

An opportunity for inclusive and human-centred design

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Key points

Introduces inclusive design and human-centred design and their significance to the trends and challenges in contemporary oral health systems.

Highlights the broad capabilities and potential contributions of design.

Discusses barriers and drivers to the adoption of inclusive and human-centred design in oral health.

Abstract

Challenges and trends, such as person-centred care, demographic shifts and technological advancements, are transforming oral health systems. Inclusive design and human-centred design are disciplines highly relevant and potentially instrumental to these oral healthcare transformations. This paper provides an overview of the definitions and characteristics of inclusive and human-centred design which centre on understanding people's multifaceted needs, expectations, behaviours and relationships, and engaging with diverse and often excluded populations. Design's broad capabilities are outlined across outcome and contribution types and the potential role of inclusive and human-centred design to oral health is explored by outlining its relevance to key transformational, societal and technological shifts. Finally, barriers and drivers to the adoption of inclusive and human-centred design in oral health are discussed around three themes: awareness and understanding of the role and value of design; disciplinary differences; and the wider healthcare systems context.

Introduction

Oral healthcare is in a period of change, with shifts towards person-centred, preventative approaches and advancements in technology transforming current models of care. Simultaneously, key challenges, such as oral health inequalities and sociodemographic shifts, are placing increasing and unsustainable pressures on oral healthcare systems.

Across the wider landscape of design and innovation, inclusive design (ID) and

human-centred design (HCD) are two core approaches that are increasingly valued by and integrated into health and social care organisations. However, their recognition and uptake in oral healthcare remains limited.¹ We propose that ID and HCD are highly relevant and potentially instrumental to oral healthcare systems. The symbiosis of the two offers robust and holistic methodologies for design-driven problem-framing, problem-solving and innovation. ID and HCD emphasise placing people at the centre of the design process while acknowledging their multifaceted needs, expectations, behaviours and relationships. They seek to understand and engage with diverse populations and co-create solutions with and for them that accommodate all, not only the mainstream user groups.

This paper examines how a timely meeting between these fields could be strategic in facilitating transformational change; promoting ID and HCD as a suitable and effective approach to help understand, address and innovate key and complex challenges facing oral healthcare.

Challenges and transitions in oral healthcare

Person-centred and prevention-oriented care

The FDI World Dental Federation's revised definition of oral health states 'oral health is multi-faceted and includes the ability to speak, smile, smell, taste, touch, chew, swallow and convey a range of emotions through facial expressions with confidence and without pain, discomfort and disease of the craniofacial complex'.² This definition is significant in overcoming the traditional perspective of oral health simply as the absence of disease. The definition and accompanying framework treat oral health as a fluid state of wellbeing, taking into account physiological, mental and psychosocial aspects, while also addressing the demands of life and daily function.³

This change in perspective is increasingly evident across the field of oral health. There is a growing focus on oral health-related quality of life^{4,5} and the long-term

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physical and psychosocial impacts that poor oral health can have. Moving on from a long-established approach focused on the treatment of established disease, dentistry is evolving towards a patient-centred,⁶ prevention-orientated⁷ system of care.

Patient-centred care (PCC) is an increasingly prominent concept in dentistry. Several theoretical models for PCC in dentistry have been proposed which highlight the importance of providing humane care and making a connection with patients.^{6,8,9,10,11}

In recent years, person-centred care has emerged as an expansion of patient-centred care.¹² It is a central goal throughout the FDI's Vision 2030 report, where it is defined as follows: 'people-centred care is focused and organised around the health needs and expectations of people and communities rather than on diseases. People-centred care extends the concept of patient-centred care to individuals, families, communities and society. Whereas patient-centred care is commonly understood as focusing on the individual seeking care – the patient – people-centred care encompasses these clinical encounters and also includes attention to the health of people in their communities and their crucial role in shaping health policy and health services'.¹³

Fostering people-centred services is also an important strategy to strengthen oral health services in the World Health Organisation's (WHO) *Global oral health strategy* and a suggested action in the WHO's *Director-General's 2021 report*, which informed the World Health Assembly resolutions on oral health.^{14,15} The WHO resolutions are significant in policy discourse, boosting people-centred care in national and international oral health policy agendas.

Despite guidelines, recommendations and standards at policy level, there is limited understanding and facilitation, and subsequently uptake and implementation, of PCC on an institutional level and in day-to-day practice.^{16,17} This gap between policy and practice of PCC is evident across the wider healthcare sector,^{18,19} where it has been noted that PCC 'has many evangelists but few practitioners'.²⁰ However, progress towards PCC in dentistry lags behind other health professions.¹⁶ This may be due to dentists' misunderstanding or reluctance towards PCC,¹⁶ as well as current target-driven contracts and systems not rewarding PCC.

It has been demonstrated that treatments can be selected based on improved remuneration, which may not align with PCC.²¹

Shifts towards prevention-orientated care are also proposed. Prevention is a dimension in a number of PCC models²² and is recommended at an organisational level. While recommendations of prevention-focused approaches have been made, current dental contracts don't adequately reward preventative activity.²³ Much of dental care remains treatment-orientated rather than prevention-orientated²⁴ and preventable diseases, such as dental caries and periodontal disease, remain prevalent across all age groups.²⁵

Societal challenges: health inequalities and population ageing

The first pillar of FDI's *Vision 2030* advocacy strategy stresses on universal coverage for oral health and states that 'quality oral healthcare should become available, accessible and affordable to all, with special attention paid to marginalised and vulnerable populations'.¹³

Tackling oral health inequalities is a major problem facing public bodies and policymakers.^{13,26} A myriad of biological, physical, psychosocial, sociodemographic and socioeconomic factors, such as education, physical and neurocognitive ability and social class, have been identified as impacting an individual's access to and quality of dental care.²⁷ Furthermore, these factors have an intersectional and interrelated nature, potentially leading to compound systemic disadvantages to those populations at their convergence. Understanding the factors involved in health inequalities and their complex interrelation is necessary to inform equally complex and effective interventions to address them.²⁸

Population ageing presents an additional societal challenge which is placing increasing demands on health and social care systems.²⁹ It is estimated that across England, Wales and Northern Ireland, the number of people aged 65 or over with an urgent dental condition could rise by more than 50% by 2040 due to population growth alone.³⁰ In addition to increased oral care demand, the nature of dental services required for older people is changing. For example, the increasing percentage of older adults retaining their natural teeth³¹ demands more complex dental management that the profession needs to address.³²

Technological advancement and adoption

Parallel to these shifts, the advancement and adoption of technology within dentistry is rapidly increasing. This can be observed through examples such as robotic dental implant placement,³³ the use of computer-aided design and manufacturing technologies³⁴ and the development of teledentistry services.³⁵ If implemented appropriately, such technologies have the potential to help meet pressures on oral healthcare systems, improving access to and quality of dental care.

We propose that ID and HCD are highly relevant to these transformational, societal and technological shifts in oral health. To frame this relevance, an overview of these fields and their definitions and capabilities within the wider design landscape is provided.

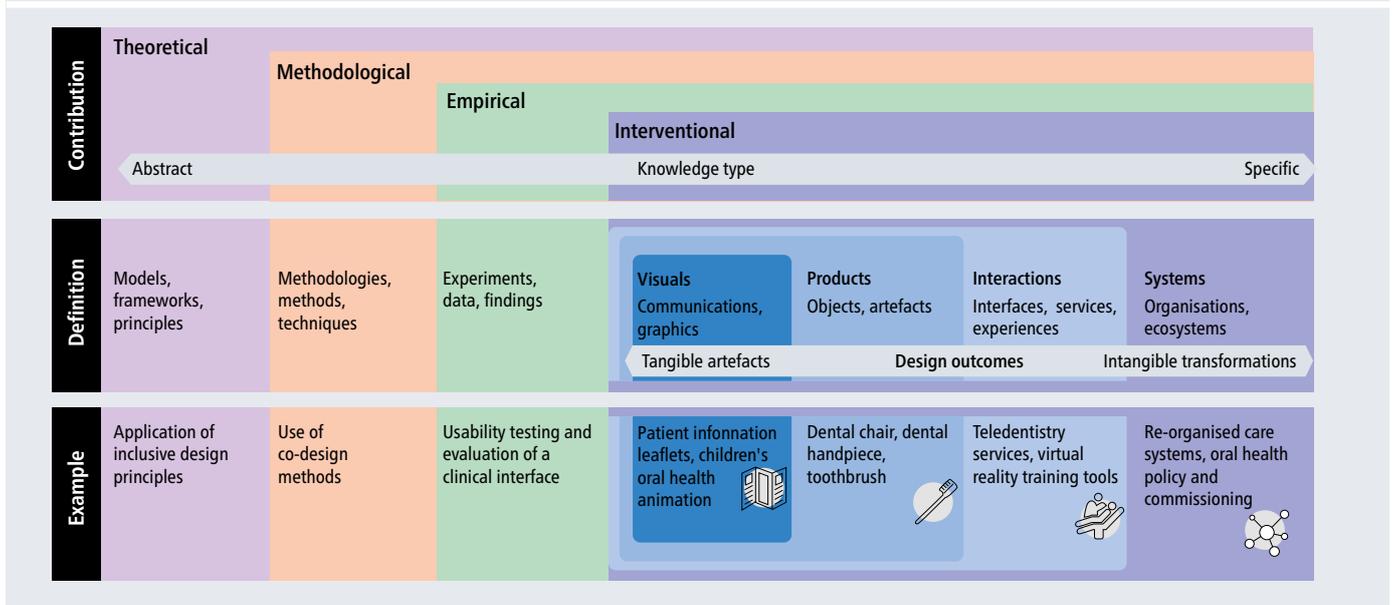
Design in the context of health: definition and capabilities

Design is widely defined as a creative, problem-framing and problem-solving activity. It is a set of principles, mindsets (ways of thinking), practices and processes (ways of working) and methods and techniques (toolkits)³⁶ which are used to understand and define problems and develop solutions. It can be adopted as a generative and creative, as well as an analytical and critical process.

Although everybody can design, it is also a professional practice in which designers gain considerable training, skills and knowledge.³⁷ Key skills include the ability to visualise and conceptualise the intangible; designing with empathy for people and planet; and making and testing prototypes.³⁸

Design as a discipline is evolving and these skills are applied in a growing number of contexts where design is making a range of contributions. Figure 1 illustrates the potential contributions and outcomes of design, providing examples to show how each is relevant to oral health. Design outcomes can be classified by four orders: visuals, products, interactions, or systems.³⁹ In oral healthcare, design outcomes could range from tangible artefacts, such as patient information leaflets or dental tools, to large-scale transformations and oral health policy. Beyond interventions, design also offers methodologies, theories and empirical contributions.⁴⁰ For example, HCD principles, or co-design methods, can be applied to oral healthcare research.

Fig. 1 Design contributions and outcomes canvas



What is human-centred design?

HCD is ‘an approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying human factors/ergonomics and usability knowledge and techniques’.⁴¹

HCD aims to produce outcomes which are useful, usable, desirable and meaningful to the people using them.⁴² To do so, it places the needs and experiences of humans at the centre of the design process, acknowledging them as the experts in their lived experience and co-creating solutions with and for them. HCD incorporates methods to understand people holistically (including their multifaceted needs, expectations, behaviours and relationships), engages with users and multiple stakeholders throughout the design process and often involves transdisciplinary collaboration.⁴³

HCD is distinct from user-centred design as it emphasises people beyond their role as users and includes different stakeholders’ needs and broader contexts.^{44,45}

Altiparmakogullari *et al.* applied HCD to investigate dental photography; specifically, the efficiency of the process and the quality of images produced.⁴⁶ While previous work had focused on equipment, their HCD approach looked at the whole system of people and equipment, considering ergonomics and human factors, as well as emotional influences on patients. The outcome was a series of recommendations to improve the dental photography equipment and processes for both clinicians and patients.

What is inclusive design?

ID is ‘the design of mainstream products and/or services that are accessible to, and usable by, as many people with the widest range of abilities within the widest range of situations without the need for special adaptation or specialised design’.⁴⁷

ID centres on designing for human diversity. It acknowledges the central role of design as an agent of inclusion or exclusion and that (dis)ability and exclusion can be thrust upon an individual in temporary, situational or permanent settings, through inadequate or inconsiderate design.⁴⁸

Through identifying ‘extremes’ and ‘mainstreams’, ID involves empathising and ultimately designing with often ignored, marginalised or excluded user groups, whose experiences pose the most extreme and diverse design challenges and opportunities. By investigating barriers to inclusion, it aims to bring those extreme and excluded users into the mainstream and create innovative solutions that include and benefit all.⁴⁸

Contemporary ID looks beyond disability, ageing and physical accessibility,⁴⁹ considers psychosocial dimensions of inclusion and exclusion, and places value on quality of life and experience.⁵⁰

An example of ID applied to oral health is the redesign of Jordan toothbrush packing.⁵¹ Rich insights were uncovered through working with extreme users, including: people with arthritis; people with low vision; children; and older people, throughout the redesign process. The outcome was user-friendly packaging that is easier to open for a wider range of people,

resulting in increased sales and strengthened brand positioning.

The relevance of inclusive and human-centred design to oral health

The potential for ID and HCD to address challenges to our society’s health is increasingly recognised.^{52,53} Design is being adopted as a central agent of innovation to rethink healthcare services and systems and tackle complex problems.^{54,55,56} Despite this, there is limited recognition and adoption of ID and HCD in oral healthcare.¹ We discuss the potential significance of ID and HCD, first as an agent for transformations in oral healthcare, then to the specific challenges previously outlined.

Inclusive and human-centred design as an agent of oral healthcare transformations

The complex nature of oral healthcare systems, the diversity of individuals within them and the social and political environments in which they are situated, mean that many of the challenges facing oral healthcare could be described as ‘wicked’.⁵⁷ Addressing wicked problems requires a systems perspective, as well as collaborative, creative, integrative and imaginative approaches.^{58,59} Through intentionally embracing complexity, utilising creative approaches and centring on human values, ID and HCD offer alternative and non-clinical perspectives and radically different strategies for addressing challenges in oral healthcare.

Systems approaches are central to HCD, which considers people, their experiences and contexts, and how these interact within systems.⁶⁰ Brocklehurst *et al.* promoted systems thinking in oral health research, highlighting the importance of understanding the complexity and contextual knowledge of the system in order to successfully implement interventions.⁶¹

Non-clinical perspectives could both offer new ideas to oral health research and lessen challenges arising through the dual clinician-researcher role. Particularly in qualitative research, a clinician's professional status can present issues, such as maintaining a duty of care while ensuring methodological integrity, or affect participants' responses due to power imbalances.⁶²

Design's creative methods, such as visualisations and prototypes, could aid oral healthcare transformations through facilitating shared communication and understanding.^{61,63} Lievesley and Wassall demonstrate the value of design for describing and reframing complex problems in their development of a person-centred view of community dental health services.⁶⁴ They produced two visual models which were key in facilitating collaboration across stakeholders and highlighting the value in taking a person-centred perspective to reframe systemic challenges. Such creative collaboration and shared reframing is relevant to the move to integrated care systems outlined in the *Health and care bill*⁶⁵ and *NHS long term plan*,⁶⁶ which requires partnerships between health providers and reorganised health systems. Design approaches might aid the integration of dental practices and their services into the wider healthcare system.

Facilitating person-centred and prevention-oriented care

The principles and values of ID and HCD are closely aligned to PCC and the prevention-orientated approaches being proposed in oral healthcare.

Apelian *et al.*'s PCC model is based on humility, hospitality and mindfulness¹¹ and Scambler and Asimakopoulou include 'feeling empathy and compassion' as one of four foundational components in their hierarchy of PCC.¹⁰ This theme of empathy is echoed in ID and HCD, where empathising and understanding users is a central concept.⁴²

Grasp live is an example of a product designed to support a trusting and empathic relationship between dentist and patient.⁶⁷ Grasp is a handheld device which the patient

can squeeze to communicate during treatment. It is connected to a smartphone, as well as an Apple Watch worn by the dentist, which provides haptic feedback. This communication during treatment allows cooperation between dentist and patient, for example, feedback can be used for quick confirmation of cavities without excessive pain. While Grasp was designed with dental anxiety in mind, it could also be of benefit to a range of patients, including those with communication difficulties.

Other PCC dimensions such as 'the patient as a whole person'¹⁰ and 'treated as a person, recognised as an individual',⁹ relate to the FDI's definition of person-centred care and echo HCD's principle of considering people beyond their role as users.

Another key component of PCC is empowering patients and involving them in treatment decisions. Mills *et al.*'s model includes shared decision making⁹ and Apelian *et al.*'s model includes 'sharing power' and 'creativity' as key attitudes in co-determining problems and co-authoring treatment plans.¹¹ Scambler and Asimakopoulou's hierarchy of PCC intends to aid reflection on the level to which patients are involved in decision-making.¹⁰ These concepts encourage participatory approaches, something which is a key skill of designers who commonly apply methods such as co-design. Brocklehurst *et al.* have promoted the use of design's participatory methods in oral health, particularly in implementation research⁶¹ and special care dentistry.⁶⁸

Whole Mouth Health is an example of a project using co-design to explore oral health literacy and behaviour change.⁶⁹ A range of participants across multiple countries and life stages are involved in a series of problem-framing and problem-solving activities, with the aim of co-producing an oral health literacy platform. The project demonstrates how participatory design approaches can facilitate the delivery of preventative and personalised health information and drive transformations towards PCC.

Reframing and tackling societal challenges

ID is highly relevant to the FDI's vision of oral healthcare that is 'available, accessible, and affordable to all, with special attention paid to marginalised and vulnerable populations'.¹³ Such populations could be considered 'extreme users' which are central to an ID approach.

Design has been applied to facilitate access to typically excluded groups, for example,

through the design of dental chairs for people in wheelchairs,⁷⁰ a communication aid for people with an intellectual disability⁷¹ and a device for nurses brushing hospital patients' teeth.⁷²

Beyond this, there is potential for ID and HCD to help reframe societal challenges and investigate oral health experiences across diverse populations. This is particularly relevant to the area of Inclusion Oral Health,⁷³ advances in which discuss the complexities of oral health inequalities and call for 'multidisciplinary research collaborations to meet the methodological challenges of this urgent new frontier in oral health inequity research'.⁷⁴ ID and HCD offer alternative perspectives and creative participatory approaches which would be valuable in such collaborations.

Limitations of the evidence-based paradigm in oral health are increasingly recognised.⁶¹ Traditional quantitative approaches don't always suit wicked problems, such as societal challenges, which have numerous variables that can't be separated and investigated in isolation. Moreover, sometimes evidence on impact, measured through lived experience, is of value. Design could contribute to complementary 'thick data' and 'big data' approaches.⁷⁵ For example, combined with big data that indicates what people do, HCD might uncover in-depth, human-centred insights that are vital to understand why people adopt a certain behaviour.

Human-centred technology and innovation

The application of technology to oral healthcare equipment, environment and systems has the potential to help meet pressures on oral healthcare systems and could play a key role in delivering PCC. However, poorly designed technology can exacerbate exclusion. The integration of ID and HCD in the development and implementation of technologies ensures that they fit the needs of users and stakeholders and are developed with consideration for the specific environments and contexts of use. In oral healthcare, such approaches could seek to enhance effectiveness and efficiency; improve human wellbeing, user satisfaction, accessibility, and sustainability; and counteract possible adverse effects of use on human health, safety and performance.

Consultation Room 2030 is an example of a project looking at how technology can facilitate changing approaches to care.⁷⁶

The project explores trends in transferring healthcare experiences from the consultation room to home and how this can be done in a human-centred way. Examining the process from before a consultation to a patient arriving back at home, they are identifying what could be innovated through the help of technology, helping doctors to improve their work and ultimately enhancing patient experience.

Barriers to adopting inclusive and human-centred design in oral health

While recognition of design is growing, it is often poorly understood by healthcare practitioners and poorly integrated into healthcare systems. Design is predominantly seen and implemented as an agent of problem solving and hence is only engaged with if or when that stage applies. Awareness and understanding of ID and HCD is particularly limited and there is a need to build understanding around their potential role and value so that oral health can engage with and utilise them fully.

Beyond awareness of ID and HCD, there is a need to negotiate disciplinary differences in approaches to data, rigour, evidence and impact. For instance, there is discussion around the nature and hierarchy of evidence in design versus health.⁷⁷ Also, where health focuses on peer-reviewed publications, design takes a more varied approach to disseminations, including areas such as exhibition, performance and making. Future work will have to navigate these differences, seeking to bring approaches together in an effective and complementary way.

The context of oral and wider healthcare systems and their political backdrop is another consideration. The adoption of ID and HCD within these may require culture change, which can be difficult to manage. Additionally, design strategies must be able to adapt to political and societal changes on local, regional and national scales.

Conclusion

This paper examines the relevance of ID and HCD to the transformational, societal and technological shifts occurring in oral health. The definitions and capabilities of ID and HCD are described and illustrated through practical examples.

We suggest that there is an opportunity for oral health to engage with ID and HCD and that designers could be of value to oral health policy,

research and practice, across issues such as person-centred practice, Inclusion Oral Health and accessible technological advancement. To progress and enhance collaborations between the fields, barriers, including awareness of the role and value of design, disciplinary differences, and the wider healthcare systems context, should be considered and addressed.

Ethics declaration

The authors declare no conflicts of interest.

Author contributions

Isobel Leason, Nicholas Longridge and Farnaz Nickpour conceived the paper. Isobel Leason wrote the first draft. Isobel Leason, Nicholas Longridge, Manu Raj Mathur and Farnaz Nickpour provided feedback, participated in the editing process and approved the final version.

References

1. Leason I, Nickpour F. The State of Inclusive and Human-Centred Design in Oral Healthcare. In Lockton D, Lenzi S, Hekkert P, Oak A, Sádaba J, Lloyd P (eds) *DRS2022: Bilbao*. Bilbao: Design Research Society, 2022.
2. FDI World Dental Federation. FDI's definition of oral health. 2016. Available at <https://www.fdiworlddental.org/fdis-definition-oral-health> (accessed June 2021).
3. Glick M, Williams D M, Kleinman D V, Vujicic M, Watt R G, Weyant R J. A new definition for oral health developed by the FDI World Dental Federation opens the door to a universal definition of oral health. *Br Dent J* 2016; **221**: 792–793.
4. Baiju R M, Peter E, Varghese N O, Sivaram R. Oral Health and Quality of Life: Current Concepts. *J Clin Diagn Res* 2017; DOI: 10.7860/JCDR/2017/25866.10110.
5. Sischo L, Broder H L. Oral health-related quality of life: what, why, how, and future implications. *J Dent Res* 2011; **90**: 1264–1270.
6. Alrawiai S, Asimakopoulou K, Scambler S. Patient-Centred Care in Dentistry: Definitions and Models – Commentary. *Eur J Dent Educ* 2021; **25**: 637–640.
7. Leggett H, Duijster D, Douglas G V A *et al*. Toward More Patient-Centred and Prevention-Oriented Oral Health Care: The ADVOCATE Project. *JDR Clin Trans Res* 2017; **2**: 5–9.
8. Lee H, Chalmers N I, Brow A *et al*. Person-centred care model in dentistry. *BMC Oral Health* 2018; **18**: 198.
9. Mills I, Frost J, Kay E, Moles D R. Person-centred care in dentistry – the patients' perspective. *Br Dent J* 2015; **218**: 407–413.
10. Scambler S, Asimakopoulou K. A model of patient-centred care – turning good care into patient-centred care. *Br Dent J* 2014; **217**: 225–228.
11. Apelian N, Vergnes J N, Hovey R, Bedos C. How can we provide person-centred dental care? *Br Dent J* 2017; **223**: 419–424.
12. Häkansson Eklund J, Holmström I K, Kumlin T *et al*. "Same same or different?" A review of reviews of person-centred and patient-centred care. *Patient Educ Couns* 2019; **102**: 3–11.
13. FDI World Dental Federation. Vision 2030: Delivering Optimal Oral Health for All. 2021. Available at https://www.fdiworlddental.org/sites/default/files/2021-02/Vision-2030-Delivering%20Optimal-Oral-Health-for-All_0.pdf (accessed September 2022).
14. World Health Organisation. Oral Health: Achieving better oral health as part of the universal health coverage and noncommunicable disease agendas towards 2030. 2020. Available at https://apps.who.int/gb/ebwha/pdf_files/EB148/B148_8-en.pdf (accessed September 2022).

15. World Health Organisation. Oral health: Executive board resolution EB148/R1. 2021. Available at https://apps.who.int/gb/ebwha/pdf_files/EB148/B148_R1-en.pdf (accessed September 2022).
16. Apelian N, Vergnes J-N, Bedos C. Is the dental profession ready for person-centred care? *Br Dent J* 2020; **229**: 133–137.
17. Mills I, Frost J, Moles D R, Kay E. Patient-centred care in general dental practice: sound sense or soundbite? *Br Dent J* 2013; **215**: 81–85.
18. Hebblethwaite S. "I Think That It Could Work But...": Tensions Between the Theory and Practice of Person-Centred and Relationship-Centred Care. *Therap Recreat J* 2013; **47**: 13–34.
19. Kane P M, Murtagh F E M, Ryan K *et al*. The gap between policy and practice: a systematic review of patient-centred care interventions in chronic heart failure. *Heart Fail Rev* 2015; **20**: 673–687.
20. Hawkes N. Seeing things from the patients' view: what will it take? *BMJ* 2015; DOI: 10.1136/bmj.g7757.
21. Haque A. *How should root filled posterior teeth be restored? A systematic review and survey to general dental practitioners*. Liverpool: University of Liverpool, 2020. Thesis.
22. Stewart M, Brown J B, Weston W, McWhinney I R, McWilliam C L, Freeman T. *Patient-Centered Medicine: Transforming the Clinical Method*. London: CRC Press, 2013.
23. Holmes R D, Steele J G, Donaldson C, Exley C. Learning from contract change in primary care dentistry: A qualitative study of stakeholders in the north of England. *Health Policy* 2015; **119**: 1218–1225.
24. Garcia R I, Sohn W. The paradigm shift to prevention and its relationship to dental education. *J Dent Educ* 2012; **76**: 36–45.
25. Kassebaum N J, Smith A G C, Bernabé E *et al*. Global, Regional, and National Prevalence, Incidence, and Disability-Adjusted Life Years for Oral Conditions for 195 Countries, 1990–2015: A Systematic Analysis for the Global Burden of Diseases, Injuries, and Risk Factors. *J Dent Res* 2017; **96**: 380–387.
26. UK Government. Inequalities in oral health in England: full report. 2021. Available at <https://www.gov.uk/government/publications/inequalities-in-oral-health-in-england> (accessed September 2022).
27. Tiwari T, Baker S, Albino J. Reducing Oral Health Disparities: Social, Environmental and Cultural Factors. *Front Public Health* 2017; **5**: 298.
28. Petticrew M, Tugwell P, Welch V *et al*. Better evidence about wicked issues in tackling health inequities. *J Public Health (Oxf)* 2009; **31**: 453–456.
29. Beard J R, Officer A M, Cassels A K. The World Report on Ageing and Health. *Gerontologist* 2016; DOI: 10.1093/geront/gnw037.
30. The Faculty of Dental Surgery of The Royal College of Surgeons of England. Improving older people's oral health. 2017. Available at file:///C:/Users/dyp0834/Downloads/FDS%20Improving%20Older%20peoples%20oral%20health%202017.pdf (accessed September 2022).
31. NHS Digital. Adult Dental Health Survey – 2009, First release. 2010. Available at <https://digital.nhs.uk/data-and-information/publications/statistical/adult-dental-health-survey/adult-dental-health-survey-2009-first-release> (accessed June 2021).
32. Hellyer P H. The older dental patient – who cares? *Br Dent J* 2011; **211**: 109–111.
33. Wu Y, Wang F, Fan S, Chow J K-F. Robotics in Dental Implantology. *Oral Maxillofac Surg Clin North Am* 2019; **31**: 513–518.
34. Susic I, Travar M, Susic M. The application of CAD/CAM technology in Dentistry. In Susic I, Travar M, Susic M (eds) *IOP Conference Series: Materials Science and Engineering*. Bristol: IOP Publishing, 2017.
35. Estai M, Kanagasangam Y, Tennant M, Bunt S. A systematic review of the research evidence for the benefits of teledentistry. *J Telemed Telecare* 2018; **24**: 147–156.
36. Carlgren L, Rauth I, Elmquist M. Framing Design Thinking: The Concept in Idea and Enactment. *Creat Innov Manag* 2016; **25**: 38–57.
37. Langley J, Wolstenholme D, Cooke J. 'Collective making' as knowledge mobilisation: the contribution of

- participatory design in the co-creation of knowledge in healthcare. *BMC Health Serv Res* 2018; **18**: 585.
38. Design Council. Design perspectives: design skills. 2020. Available at <https://www.designcouncil.org.uk/fileadmin/uploads/dc/Documents/Design%2520Perspectives-%2520Design%2520Skills.pdf> (accessed January 2022).
 39. Buchanan R. Wicked Problems in Design Thinking. *Design Issues* 1992; **8**: 5–21.
 40. O'Sullivan C, Nickpour F. 50 Years of Inclusive Design for Childhood Mobility; Insights from an Illustrative Mapping Review. In Boess S, Cheung M, Cain R (eds) *DRS2020: Synergy*. UK: Design Research Society, 2020.
 41. British Standards Institution. BS EN ISO 9241-210:2019. Ergonomics of human-system interaction – Human-centred design for interactive systems. 2019. Available at <https://knowledge.bsigroup.com/products/ergonomics-of-human-system-interaction-human-centred-design-for-interactive-systems/tracked-changes> (accessed September 2022).
 42. Giacomini J. What Is Human Centred Design? *Design J* 2014; **17**: 606–623.
 43. Zhang T, Dong H. Human-Centred Design: An Emergent Conceptual Model. In *Include 2009*. London: Royal College of Art, 2009.
 44. Steen M. Tensions in human-centred design. *CoDesign* 2011; **7**: 45–60.
 45. Jordan P W. Human factors for pleasure seekers. In Frascara J (ed) *Design and the Social Sciences: Making Connections*. pp 26–40. London: CRC Press, 2002.
 46. Altiparmakogullari Y, Cifter M, Cifter A S. A Multidisciplinary inspection of Dental Photography: What Do Dentist Think and What Can Designer Do? *Design J* 2017; DOI: 10.1080/14606925.2017.1352718.
 47. British Standards Institution. BS 7000-6:2005: Design management systems – Managing Inclusive Design – Guide. 2005. Available at <https://knowledge.bsigroup.com/products/design-management-systems-managing-inclusive-design-guide/standard> (accessed September 2022).
 48. John Clarkson P, Coleman R. History of Inclusive Design in the UK. *Appl Ergon* 2015; **46**: 235–247.
 49. Nickpour F, Dong H. Designing for Diversity: Inclusive Design as a catalyst for change? In *DRS2018: Catalyst*. UK: Design Research Society, 2018.
 50. Lim Y, Giacomini J, Nickpour F. What Is Psychosocially Inclusive Design? A Definition with Constructs. *Design J* 2021; **24**: 5–28.
 51. DOGA. Jordan – toothbrush packaging. Available at <https://doga.no/en/tools/inclusive-design/cases/jordan-toothbrush-packaging/> (accessed November 2021).
 52. Campbell D, Stockman K, Burns D. Design and Systems Thinking for Healthcare Practitioners. In Melles G (ed) *Design Thinking in Higher Education*. pp 91–125. Singapore: Springer, 2020.
 53. Chamberlain P, Wolstenholme D, Dexter M, Seals E. *The State of the Art of Design in Health: An expert-led review of the extent of the art of design theory and practice in health and social care*. Sheffield: Sheffield Hallam University, 2015.
 54. Komashie A, Ward J, Bashford T et al. Systems approach to health service design, delivery and improvement: a systematic review and meta-analysis. *BMJ Open* 2021; DOI: 10.1136/bmjopen-2020-037667.
 55. Tseklevs E, Cooper R. Emerging Trends and the Way Forward in Design in Healthcare: An Expert's Perspective. *Design J* 2017; DOI: 10.1080/14606925.2017.1352742.
 56. NHS Digital. Design is the strategy. 2020. Available at <https://digital.nhs.uk/blog/design-matters/2020/design-is-the-strategy> (accessed October 2021).
 57. Baker S R. 'No simple solutions, no single ingredient': systems orientated approaches for addressing Wicked Problems in population oral health. *Community Dent Health* 2019; **36**: 3–4.
 58. Thomas W, Hujala A, Laulainen S, McMurray R. *The Management of Wicked Problems in Health and Social Care*. Oxfordshire: Routledge, 2019.
 59. Irwin T. The Emerging Transition Design Approach. *Cuad Cent Estud En Diseño Comun Ens* 2019; **73**: 147–179.
 60. Interaction Design Foundation. What is Human-Centered Design. Available at <https://www.interaction-design.org/literature/topics/human-centered-design> (accessed April 2022).
 61. Brocklehurst P R, Baker S R, Langley J. Context and the evidence-based paradigm: The potential for participatory research and systems thinking in oral health. *Community Dent Oral Epidemiol* 2021; **49**: 1–9.
 62. Geddis-Regan A, Exley C, Taylor G D. Navigating the Dual Role of Clinician-Researcher in Qualitative Dental Research. *JDR Clin Trans Res* 2022; **7**: 215–217.
 63. Robinson T A. Getting it all together: the fragmentation of the disciplines and the unity of knowledge. *Headwaters* 2008; **25**: 102–114.
 64. Lievesley M, Wassall R. Designing across organisational boundaries – Community Dentistry Services. In Christer K (ed) *Proceedings of the 3rd European Conference on Design4Health*. Sheffield: Sheffield Hallam University, 2015.
 65. UK Parliament. Health and Care Act 2022. 2022. Available at <https://bills.parliament.uk/bills/3022> (accessed November 2021).
 66. NHS. NHS Long Term Plan. 2019. Available at <https://www.longtermplan.nhs.uk/> (accessed November 2021).
 67. Guribye F, Gjøsaeter T. Tangible Interaction in the Dentist Office. In *Proceedings of the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '18)*. New York: Association for Computing Machinery, 2018.
 68. Brocklehurst P R, Langley J, Baker S R, McKenna G, Smith C, Wassall R. Promoting co-production in the generation and use of research evidence to improve service provision in special care dentistry. *Br Dent J* 2019; **227**: 15–18.
 69. FDI World Dental Federation. Whole mouth health. Available at <https://www.fdiworlddental.org/whole-mouth-health> (accessed September 2021).
 70. Design Specific. Available at <https://www.designspecific.co.uk/> (accessed December 2020).
 71. Menzies R, Herron D, Scott L, Freeman R, Waller A. Involving clinical staff in the design of a support tool to improve dental communication for patients with intellectual disabilities In *Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '13)*. New York: Association for Computing Machinery, 2013.
 72. Coventry University. Teggy. Available at <https://www.coventry.ac.uk/business/our-services/health-design-technology-institute/health-design-technology-institute-case-study-menu/teggy/> (accessed December 2021).
 73. Freeman R, Doughty J, Macdonald M E, Muirhead V. Inclusion oral health: Advancing a theoretical framework for policy, research and practice. *Community Dent Oral Epidemiol* 2020; **48**: 1–6.
 74. Elaine Muirhead V, Milner A, Freeman R, Doughty J, Macdonald M E. What is intersectionality and why is it important in oral health research? *Community Dent Oral Epidemiol* 2020; **48**: 464–470.
 75. Hong A, Baker L, Prieto Curiel R et al. Reconciling big data and thick data to advance the new urban science and smart city governance. *J Urban Affairs* 2022; DOI: 10.1080/07352166.2021.2021085.
 76. Spreekamer 2030. About us. Available at <http://www.spreekamer2030.nl/about-us/> (accessed January 2022).
 77. Kirk Hamilton D. Evidence-Based Practice: Four Levels Revisited. *HERD* 2020; **13**: 26–29.