Guidelines on prophylaxis to prevent infective endocarditis

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IN BRIEF

- Describes the outcome of two important new guideline reviews with conflicting advice regarding the use of antibiotic prophylaxis to prevent infective endocarditis (IE).
- Provides guidance for dentists who are managing patients at risk of IE in the current climate of conflicting guidance and the new legal requirements on obtaining informed consent.

OPINION

Infective endocarditis is a devastating disease with high morbidity and mortality. The link to oral bacteria has been known for many decades and has caused ongoing concern for dentists, patients and cardiologists. Since 2008, the UK has been out of step with the rest of the world where antibiotic prophylaxis is recommended for high-risk patients undergoing invasive dental procedures. Recent evidence that identified an increase in endocarditis incidence prompted a guideline review by NICE and the European Society for Cardiology – which produces guidance for the whole of Europe. Despite reviewing the same evidence they reached completely opposing conclusions. The resulting conflict of opinions and guidance is confusing and poses difficulties for dentists, cardiologists and their patients. Recent changes in the law on consent, however, may provide a patient-centred and pragmatic solution to these problems. This Opinion piece examines the evidence and opposing guidance on antibiotic prophylaxis in the context of the recent changes in the law on consent and provides a framework for how patients at risk of endocarditis might be managed in practice.

BACKGROUND

Infective endocarditis (IE) is a serious disease with severe consequences (Table 1).[1] The concept that invasive dental procedures could cause IE was first suggested in 1923.[2] With the advent of antibiotics, the idea developed that antibiotic prophylaxis could be used before invasive dental procedures to reduce the risk of IE in susceptible individuals. Soon guideline committees were advising on the antibiotic regimens that should be used and the individuals who should receive cover. Prior to March 2008, all patients thought to be at increased risk of IE in the UK were given antibiotic prophylaxis, usually a single 3 g oral dose of amoxicillin or 600 mg dose of clindamycin, one hour before an invasive dental procedure. However, there was little evidence regarding the efficacy of antibiotic prophylaxis and a randomised controlled trial (RCT) of its efficacy (or safety) has never been performed. This, along with concerns that the number and severity of adverse drug reactions caused by antibiotic prophylaxis would outweigh the benefit from preventing any cases of IE, led NICE to conclude that antibiotic prophylaxis was not cost effective. As a result, they published guidance in March 2008 recommending that antibiotic prophylaxis prior to invasive dental, and other, procedures should stop.[3]

Guideline committees across the rest of the world, including those for Europe[4] (led by the European Society of Cardiology [ESC]) and North America (led by the American Heart Association [AHA]),[5] drew a different conclusion to NICE. They felt that the risks associated with IE in the highest risk groups (those more likely to have a bad outcome

Table 1 Infective endocarditis: basic facts

There are approximately 2,150 cases of infective endocarditis in the UK annually
The incidence of infective endocarditis is rising
15–20% of infective endocarditis patients die during their initial hospital admission
A further 10–15% die over the following year
35–45% of cases are caused by oral viridans group Streptococci
A similar proportion are caused by skin-related Staphylococci
40–45% require surgery during the initial hospital admission, often involving prosthetic replacement of one or more heart valves, and a further 10% need surgery in the year after discharge
Many survivors will have significantly reduced quality and length of life
Presentation can be subtle, with malaise, weight loss and fever being the most common presenting symptoms

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if they developed IE as well as those more likely to develop it) were likely to exceed the risks associated with adverse drug reactions. So in the absence of evidence either for or against antibiotic prophylaxis, they concluded that it was safer to recommend it for high-risk individuals (patients with a previous history of IE, prosthetic heart valve or valve repaired with prosthetic material, unrepaired cyanotic congenital heart disease, or certain repaired congenital heart defects), but did recommend it should stop for those at moderate-risk (history of rheumatic fever, non-rheumatic valve disease for example, mitral valve prolapse or unrepaired congenital heart valve anomaly). As a result, the UK became the only place in the world not to recommend antibiotic prophylaxis for high-risk individuals and this has been a cause for concern for many dental practitioners, cardiologists and patients ever since.

What prompted the 2015 review of antibiotic prophylaxis guidelines?

In March, a study was published in the *Lancet*[6] that found a very significant 88% fall in antibiotic prophylaxis prescribing in the 5 years following the NICE guidelines, and a significant increase in the incidence of IE. This increase was over and above what would have been expected from projection of the background pre-NICE upward trend in IE incidence, and suggested that by March 2013 there were an extra 419 IE cases per year than expected. The 95% confidence limits (CI) suggested this figure could be as high as 743 or as low as 117 extra cases. The problem with observational data, such as this, is that just because we see a relationship it does not prove that the fall in antibiotic prophylaxis caused the increase in IE. However, a careful search for other causes of the increase was unable to identify any satisfactory alternative explanations.

These data raised the possibility that the NICE guidance was causing an increase in the number of IE cases and led NICE to announce a review of its guidance. At the same time the European Society for Cardiology (ESC), who produce antibiotic prophylaxis guidance for the whole of Europe, scheduled a review of its guidance and the American Heart Association, who produce similar guidance for North America, also announced a review. Although they have decided to await the outcome of the NICE and ESC review before starting.

Outcome of the 2015 reviews of antibiotic prophylaxis guidance

In September, NICE and the ESC announced the results of their reviews after evaluation of exactly the same evidence. The results could not have been more different. NICE announced that there was insufficient evidence to warrant any change to their existing guidance not to recommend antibiotic prophylaxis.[7] In contrast, the ESC concluded 'the weight of evidence and opinion was in favour of the efficacy and usefulness of antibiotic prophylaxis in preventing IE in those at high-risk'.[8] They also concluded that the risk of not giving antibiotic prophylaxis outweighed any risk of giving it and therefore recommended that 'antibiotic prophylaxis should be given before invasive dental procedures to all patients at high-risk of IE'. Furthermore, the ESC guideline committee[8] considered but rejected the NICE view for the following reasons: (a) the remaining uncertainties regarding estimations of the risk of IE; (b) the worse prognosis of IE in high-risk patients, in particular those with prosthetic valves; (c) the fact that high-risk patients account for a very small proportion of those previously covered by antibiotic prophylaxis, thereby reducing the number exposed to any possible harmful adverse effects. The current AHA guidelines take a very similar view to the ESC guidelines.[5]

How has this difference in guidance between NICE and the rest of the world arisen?

The ESC guideline review panel consisted of more than 40 clinicians from across Europe, including the UK, all with relevant clinical expertise, including cardiologists, cardiothoracic surgeons, infectious disease experts and dentists. The AHA guideline committee was similarly composed. In both cases, the relevant professional bodies reviewed the guidance before submission to international peer-reviewed journals where they were subjected to further external review. They were published with transparent authorship and have been presented and discussed at open academic meetings. Both committees reviewed all the available evidence, including animal studies and observational studies, before reaching their conclusions.

In contrast, NICE is a body set up by government statute to function under the direction of the Secretary of State for Health to operate 'in connection with the promotion of clinical excellence and the effective use of available resources within the health service'.[9] Its primary purpose is to evaluate the cost-effectiveness of drugs and technologies for use in the NHS. The antibiotic prophylaxis review was performed by a 14-member standing committee that deals with lots of different guidelines but has no particular expertise in IE. For the antibiotic prophylaxis review, this was supplemented by a 'topic specific' panel of two dentists, two cardiologists (only one of whom was permitted to vote), a microbiologist, an epidemiologist and a lay person. Together, these had a minority of votes on the committee. Most committee members had no clinical experience of IE – the only voting members of the committee with any direct experience of IE were the microbiologist and one cardiologist. The data were summarised and presented by two technical analysts and an adviser who were part of a team of administrative staff who drafted the revised guidance.

NICE review committees work to set principles, largely designed for evaluating treatments for which RCT data is available. There is a strong focus on cost effectiveness as well a clinical effectiveness. In such cases their standard methodologies work well. But that is not the case where no RCT data are available, as is the case with antibiotic prophylaxis for IE.[10,11] This problem is exacerbated when animal studies are automatically excluded and the criteria used to evaluate observational studies rate even the best as being of low quality – 'as only observational studies were identified for this review, the quality rating began at "low" and was further downgraded for potential bias'.[7] Using this approach to dismiss all observational studies, including the *Lancet* study,[6] it is perhaps not surprising that the review committee was left with insufficient evidence to change the existing guidance. In contrast, in 2008, when even less evidence was available, NICE moved decisively to change existing guidance recommending antibiotic prophylaxis for patients at moderate and high risk of IE and recommended its cessation. Accordingly, one has to question why it was acceptable to change guidance in the absence of evidence in 2008, but not to do so in 2015. Ethical concerns have also been raised about the action of NICE in changing the 2008 guidelines in the absence of evidence either for or against the use of antibiotic prophylaxis.[10,11] The problem about adopting a policy now of requiring high level evidence, such as RCTs, before changing guidance, is that if the 2008 decision was wrong, which the *Lancet* data suggests is possible,[6] the error is locked in until RCT evidence becomes available – which could be a very long time (or never).[12]

Does this difference in guidance matter?

Clearly it does. Dentists and their patients are left with confusing and contradictory advice. Furthermore, both guidelines cannot be right. If the NICE guidance is correct and antibiotic prophylaxis is ineffective in reducing the incidence of IE, then the prescribing of antibiotic prophylaxis as recommended by the ESC could result in patients

unnecessarily developing adverse reactions to antibiotic prophylaxis. Alternatively, if the ESC guidelines are correct and antibiotic prophylaxis reduces the number of individuals developing IE, then following the NICE guidance could lead to more patients unnecessarily developing IE and all its associated complications, including death.

In April 2015 new data were published quantifying the risk of adverse drug reactions following use of antibiotic prophylaxis.[13] This confirmed earlier data showing that there has never been a reported death from the use of amoxicillin antibiotic prophylaxis and showed that the risk of non-fatal adverse reactions is much lower than previous estimates.[13,14] It also showed that clindamycin antibiotic prophylaxis had a worse adverse reaction profile than amoxicillin and resulted in approximately one death every three years. Whilst worse than expected, this is still comparatively low. Unfortunately, these data were published too late to be taken into account by the ESC guidelines committee but show that the risk is likely to be even lower than they took into account in their deliberations. Although the data were made available to NICE they did not take them into account in their assessment.

These data allow us to directly compare the risks of implementing the NICE and ESC guidance (Fig. 1). If the *Lancet*[6] and adverse drug reaction data[13,14] are correct, then the potential risk of implementing the no antibiotic prophylaxis guidance of NICE could be an extra 419 cases of IE per year including a possible extra 66 deaths.[6,12] In contrast, the potential risk of implementing the ESC guidance to give antibiotic prophylaxis could be an extra seven reportable adverse drug reactions a year (including one death every 3 years).[13,14] If antibiotic prophylaxis were restricted to the use of amoxicillin or a safer alternative to clindamycin was used, this could be reduced further to just two reportable adverse reactions a year. These extrapolations suggest that adoption of the ESC guidance is likely to be safer for most patients than adoption of the NICE guidance (until further evidence becomes available to change these figures). The data also suggests that even if the *Lancet* data were wrong, so long as antibiotic prophylaxis prevented more than seven cases of IE per year, adoption of the ESC guidance would pose less risk to patients than the NICE guidance.

Even without these data, the risk analysis performed by the ESC resulted in them concluding that the balance of risks and benefits of antibiotic prophylaxis favoured its use in high-risk individuals. In contrast, NICE appears not to have performed a risk assessment despite these risks being published in the *British Dental Journal* (*BDJ*) and being made available to them during the public consultation period of the NICE review.[12]

The ESC guidance has now been adopted as their official guidance for the 56 national cardiac societies and 85,000 cardiology professionals across Europe that it represents (including the British Cardiac Society). The ESC guidance is also accepted by dental organisations across Europe as the standard of care for dental patients who are at risk of IE.

SO WHAT SHOULD UK DENTISTS DO?

As was pointed out in a recent letter to the *BDJ* on this issue, guidance is just that – guidance.[15] It is not mandatory, although at times it may seem like it, mainly because clinicians feel the need to justify any deviation from that guidance, not least for fear of the legal consequences.[16,17] Clinical guidelines, however, are not applicable to every patient and every situation and even the NICE guidelines point this out: 'Healthcare professionals are expected to take NICE clinical guidelines fully into account when exercising their clinical judgement. However, the guidance does not override the responsibility of healthcare professionals to make decisions appropriate to the circumstance of each patient, in consultation with the patient and/or their guardian or carer.'

In the current climate, informed patient care is paramount. Although this requires a knowledge of the best evidence and advice, it also requires an understanding of individual patients' expectations, concerns and values so that a dialogue can occur between patient and clinician to enable an informed and individualised choice.[18] Recent changes in the law on informed consent in the UK are particularly relevant. Following a Supreme Court judgment in the case 'Montgomery *v* Lanarkshire Health Board',[19–22] doctors and dentists must now ensure that patients are aware of any 'material risks' involved in a proposed treatment, and of reasonable alternatives. This is a marked change to the previous Bolam test,[23] which asks whether a doctor or dentist's conduct would be supported by a responsible body of medical opinion. This test will no longer apply to the issue of informed consent. The new test 'is whether, in the circumstances of the particular case, a reasonable person in the patient's position would be likely to attach significance to the risk, or the doctor is or should reasonably be aware that the particular patient would be likely to attach significance to it.' Having been provided with this information, it is then for the patient, not the clinician, to decide which treatment they want. It is notable that this decision puts into law principles that were already present in the GMC's guidance on consent *Consent: Patients and doctors making decisions together* (2008), the GDC's *Standards for the dental team* (2013) and the advice on consent of both the MDU/DDU and MPS/DPS. The new judgment also indicates that patients are entitled to know not just what the risk of different treatment or preventative options are, but also the nature of the potential risks.[19–21]

What does this mean with regard to antibiotic prophylaxis?

Clearly any patient at increased risk of IE would be likely to attach significance to knowing about the possible risks posed by invasive dental procedures and the conflicting views on the use of antibiotic prophylaxis.

Figure 1 provides a possible starting point for discussion of the relative risks and benefits of antibiotic prophylaxis. However, the new legal framework suggests that the

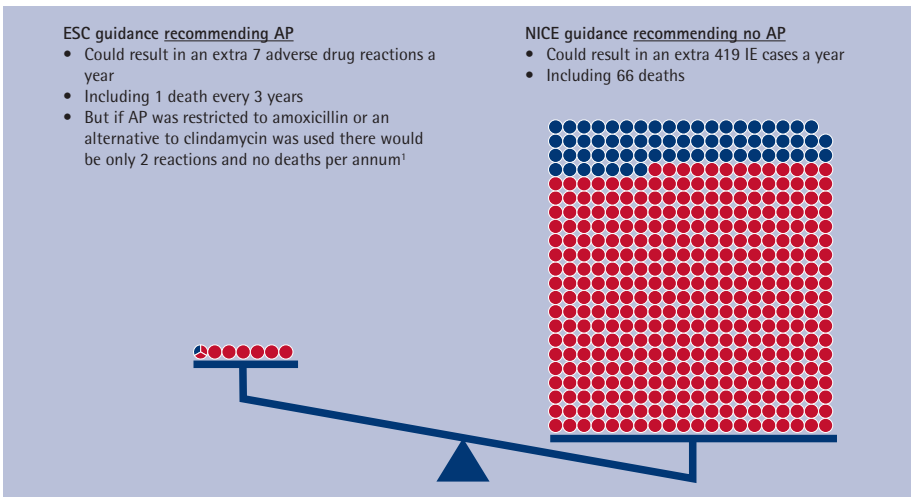

Fig. 1 Risks of recommending antibiotic prophylaxis (AP) or no AP. Based on data discussed in references 6 and 13

potential consequences of developing IE need to be described as well as the potential consequences of any adverse drug reaction to antibiotic prophylaxis. It is then for the patient, rather than the clinician, to decide if they wish to have, or not to have, antibiotic prophylaxis. GMC/GDC standards and the advice of the medical/dental defence organisations highlight the need for the nature of the discussion and the patient's decision to be recorded in the clinical records.

The risk of IE developing in an individual with no risk factors is so low that, in the new legal framework, it would be reasonable for the clinician to conclude that it is unlikely the patient would attach significance to the risk, and therefore not to inform them of these issues.

What do I do if my patient chooses to have antibiotic prophylaxis?

Currently, the ESC guidelines are the most up to date with regard to recommendations on giving antibiotic prophylaxis. Current NICE guidance, while recognising that some patients are at increased risk of IE, provides no guidance on how to reduce that risk or how to provide antibiotic prophylaxis for those who request it.

The ESC guidelines have been published in full[8] and are also available as a smart phone app and a pocket guide from the ESC at http://www.escardio.org/Guidelines-&t-Education/Clinical-Practice-Guidelines/Infective-Endocarditis-Guidelines-on-Prevention-Diagnosis-and-Treatment-of. The ESC guidelines recommend antibiotic prophylaxis is limited to patients at highest risk of IE (Table 2) who are undergoing the highest risk dental procedures (Table 3). In addition, they emphasise that good oral hygiene and regular dental review are more important than antibiotic prophylaxis in reducing the risk of IE. They recommend strict dental and cutaneous hygiene, and say that dental follow up should be performed at least twice a year in high-risk patients and once a year for all other (that is, moderate risk) patients at risk of IE (Table 2). They also point out the need to effectively treat foci of infection, adhere to aseptic measures during at-risk procedures and explain the risks of body piercing and tattooing in those at risk of IE.

NICE suggests that daily activities such as tooth brushing, chewing etc account for a significant proportion of the cases of IE caused by oral bacteria. This is probably true, particularly for those with poor oral hygiene,[24] although there is little evidence to support this. However, this does not preclude the possibility that some cases of IE are also caused by invasive dental procedures. In either case, good oral hygiene is paramount, as it is likely to reduce the risk of IE arising from daily activities and invasive dental procedures.[24] For those high-risk patients who need scaling and other periodontal treatments to improve their oral hygiene, it may be particularly important that they are aware of the risks and benefits of antibiotic prophylaxis cover for these procedures.

Which patients are considered at increased risk of infective endocarditis?

Those individuals considered to be at high-risk of IE (and therefore recommended for antibiotic prophylaxis by the ESC guidelines) are shown in Table 2. The AHA guidelines committee and NICE also consider these individuals at high risk.[5,7] Those generally considered at moderate risk are also shown. Whilst, the ESC does not currently recommend antibiotic prophylaxis for these latter individuals, they do recommend that they adopt the non-specific preventative measures mentioned above and receive regular annual dental review. In most cases the risk status of a patient will be clear from the medical history, for example, previous history of IE or of having a prosthetic heart valve inserted. For others it may be less clear. Where there is any uncertainty, advice should be sought from the patient's cardiologist (with the patient's consent) to clarify their risk status and need for antibiotic prophylaxis (or not). A record of any such communication should be kept with their clinical record.

Table 2 Patients at increased risk of developing infective endocarditis

High-risk:
Patients with a previous history of infective endocarditis
Patients with any form of prosthetic heart valve (including a transcatheter valve)
Those in whom prosthetic material was used for cardiac valve repair
Patients with any type of cyanotic congenital heart disease
Patients with any type of congenital heart disease repaired with prosthetic material, whether placed surgically or by percutaneous techniques, for the first 6 months after the procedure or lifelong if a residual shunt or valvular regurgitation remains
Moderate-risk:
Patients with a previous history of rheumatic fever
Patients with any other form of native valve disease (including the most commonly identified conditions: bicuspid aortic valve, mitral valve prolapse and calcific aortic stenosis)
Patients with unrepaired congenital anomalies of the heart valves

Note: ESC only recommends antibiotic prophylaxis for high-risk patients. Non-specific prevention measures are recommended for both groups. This table has been adapted from the 2015 ESC Guidelines for the management of infective endocarditis[8] with the permission of Oxford University Press (UK) and the European Society of Cardiology, www.escardio.org.

Table 3 Dental procedures: when to consider antibiotic prophylaxis

Considered high-risk:
Antibiotic prophylaxis should only be considered for dental procedures requiring manipulation of the gingival (including extractions and scaling) or periapical region of the teeth (including root canal procedures) or perforation of the oral mucosa
NOT considered high-risk:
Antibiotic prophylaxis is not recommended for:
Local anaesthetic injections in non-infected tissue
Treatment of superficial caries not requiring gingival manipulation
Removal of sutures
Dental X-rays
Placement or adjustment of removable prosthodontics or orthodontic appliance or braces
Following shedding of deciduous teeth
Following trauma to the lips or oral mucosa

Note: ESC does not recommend antibiotic prophylaxis for any non-dental procedures. This table has been adapted from the 2015 ESC Guidelines for the management of infective endocarditis[8] with the permission of Oxford University Press (UK) and the European Society of Cardiology, www.escardio.org

Which dental procedures are considered high-risk procedures?

The ESC consider those procedures identified in Table 3 as high-risk procedures. This closely matches the recommendations in the AHA guidelines.[5]

What antibiotic prophylaxis regime should be provided for those requesting it?

The regime recommended by the ESC (Table 4) is very similar to that of the AHA[5] but differs in two main respects from that previously used in the UK. First, the oral dose of amoxicillin used is 2 g rather than 3 g – the 3 g sachets of amoxicillin oral powder were previously very popular and widely used for antibiotic prophylaxis in the UK, but are not generally available in other European or North American markets. Amoxicillin 3 g oral sachets are still widely available in the UK and the adverse drug reaction data showing a low level of adverse reactions to amoxicillin antibiotic prophylaxis was based on the 3 g dose.[13] It does not seem unreasonable, therefore, to prescribe this formulation where more convenient. The other change is that the pre-NICE guidance recommended using clindamycin if a patient had received a dose of amoxicillin within the previous month. This is not a feature of the ESC or AHA guidance and, given the higher risk of adverse reactions with clindamycin, the ESC guidance is likely to be safer.

Both the ESC and AHA guidance currently recommend clindamycin antibiotic prophylaxis for those allergic to penicillins. At this point in time neither the ESC nor the AHA guideline committees have had the opportunity to take account of the recent adverse reaction data concerning clindamycin.[13] Both are likely to do so in the not too distant future and may consider changing their recommendations. In the meantime, however, whilst not as safe as amoxicillin, clindamycin antibiotic prophylaxis is relatively safe, and, as shown in Figure 1, likely to be safer than the risk of developing IE, particularly for those at high risk. As such, it is probably advisable to adhere to ESC recommendations until any change in this guidance is announced.

Table 4 Recommended antibiotic prophylaxix for high-risk dental procedures in high-risk patients

Situation	Antibiotic	Single-dose 30–60 minutes before procedure	
		Adults	Children
No allergy to penicillin or ampicillin	Amoxicillin or ampicillin[1]	2 g orally[2] or IV	50 mg/kg orally or IV
Allergy to penicillin or ampicillin	Clindamycin	600 mg orally or IV	20 mg/kg orally or IV

Note:
1 Alternatively, cephalexin 2 g IV for adults or 50 mg/kg IV for children, cefazolin or ceftriaxone 1 g IV for adults or 5 0mg/kg IV for children. Cephalosporins should not be used, however, in patients with anaphylaxis, angio-oedema or urticaria after intake of penicillin or ampicillin due to cross-sensitivity.
2 In the UK, a practical alternative is the 3 g amoxicillin oral powder sachet to be made up with water.

This table has been adapted from the 2015 ESC Guidelines for the management of infective endocarditis[8] with the permission of Oxford University Press (UK) and the European Society of Cardiology, www.escardio.org

Table 5 Symptoms of endocarditis

Presentation:
There are two ways symptoms of endocarditis can develop:
Over the course of a few days, rapidly getting worse (acute endocarditis)
Slowly, over the course of a few weeks or possibly months (subacute endocarditis)
Symptoms of endocarditis:
High temperature of 38 °C or above
Night sweats
Shortness of breath on exertion
Tiredness (fatigue)
Muscle and joint pains
Unexplained weight loss
Other possible symptoms and signs:
The development of a new or worsening heart murmur
The appearance of a spotty red rash on the skin (petechiae)
Narrow, reddish-brown streaks under the nails (splinter haemorrhages)
Red tender lesions under the skin of the fingers or toes (Osler's nodes)
Confusion
Stroke

IMPORTANCE OF EARLY DIAGNOSIS – ROLE OF DENTIST

Early diagnosis of IE is associated with improved outcomes. Unfortunately, early symptoms are often relatively non-specific and diagnosis is difficult. A low threshold of clinical suspicion is therefore vital. Patients at increased risk should be advised of the symptoms and signs of IE (Table 5) and the need to see their GP quickly should they occur, particularly if they develop soon after a high-risk dental or other invasive procedure for example, body piercing. Early assessment by the GP – who should be made aware of the patient's risk status and the timing/nature of any risk related procedure – and appropriate onward referral to a cardiologist could be lifesaving. The British Heart Foundation produces warning cards that can be given to patients providing simplified advice – available at: https://www.bhf.org.uk/publications/heart-conditions/m26a-endocarditis-card.

FINALLY

It can only be hoped that current and future research will better define the role of antibiotic prophylaxis and other measures in reducing the risk of IE. Individuals and guideline committees will need to stay abreast of such developments and be prepared to change their views and advice depending on the available evidence. Future disparities in guidance should be prevented by the development of consistent internationally agreed guidelines prepared by experts in the field.

Declarations of interest
MHT, MD, PBL and BP were co-authors of the Lancet paper that prompted the guideline review.[6] MD was a non-voting 'topic specific' member of the 2015 NICE guideline review panel.[7] PBL is a member of the American Heart Association's Committee on Rheumatic Fever, Endocarditis and Kawasaki Disease and was involved in producing the 2007 American Heart Association guideline on prevention of infective endocarditis.[5] MD, BP and JBC are members of the ESC, but were not involved in review of their 2015 guidelines. The other authors declare no interests.

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Corrigendum

Practice article (*BDJ* 2015; **219:** 521-529)

3D printing in dentistry

In the above Practice article Figure 2b was incorrect. The correct image and caption are as follows:

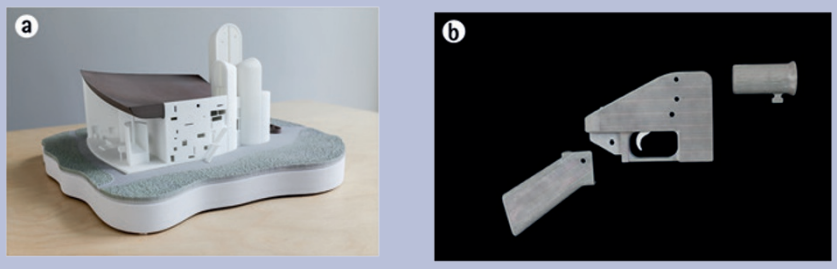

Fig. 2 (a) A 3D printed colour plaster architectural model of one of the most iconic examples of twentieth-century religious architecture designed by Le Corbusier. Model printed by digits2widgets.com. Photograph Chris Sullivan. (b) 3D printed gun. Production file controversially disseminated on the internet by American Cody Wilson. The version pictured here was produced by digits2widgets.com for London's Victoria and Albert Museum collection

The incorrect Fig. 2b published in the paper was of the complete 3D printed gun; the production file for which was controversially disseminated on the internet by American Cody Wilson.

The authors apologise for any inconvenience caused by the error in this figure in the original paper.