonding of a cement retained restoration may be harmful, and also makes it more likely that cement will be extruded subgingivally. Placing restorative margins subgingivally in an attempt to improve retention will exacerbate this issue, however placing restorative margins supragingivally may reduce the height of an abutment making retention less reliable. In such cases the vertical walls of the abutment should

Official journal of the British Dental Association.

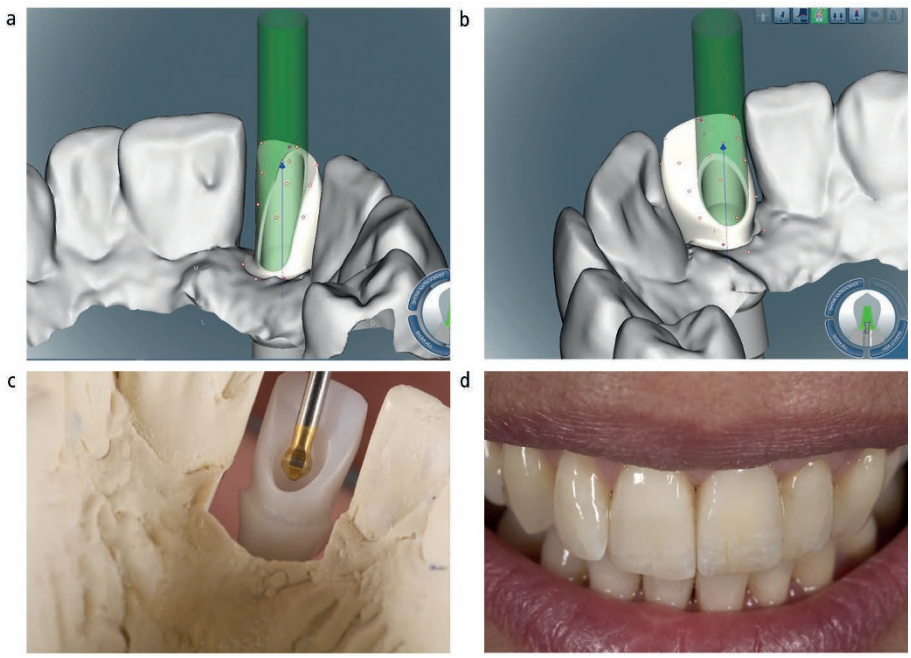

Fig. 6 CAD CAM design of a zirconia abutment onto which porcelain will be directly bonded. The screw channel would emerge through the incisal edge of the tooth (a) without angle correction (b) which makes it possible to re-angulate the channel to emerge on the palatal surface of the abutment where use of a special screwdriver (c) allows the crown to be screw-retained (d)

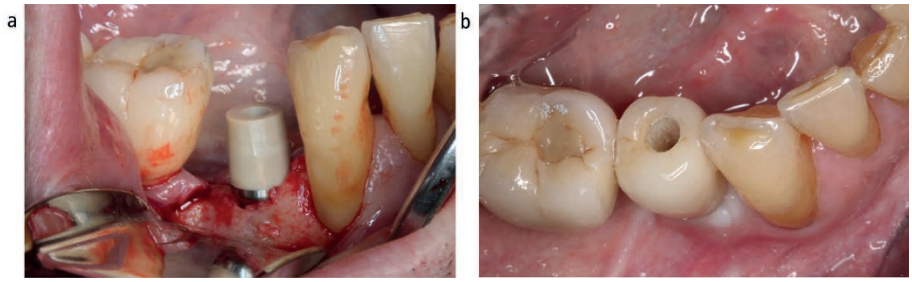

Fig. 9 An abutment (On1, Nobelbiocare) fitted and scanned at the time of surgery – the healing cap acts as a IOS scan flag (a); The all-ceramic crown ready to seat definitively 6 weeks later (b)

be sandblasted to improve retention, and where the abutment lacks bulk, the use of zirconia as an abutment material should be avoided as it is more fragile. It generally makes sense to use screw retention where there is little interocclusal space, or to use permanent adhesives and perforate the restoration to allow screw retention, particularly for single tooth restorations on titanium abutments, avoiding the use of less reliable temporary materials and allowing the cementation process to take place extraorally (Fig. 8), rather than intraorally – Figure 8a also shows the concave form of the abutment as it emerges from the implant platform, another desirable[34] feature of the abutment design.

There is controversy regarding the benefits of using an abutment of a lesser diameter than the implant platform.[35,36] The consensus appears to be that the abutment should emerge with a concave contour, allowing for maintenance of an increased tissue volume, though the long-term benefits of this morphology have not been well documented. However, fitting abutments of this form is a more comfortable process for the patient, and the tissues seem to be less prone to recession. For CAD-CAM abutments, milling devices have inherent geometric constraints such that creating a defined concavity may need to be accomplished by hand.

As described above, abutments are ideally fitted at the time of surgery and would ideally be designed for screw retention of easily retrievable prostheses (Fig. 9). However, this is not always practical or possible because of constraints which lie in the implant system or implant position.

The combination of a poorly fitting, poorly sealed, and deeply placed abutment may be particularly damaging.

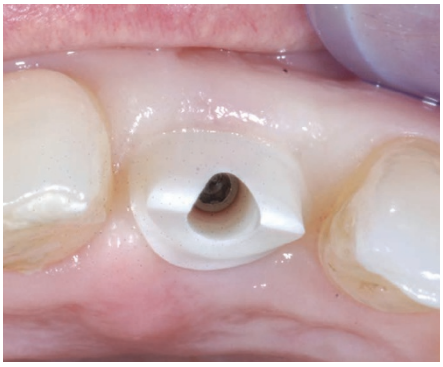

Fig. 7 A CAD CAM zirconia abutment designed to have supragingival margins palatally, with the buccal margin just beneath the buccal gingival margin so as to minimise the potential for cement extrusion

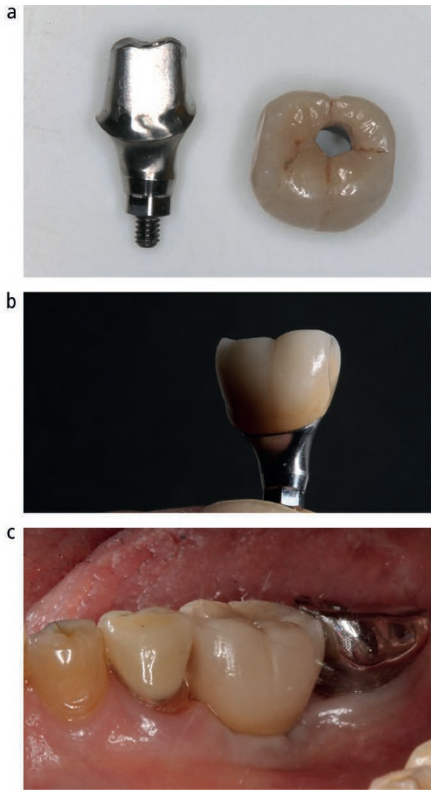

Fig. 8 This porcelain bonded to metal crown (a) has been perforated so that it can be permanently cemented onto a CAD CAM titanium abutment extraorally (b) and then fitted as a screw retained restoration (c). Note the concave emergence from the implant platform

Designing for maintenance

Excellent hygiene maintenance has been shown to improve long-term outcome.[37] Designing for maintenance begins with the correct planning and management of the surgical phase of treatment to ensure that the implant is in the correct position to support a well-designed

Official journal of the British Dental Association.

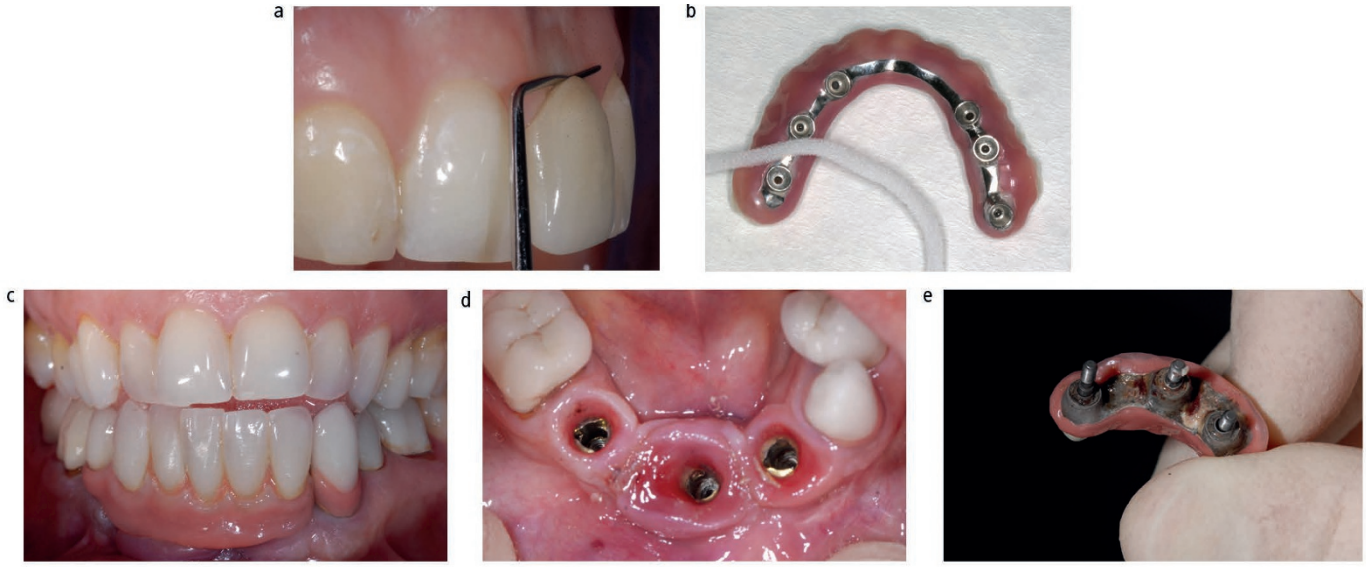

Fig. 10 The poorly positioned implant is restored with a cemented single crown estoration. Removal of any extruded cement and normal hygiene procedures are compromised by this positioning (a); Design of fixed implant-retained bridges for oral hygiene maintenance: flat and polished surfaces that allow the introduction of floss or interdental brushes; (b) This poorly designed prosthesis entirely covers the tissues around the implants, the tissues are highly inflamed with peri-implantitis and deep pocketing; (c) The prosthesis is uncleansable, and has been made on a dental alloy casting which will inevitably fit poorly and accumulate plaque (c-e)

prosthesis. Although patients may well prefer to have prostheses that tightly conform to the tissues beneath, it is important to make sure in the laboratory that there is easy access for oral hygiene procedures suited to the patient's physical capacity (Fig. 10). Ridge-laps are to be avoided, and the under surface of fixed bridgework should be easily accessed – ideally convex along its entire length. Preferably the under surface of the bridgework would fit against the tissues with a polished titanium or zirconia surface. Fixed bridges may be provided with grooves which guide the introduction of floss or interdental brushes[38] – it may be useful for the technician to try these aids in the laboratory before fitting a prosthesis.

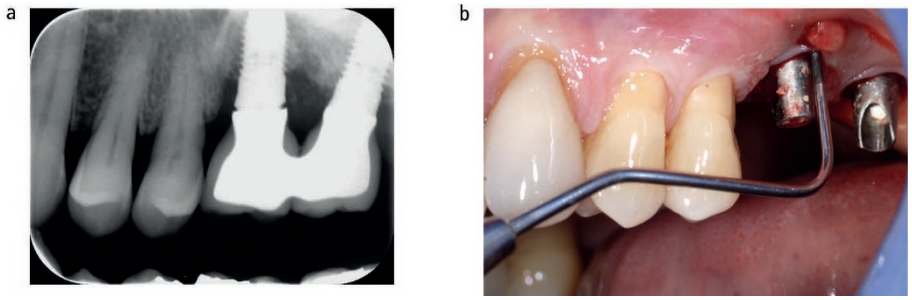

Fig. 11 The poor fit of the front implant crown (a) has led to peri-implantitis and deep pocketing (b)

The second prosthodontic phase

Decontamination

Upon completion of laboratory work, abutments that have been open and manipulated in the laboratory should be de-contaminated and sterilised. Removing fine debris such as porcelain or abrasive particles or metal swarf will improve seating. The presence of debris in a screw joint will increase friction and reduce dependability, making screw-loosening more likely.[39] Similarly, single tooth restorations fitting at fixture level such as one-piece zirconia-bonded crowns require careful decontamination.

Fitting screw-retained restorations

Seating screw-retained restorations should be straightforward. For fixed bridgework, each screw should rotate freely as it is tightened into place, with no build-up in tension at all until the last quarter rotation – ideally less

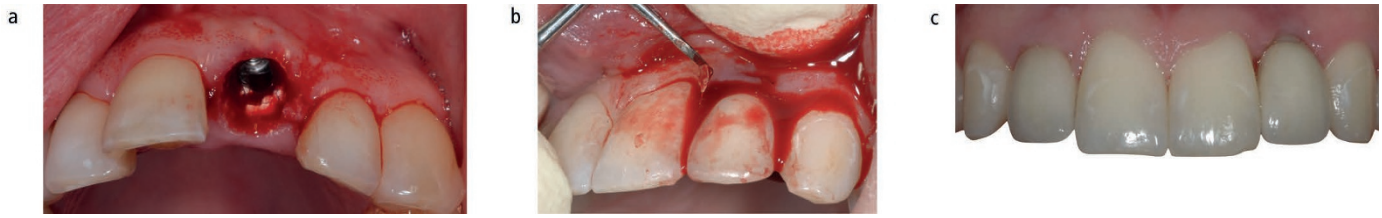

Fig. 12 Gross extrusion of cement can be painful and cause severe inflammation, (a) Even a small amount of extruded adhesive can cause severe problems (b) – at the time of removal of a small fragment of extruded adhesive; (c) 2 months later, note recession and remodelling exposing the abutment margin – compare with contralateral incisor implant

Official journal of the British Dental Association.

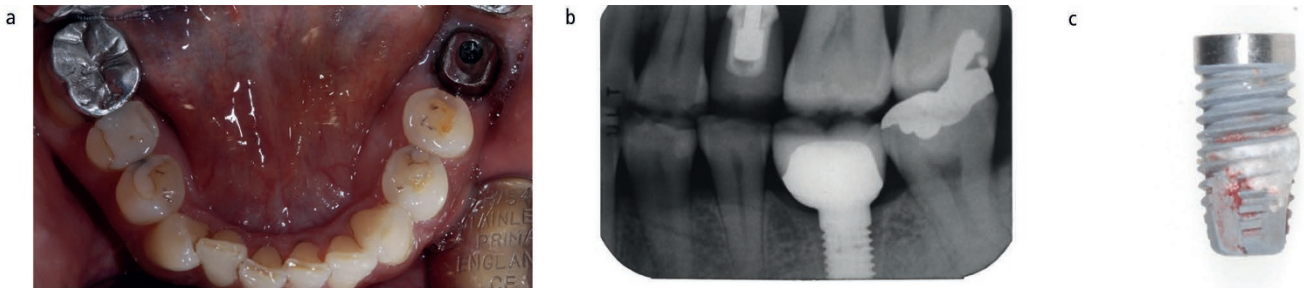

Fig. 13 The patient reported increasing awareness of the lower left first molar implant which had been provided 10 years earlier, and that the crown had debonded on multiple occasions and was now tender to pressure. The implant crown was found to be in supra occlusion because of moderate erosive wear and attrition (a) affecting the other teeth (pictured with the crown off). A radiograph of the implant revealed a distinct bone defect associated with the implant (b). A week later the implant was loose and painful and was removed; note that there is bone adherent to the implant surface

– indicating that the framework fits passively (ideally onto an abutment rather than directly to the implant),[40] the screws simply serving to hold the prosthesis in place. The clinician would be unwise to accept a poorly fitting framework; apart from possible contributions to the development of peri-implantitis later on,[41] component failure is more likely.[42]

The abutment screw access should be adequately sealed to prevent it from acting as a channel and reservoir of microbial species.[43] The use of polytetrafluoroethylene tape and composite resin minimises microbial leakage.[44]

Fitting cement-retained restorations

There is a view that a cement-retained prosthesis will have a better tolerance for slight misfit,[45] however, a poor fit and subgingival open margin may cause inflammation, as it would in a conventional prosthesis, which may lead to plaque accumulation and the initiation of peri-implant inflammation (Fig. 11). Cement extrusion is one of the most conspicuous and widely recognised causes of peri-implantitis. Extruded cement (Fig. 12) has been widely reported as being found in association with peri-implant lesions,[46] and may sometimes be resolved after removal of the excess cement.[47] The risk of cement extrusion may be minimised by planning for supragingival abutment margins, and by using just sufficient cement for the purpose; various means to achieve this have been proposed.[48]

Occlusal considerations

Screw loosening may result from non-axial or excessive forces, and the long-standing presence of an unstable abutment or restoration may again act as an initiator for peri-implantitis.

There is no consensus as to whether heavy occlusal forces may promote peri-implantitis,[49] but implants may well fail with little warning if inappropriately loaded. It is the authors' belief that this sort of rare failure is distinctly different to peri-implantitis, but suggests that there may well be an occlusal influence. High loading forces should be avoided, making sure that implant restorations do not feature non-working-side or unplanned heavy working side contacts. Excessively worn anterior guiding surfaces should be repaired when necessary, to avoid unplanned posterior loading (Fig. 13). The occlusion may slowly change with time[50] and surgeon, prosthodontist and patients must understand the ongoing need for the implant restoration to be monitored both in the immediate post-fitting period, and subsequently over the patient's lifetime.

Conclusion

At this time no one can reasonably claim to fully comprehend all the causes of peri-implantitis, but it is evident that there are many factors which may initiate the problem, and that many of these relate to prosthodontic and dental laboratory-based aspects of the treatment. While there is no evidence to support a particular approach to the treatment of peri-implantitis, the authors suggest that the selection of a well tried and tested implant with scrupulous attention to the execution and delivery of a biologically and biomechanically sound prosthesis is a sensible approach to the avoidance of peri-implant problems.

1. Zitzmann N U, Berglundh T. Definition and prevalence of peri-implant diseases. *J Clin Periodontol* 2008; **35:** 286–291.
2. Lindhe J, Meyle J; Group D of European Workshop on Periodontology. Peri-implant diseases: consensus report of the sixth European workshop on periodontology. *J Clin Periodontol* 2008; **35:** 282–285.
3. Fransson C, Wennström J, Tomasi C, Berglundh T. Extent of periimplantitisassociated bone loss. *J Clin Periodontol* 2009; **36:** 357–363.
4. Albrektsson T, Zarb G, Worthington P, Eriksson A R. The long-term efficacy of currently used dental implants: a review and proposed criteria of success. *Int J Oral Maxillofac Implants* 1986; **1:** 11–25.
5. Roos J, Sennerby L, Lekholm U, Jemt T, Gröndahl K, Albrektsson T. A qualitative and quantitative method for evaluating implant success: a 5-year retrospective analysis of the Brånemark implant. *Int J Maxillofac Implants* 1997; **12:** 504–514.
6. Roos-Jansåker A M, Lindahl C, Renvert H, Renvert S. Nine-to-fourteen-year follow-up of implant treatment. Part II: presence of peri-implant lesions. *J Clin Periodontol* 2006; **33:** 290–295.
7. Jemt T, Albrektsson T. Do long-term followed-up Brånemark implants commonly show evidence of pathological bone breakdown? A review based on recently published data. *Periodontol 2000* 2008; **47:** 133–142.
8. Albrektsson T, Canullo L, Cochran D, De Bruyn H. 'Peri-implantitis': a complication of a foreign body or a man-made 'disease'. Facts and fiction. *Clin Impant Dent Relat Res* 2016; **18:** 840–849.
9. Graziani F, Figuero E, Herrera D. Systematic review of quality of reporting, outcome measurements and methods to study efficacy of preventive and therapeutic approaches to peri-implant diseases. *J Clin Periodontol* 2012; **39:** 224–244.
10. Esposito M, Grusovin M G, Worthington H V. Interventions for replacing missing teeth: treatment of peri-implantitis. *Cochrane Database Syst Rev* 2012; **1:** CD004970.
11. Salvi G E, Carollo-Bittel B, Lang N P. Effects of diabetes mellitus on periodontal and peri-implant conditions: update on associations and risks. *J Clin Periodontol* 2008; **35:** 398–409.
12. Turri A, Rossetti P H, Canullo L, Grusovin M G, Dahlin C. Prevalence of peri-implantitis in medically compromised patients and smokers: a systematic review. *Int J Oral Maxillofac Implants* 2016; **31:** 111–118.
13. Mombelli A, Müller N, Cionca N. The epidemiology of peri-implantitis. *Clin Oral Implants Res* 2012; **23:** 67–76.
14. Heitz-Mayfield L J. Peri-implant diseases: diagnosis and risk indicators. *J Clin Periodontol* 2008; **35:** 292–304.
15. Albrektsson T, Wennerberg A. Oral implant surfaces: Part 1 – review focusing on topographic and chemical properties of different surfaces and in vivo responses to them. *Int J Prosthodont* 2004; **17:** 536–543.
16. Alani A, Bishop K. Peri-implantitis. Part 2: Prevention and maintenance of peri-implant health. *Br Dent J* 2014; **217:** 289–297.
17. Alani A, Bishop K, Renton T, Djemal S. Update on guidelines for selecting appropriate patients to receive treatment with dental implants: priorities for the NHS-the position after 15 years. *Br Dent J* 2014; **217:** 189–190.
18. Mattheos N, Albrektsson T, Buser D et al. 1st European Consensus Workshop in Implant Dentistry University Education. Teaching and assessment of implant dentistry in undergraduate and postgraduate education: a European consensus. *Eur J Dent Educ* 2009; **13:** 11–17.
19. Canullo L, Bignozzi I, Cocchetto R, Cristalli M P, Iannello G. Immediate positioning of a definitive abutment versus repeated abutment replacements in post-extractive implants: 3-year follow-up of a randomised multicentre clinical trial. *Eur J Oral Implantol* 2010; **3:** 285–296.
20. Swope E M, James R A. A longitudinal study on hemidesmosome formation at the dental implant-tissue overflow. *J Oral Implantol* 1981; **9:** 412–422.

Official journal of the British Dental Association.

21. Abrahamsson I, Berglundh T, Lindhe J. The mucosal barrier following abutment dis/reconnection. An experimental study in dogs. *J Clin Periodontol* 1997; **24:** 568–572.
22. Rompen E, Domken O, Degidi M, Pontes A E, Piatelli A. The effect of material characteristics, of surface topography and of implant components and connections on soft tissue integration: a literature review. *Clin Oral Implants Res* 2006; **17:** 55–67.
23. Grandi T, Guazzi P, Samarani R, Maghaireh H, Grandi G. One abutment-one time versus a provisional abutment in immediately loaded post-extractive single implants: a 1-year follow-up of a multicentre randomised controlled trial. *Eur J Oral Implantol* 2014; **7:** 141–149.
24. Machtei E E, Frankenthal S, Levi G *et al.* Treatment of peri-implantitis using multiple applications of chlorhexidine chips: a double-blind, randomized multi-centre clinical trial. *J Clin Periodontol* 2012; **39:** 1198–1205.
25. Wadhwani C, Schonnenbaum T R, Audia F, Chung K H. In-Vitro Study of the Contamination Remaining on Used Healing Abutments after Cleaning and Sterilizing in Dental Practice. *Clin Implant Dent Relat Res* 2016; **18:** 1069–1074.
26. Cakan U, Delibasi C, Er S, Kivanc M. Is it safe to reuse dental implant healing abutments sterilized and serviced by dealers of dental implant manufacturers? An in vitro sterility analysis. *Implant Dent* 2015; **24:** 174–179.
27. Ko H C, Han J S, Bächle M, Jang J H, Shin S W, Kim D J. Initial osteoblast-like cell response to pure titanium and zirconia/ alumina ceramics. *Dent Mater* 2007; **23:** 1349–1355.
28. Abrahamsson I, Berglundh T, Glantz P O, Lindhe J. The mucosal attachment at different abutments. An experimental study in dogs. *J Clin Periodontol* 1998; **25:** 721–727.
29. Park J M, Lee J B, Heo S J, Park EJ. A comparative gold UCLA-type and CAD/CAM titanium implant abutments. *J Adv Prosthodont* 2014; **6:** 46–52.
30. Kano S C, Binon P, Bonfante G, Curtis D A. Effect of casting procedure on screw loosening in UCLA-type abutments. *J Prosthodont* 2006; **15:** 77–81.
31. Carlson B, Carlsson G E. Prosthodontic complications in osseointegrated dental implant treatment. *Int J Oral Maxillofac Implants* 1994; **9:** 90–94.
32. Chee W, Jivraj S. Screw versus cemented implant-supported restorations. *Br Dent J* 2006; **201:** 501–507.
33. Gjelvold B, Sohrabi M M, Chrcanovic B R. Angled screw channel: an alternative to cemented single-implant restorations – three clinical examples. *Int J Prosthodont* 2016; **29:** 74–76.
34. Su H, González-Martin O, Weisgold A, Lee E. Considerations of implant abutment and crown contour: critical contour and subcritical contour. *Int J Periodontics Restorative Dent* 2010; **30:** 335–343.
35. Chrcanovic B R, Albrektsson T, Wennerberg A. Platform switch and dental implants: A meta-analysis. *J Dent* 2015; **43:** 629–646.
36. Romanos G E, Javed F. Platform switching minimises crestal bone around dental implants: truth or myth? *J Oral Rehabil* 2014; **41:** 700–708.
37. Heitz-Mayfield L J, Needleman I, Salvi G E, Pjetursson B E. Consensus statements and clinical recommendations for prevention and management of biologic and technical implant complications. *Int J Oral Maxillofac Implants* 2014; **29:** 346–350.
38. Serino G, Ström C. Peri-implantitis in partially edentulous patients: association with inadequate plaque control. *Clin Oral Implants Res* 2009; **20:** 169–174.
39. Haack J E, Sakaguchi R L, Sun T, Coffey J P. Elongation and preload stress in dental implant abutment screws. *Int J Oral Maxillofac Implants* 1995; **10:** 529–536.
40. Jemt T. Failures and complications in 391 consecutively inserted fixed prostheses supported by Brånemark implants in edentulous jaws: a study of treatment from the time of prosthesis placement to the first annual checkup. *Int J Oral Maxillofac Implants* 1991; **6:** 270–276.
41. De Araújo Nobre M A, Maló P. The influence of rehabilitation characteristics in the incidence of peri-implant pathology: a case-control study. *J Prosthodont* 2014; **23:** 21–30.
42. Berglundh T, Persson L, Klinge B. A systematic review of the incidence of biological and technical complications in implant dentistry reported in prospective longitudinal studies of at least 5 years. *J Clin Periodontol* 2005; **29:** 197–212.
43. Quirynen M, Bollen C M, Eyssen H, van Steenberghe D. Microbial penetration along the implant components of the Brånemark system. An in vitro study. *Clin Oral Implants Res* 1994; **5:** 239–244.
44. Do Nascimento C, Pita M S, Calefi PL, de Oliveira Silva T S, Dos Santos J B, Pedrazzi V. Different sealing materials preventing the microbial leakage into the screw-retained implant restorations: an in vitro analysis by DNA checkerboard hybridization. *Clin Oral Implants Res* 2017; **28:** 242–250.
45. Hebel K S, Gajjar R C. Cement-retained versus screw-retained implant restoration: achieving optimal occlusion and esthetics in implant dentistry. *J Prosthet Dent* 1997; **77:** 28–35.
46. Wilson TG Jr. The positive relationship between excess cement and peri-implant disease: a prospective clinical endoscopic study. *J Periodontol* 2009; **80:** 1388–1392.
47. Korsch M, Obst U, Walther W. Cement-associated peri-implantitis: a retrospective clinical observational study of fixed implant-supported restorations using a methacrylate cement. *Clin Oral Implants Res* 2014; **25:** 797–802.
48. Liang T, Hu X, Zhu L, Pan X, Zhou Y, Liu J. Comparative in vitro study of cementing techniques for implant-supported restorations. *J Prosthet Dent* 2016; **116:** 59–66.
49. Naert I, Duyck J, Vandamme K. Occlusal overload and bone/implant loss. *Clin Oral Implants Res* 2012; **23:** 95–107.
50. Kim Y, Oh T J, Misch C E, Wang H L. Occlusal considerations in implant therapy: clinical guidelines with biomechanical rationale. *Clin Oral Implants Res* 2005; **16:** 26–35.

Official journal of the British Dental Association.