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Engineering standards for trauma and orthopaedic implants worldwide: a systematic review protocol

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ABSTRACT

Introduction Despite multiple scandals in the medical implant sector, premarket testing has been the attention of little published research. Complications related to new devices, such as the DePuy Articular Surface Replacement (ASR, DePuy Synthes, USA), have raised the issue of how designs are tested and whether engineering standards remain up to date with our understanding of implant biomechanics. Despite much work setting up national joint registries to improve implant monitoring, there have been few academic studies examining the premarket engineering standards new implants must meet. Emerging global economies mean that the markets have changed, and it is unknown to what degree engineering standards vary around the world. Governments, industry and independent regulatory bodies all produce engineering standards; therefore, the comparison of surgical implants across different manufacturers and jurisdictions is difficult. In this review, we will systematically collate and compare engineering standards for trauma and orthopaedic implants around the world. This will help inform patient, hospital and surgeon choice and provide an evidence base for future research in this area.

Methods and analysis This protocol is based on Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocol (PRISMA-P) guidelines. We will conduct a systematic review of trauma and orthopaedic engineering standards from four main sources of information as identified in our preliminary scoping searches: governments, industry, independent regulatory bodies and engineering and medical publications. Any current standard relevant to trauma and orthopaedic implants will be included. We will use a predefined search strategy and follow the recommendations of the Cochrane handbook where applicable. We will undertake a narrative synthesis with qualitative evaluation of homogeneity between engineering standards.

Ethics and dissemination No ethics approval is required as no primary data are being collected. The results will be made available by peer-reviewed publication and reported according to PRISMA-P guidelines.

Strengths and limitations of this study

- Multidisciplinary team carrying out a systematic review from both a medical and engineering perspective.
- A team with experience in conducting systematic reviews and with the specific search methodology used in this review.
- Engineering standards may not be open to public scrutiny limiting our ability to carry out comprehensive comparisons.
- For practical reasons, the study is limited to the G20 group of developed nations, the G23 groups of low-income and middle-income nations and the top 10 trauma and orthopaedic manufacturers by market value. This may lead to exclusion bias for less economically developed countries.

INTRODUCTION

Recent scandals in the field of medical implants[1 2] have brought the sector under greater public and regulatory scrutiny, with questions about whether the current system is fit for purpose.[3] Trauma and orthopaedic implants are classified among the riskiest devices by government regulators.[4] Over 11 000 revision operations for failed implants were required in the UK in 2016 alone.[5] Revision surgery is more costly than primary arthroplasty requiring longer operations, more postoperative investigations and lengthier hospital stays.[6] Previous qualitative studies of implant regulation have described a reactive system that relies on postmarket surveillance of revision rates rather than rigorous premarket testing.[4 7] This was demonstrated by the DePuy ASR resurfacing hip (DePuy Synthes, Raynham, Massachusetts, USA), a product that passed all premarket engineering standards before being discontinued due to high revision rates.[8] Despite this, there have been few scientific studies examining the breadth and suitability of engineering standards that implants must meet before going to market.

Implant revision is costly for both the patient and the wider economy. In recent years, several countries have initiated joint

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registries to monitor implants and catch those with high revision rates early.[7] These registries show large disparities in failure rates between different brands of implant. The UK National Joint Registry's (NJR) worst performing total knee arthroplasty implant has a revision rate at 13 years of 7.9% compared with 3.1% for the best.[5] Such variability between brands is frequently put down to differences in design or materials[2 5 9] and while the causes of implant failure are multifactorial, several key modes of failure are related to the quality of manufacturing of the implant. The medical literature does not reflect this; one systematic review found implant fracture rates in total hip arthroplasty as high as 16.3% yet no comment was made on the role of implant engineering standards.[10] Similarly, interbrand differences are often put down to surgical technique or patient factors while the role of the manufacturing process is rarely mentioned.

Implants are increasingly being used in younger patient groups who place greater functional demands on their prostheses over a greater time period. As a result, they have substantially higher revision rates; for total hip arthroplasty, females aged under 55 have a revision rate of 13.5% compared with an average of 6.8% for the wider population.[5] To cope with this increasing burden, implants need to be engineered and manufactured to the highest standard. The NJR found the incidence of implant fracture is greatest in the first year[5] which suggests that implants manufactured to an insufficient standard are entering the market. While many publications offer evidence regarding the suitability of design or materials, there is little research to help surgeons, patients and purchasers discern the differences in the engineering quality of rival implants.

The topic of engineering standards is not widely explored in the medical literature, and this review aims to be the first to systematically address variability in trauma and orthopaedic engineering standards worldwide. Due to the paucity of information in traditional medical databases, we will adopt a cross-disciplinary approach searching both medical and engineering publications, as well as government and industry sources. We are not aware of any previous reviews describing and comparing the different engineering standards in use. A systematic review is required to aid policy-makers, purchasers and stakeholders in making informed decisions regarding the engineering quality of an implant.

Objectives

To provide an overview of publicly available engineering standards for trauma and orthopaedic implants. To assess the homogeneity of engineering standards that are produced by different sources and applied in different jurisdictions. To examine the public availability of the contents of trauma and orthopaedic engineering standards, specifically the tests that they specify and any pass/fail criteria that they set.

METHODS AND ANALYSIS

This protocol will, where possible, conform to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocol guidelines.[11]

Inclusion criteria

Our preliminary scoping review has shown engineering standards fall into three broad categories. First, general biocompatibility standards that all medical devices must meet, these will all be included. Second, material-specific standards, we will include: steel, titanium alloys, cobalt and chromium alloys, polyethylene, polyether ether ketone, zirconia and alumina ceramics. Third, standards specific to individual implant types, we will include: hip arthroplasty, knee arthroplasty, plates, nails, screws and wires. Due to the large number of different materials and implants in use and the expense of purchasing the associated engineering standards, our inclusion criteria will be limited to the most common materials and implant types as identified in our early scoping searches.[5 12 13]

For a standard to be included, it must come from one of the following sources: published scientific research paper, government of a G20 or G23 nation, organisations appointed by a government of a G20 or G23 nation to regulate trauma and orthopaedic implants, trauma and orthopaedic implant manufacturers, for example, Johnson & Johnson, Zimmer Biomet or industry standards body, for example, International Standards Organisation, British Standards Institute. Including both G20 developed nations, G23 low-income and middle-income nations and international bodies associated with one or more members of the G20 and G23 will capture a representative sample of government produced or sanctioned engineering standards. It will also enable comparison between standards in developed and less economically developed countries. For the purposes of this study, the European Union will be treated as one state, and member nations will not be searched separately.

Engineering standards that are identified but do not come from these sources will be noted and discussed in the conclusion.

Exclusion criteria

We will exclude any engineering standard that has been repealed or superseded and engineering standards not available in the English language.

Population

The engineering standards for elective orthopaedics to be included are hip and knee implants. For trauma implants, any nail, plate, wire or screw will be considered.

Patient data are not being assessed in this review.

Intervention

Any published standard relevant to any process required for the manufacture of trauma and orthopaedic implants.

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Outcome

The publication of engineering standards for trauma and orthopaedic implants is of primary interest. We will record the engineering standards name, origin, category and the device class it applies to.

Where engineering standards are publicly available, we will explore our secondary outcomes. We will investigate if they state any specific tests implants must undergo and where there are specific tests, we will investigate the existence of pass/fail criteria.

Search strategy

The search strategy has been developed in consultation with librarians with experience of both engineering and healthcare journals. Our scoping searches have identified four sources of information on engineering standards for trauma and orthopaedic implants: governments or agencies appointed by governments to regulate engineering standards on their behalf, international standards organisations, trauma and orthopaedic implant manufacturers and published scientific papers. We will search medical and engineering online databases with the following search terms: 'orthop*edic implant *', 'standard*': and 'manufactur*'. We will search the following databases: Engineering Village, Scopus, Web of Science, Biotechnology Research Abstracts, Biotechnology and Bioengineering abstracts, Ceramic abstracts, Medline (Ovid), Biological Sciences (Proquest), Cochrane library and Pubmed.

Government websites for all G20 and G23 nations will be searched for relevant standards databases or for the non-governmental organisations (NGOs) appointed to regulate trauma and orthopaedic engineering standards. In the case of NGOs being appointed, a further search of the NGO's website will be carried out to identify relevant engineering standards. The websites will be searched using the terms 'medical device' and 'implant'. Where no engineering standards are identified, we will first email the government body or NGO responsible for producing standards. If this fails, we will approach appropriate academic staff at universities in the relevant country. We will ask them to contact the organisation responsible for producing engineering standards in that country and obtain the engineering standards on our behalf.

The G20 nations to be searched are: Argentina*, Australia, Brazil*, Canada, China*, European Union, India*,Indonesia*, Japan, Mexico*, Russia, Saudi Arabia, South Africa*, South Korea, Turkey and United States of America (*denotes nations who are also in the G23).

The G23 nations to be searched are: Bolivia, Chile, Cuba, Ecuador, Egypt, Guatemala, Nigeria, Pakistan, Paraguay, Peru, Philippines, Tanzania, Thailand, Uruguay, Venezuela and Zimbabwe. Kenya will also be included in this list, as it is the nationality of several of our coauthors.

We will search the websites of international standards organisations and national standards organisations for G20 and G23 countries using the search terms 'Medical Device' and 'Implant'.

The websites of the top 10 trauma and orthopaedic manufacturers by market capitalisation will be searched: currently, Johnson & Johnson, Zimmer Biomet, Stryker, Medtronic, Smith & Nephew, Arthrex, NuVasive, Globus Medical, Wright Medical Group and Tornier. The search terms used will be: 'Engineering standard' and 'Device Standard'. Scoping reviews revealed limited search functionality on some company websites. Therefore, we will also contact each company to ask which engineering standards they use for products marketed in our jurisdictions of interest.

Where engineering standards are not fully accessible via the above databases, the organisation responsible for publishing the standard will be contacted and a request made for the full standard. Results will be screened by FH and UR with those not relevant removed. Where there is a conflict about whether a document meets the inclusion or exclusion criteria, senior team members (EK, MW and AM) will arbitrate.

If there is consistent disagreement, the reviewing team will meet to re-evaluate the search criteria. Any changes to the methods described in this protocol will be clearly documented in the Methods section of the review.

Study records

Search results from medical and engineering databases will be downloaded and managed in Mendeley. They will then be screened by using their title and abstract against the inclusion criteria. Studies emerged from this stage will then be judged against the inclusion criteria in their entirety. Documents yielded from websites or Google searches will only be downloaded if they meet inclusion criteria. Data extraction from the included articles will be carried out by FH and UR.

Patient and public involvement

There has been no direct patient or public involvement in the design of this study.

However, it is hoped that this study will inform public debate around the regulation of implant manufacturing, ultimately improving patient outcomes.

Risk of bias

As the protocol is investigating engineering standards and not original research papers, a risk of bias assessment is not appropriate.

Data synthesis and analysis

We will provide a narrative synthesis of our findings structured around the standard category (biocompatibility, material and implant specific) and origin (country, manufacturer, standards organisation). We will provide summaries of the tests each country or region requires, if they are mandatory and any parameters that they set. We will then assess the homogeneity of engineering standards between different countries by comparing the number of shared engineering standards. Where multiple standards exist, we will assess consistency between specific test protocols. This will most likely be qualitative but quantitative

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summaries will be performed where appropriate. We will also assess whether pass/fail parameters are consistent between standards using the same approach. Where testing processes are considered comparable between standards, we will present pass/fail parameters as box and whisker plots, range and, if appropriate, median IQR.

ETHICS AND DISSEMINATION

This study will not look at patient data and therefore does not require ethical approval.

The results will be disseminated through publication in a peer-reviewed journal.

DISCUSSION

Most research into why trauma and orthopaedic implants fail has focused on the design or material used in the implant. Little attention has been paid to differences in engineering quality between implants. This systematic review is needed to provide an overview of the engineering standards currently in use and highlight areas for further research.

It is accepted that some of the standards in current use will be confidential standards applied by manufacturers. This is accepted as a weakness of the review, but equally such standards are not independently verifiable and cannot be externally audited. It is therefore still relevant to ascertain what publicly available standards are in current use, as part of a package of work to improve the appropriateness and transparency of orthopaedic device standards in current use, for both established and emerging economies around the world.

Scoping searches prior to this review have found few publicly available engineering standards; this review will provide a systematic record of how many trauma and orthopaedic engineering standards are open to public scrutiny, the tests that they require and the variability in engineering standards between different countries.

Contributors Conception and design of protocol: FH, EK, MW, AM. Drafting of protocol: FH, EK, MW, AM. Critical revision of protocol: FH, EK, UR, RK, DL, JM, FO, VM, JA, MU, MW, AM.

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Competing interests MU was Chair of the NICE accreditation advisory committee until March 2017 for which he received a fee. He is chief investigator or co-investigator on multiple previous and current research grants from the UK National Institute for Health Research, Arthritis Research UK and is a co-investigator on grants funded by Arthritis Australia and Australian NHMRC. He has received travel expenses for speaking at conferences from the professional organisations hosting the conferences He is a director and shareholder of Clinvivo Ltd that provides electronic data collection for health services research. He is part of an academic partnership with Serco Ltd related to return to work initiatives. He is an editor of the NIHR journal series for which he receives a fee.

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